Flood hydrology roadmap

Roadmap development and the action plan

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We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can’t do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

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Executive summary

The flood hydrology roadmap (summarised in Figure S1) sets out a 25 year vision for flood hydrology in the UK and an action plan to realise that vision. The Environment Agency has led the roadmap project, but the roadmap itself has been developed by and for the UK flood hydrology community.

The roadmap is intended to cover England, Wales, Scotland and Northern Ireland from 2021 to 2046. It considers all sources of inland flooding, including fluvial, surface water, groundwater and reservoirs. It also considers the full range of inland flood hydrology activities in the UK, from operational practice to scientific research.

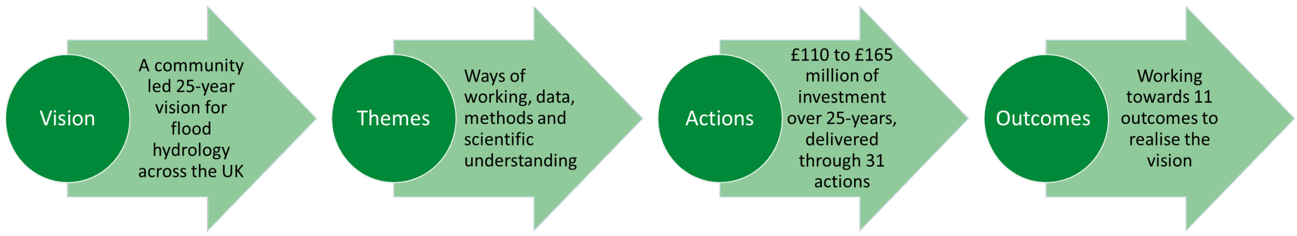
Development of the roadmap has been driven by:

- the scale of investment that flood hydrology data, methods, models and expertise underpin (around £6 billion over the next 6 years)
- the need to support the implementation of flood risk management strategies across the UK
- the need to improve partnership working and collaboration across the UK flood hydrology community
- the need to improve the translation of science into practice
- the need to deal with known limitations and issues in existing operational flood hydrology methods
- the need for flood hydrology to account for and predict the impacts of future environmental change (climate change and land use change)
- the opportunity for flood hydrology to contribute to net zero carbon targets

The flood hydrology roadmap has been developed through multiple phases of consultation with the flood hydrology community in the UK. It is built around a vision for the next 25 years which states that:

- during the next 25 years society will have improved hydrological information and understanding to manage flood hazard in a changing world
- flood hydrology and whole-system process understanding will be underpinned by excellent evidence with quantified uncertainty
- leadership and collaboration are crucial to achieving this vision

Figure S1: Summary of the flood hydrology roadmap for the UK



This vision will be realised through 31 actions grouped into 4 thematic work areas:

- ways of working
- data
- methods
- scientific understanding

Successfully achieving the vision of the UK flood hydrology roadmap will require strong leadership, and improved partnership working and collaboration across the flood hydrology community. The estimated funding required to implement the roadmap is between £110 million and £165 million over its 25 year lifetime.

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51 respondents (representing 270 individuals) to a **questionnaire** sent out in May 2018 to gather initial thoughts and ideas on a vision for the flood hydrology roadmap and current challenges and opportunities.

Participants of a **workshop in Birmingham** on 24 and 25 September 2018 to start to develop the vision and needs of the flood hydrology roadmap: Craig Woolhouse (Environment Agency), Dr Sean Longfield (Environment Agency), Anita Asadullah (Environment Agency), Dr Sue Manson (Environment Agency), Dr Mike Vaughan (Environment Agency), Alan Brown (Reservoir Safety Advisory Group), Amanda McKevitt (Environment Agency), Becky Wilson (Scottish Environment Protection Agency), Owain Sheppard (Natural Resources Wales), Alex Cornish (Bureau of Meteorology, Australia), Dr Nevil Quinn (University of the West of England), Bridget Woods-Ballard (HR Wallingford), Dr Charlie Pilling (Flood Forecasting Centre), Dr David MacDonald (British Geological Survey), Dr David Mould (CIWEM Rivers and Coastal Group), Deborah Lee (Met Office), Debra Thomson (Environment Agency), Duncan Faulkner (JBA Consulting), Emma Bergin (Insurance industry- FloodRe), Professor Hannah Cloke (Reading University), Professor Hayley Fowler (Newcastle University), Helen Harfoot (Aecom), Ian Scholefield (United

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125 respondents to an **online survey** that sought wide input on draft vision statements and potential work areas in the flood hydrology roadmap.

4 voluntary **current practice task groups** were established to summarise current practice in flood hydrology for reservoirs, groundwater, surface water and fluvial flood risk for both forecasting and planning perspectives.

Fluvial task group members were: Phil Raynor (Jacobs), Dr David Mould (CIWEM and Canal and River Trust), Dr Mike Vaughan (Environment Agency), and Dr David Price (Flood Forecasting Centre).

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1 Introduction

The flood hydrology roadmap aims to set out a 25 year vision for flood hydrology in the UK and an action plan to realise that vision. The roadmap project has been led by the Environment Agency on behalf of the UK flood hydrology community.

The British Hydrology Society (BHS) defines hydrology as the study of water in the environment[1] which tries to "understand the complex water systems of the Earth, to study and predict how water will behave under different circumstances as it moves through the land phase of the water cycle". The World Health Organization (WHO) defines flooding as a type of natural disaster that occurs when an overflow of water submerges land that is usually dry[2].

Flood hydrology is a subset of hydrology that specialises in aspects of the water cycle related to flooding. There are 2 primary technical areas of flood hydrology that this roadmap focuses on, flood forecasting and flood estimation.

Flood forecasting aims to estimate and predict the magnitude, timing and duration of flooding at a given location. Flood forecasts are typically required between 5-days and 2-hours in advance of potential flood impacts to inform operational and emergency response. Timely and accurate flood forecasts are critical for effective incident response to flooding, particularly for issuing flood warnings and providing advice and guidance to those at risk from flooding and those responsible for responding to that risk. The models used to derive flood forecasts often comprise rainfall-runoff models, river routing models or combinations of the two. The flood hydrology roadmap focuses on these hydrological elements of flood forecasting rather than the meteorological inputs to these models.

Flood estimation is used in longer-term, non-real-time situations, such as spatial planning or the design or flood defence schemes, with the aim of estimating the peak river flow or rainfall of a given frequency (or rarity); for example, what is the peak river flow we can expect at a particular location that has a 1% chance of being exceeded in any year. Flood estimation often relates to both rainfall and flood frequency estimation in the UK.

The roadmap focuses on inland flood hydrology and considers the hydrological elements of flooding from fluvial, surface water, groundwater and reservoir sources. The roadmap also covers broader aspects of flood hydrology such as the physical processes that generate floods, long-term variability of rainfall and flooding, and the data, models, systems and ways of working needed to improve flood hydrology over the next 25 years.

[1] British Hydrological Society definition of hydrology [Last accessed 22 November 2021]

[2] World Health Organization definition of flooding [Last accessed 22 November 2021]

1.1 Principles

The principles that the flood hydrology roadmap has been built on are that the roadmap will:

- set out a 25 year vision for flood hydrology in the UK and an action plan to realise that vision
- be developed by and for the UK flood hydrology community (see section 2.3)
- seek to achieve its vision and action plan through improved partnership working and collaboration
- have equality, diversity and inclusion at its heart
- cover all sources of inland flooding (fluvial, surface water, groundwater and reservoirs)
- cover the full breadth of flood hydrology activities in the UK, ranging from operational practice to fundamental science
- encourage the development of open, freely accessible tools, techniques and methods
- seek to improve the translation of the science of flood hydrology into practice
- focus on flood estimation and flood forecasting
- make links to other disciplines, such as low flow, estuarine, and coastal hydrology and hydrodynamic and hydraulic where appropriate
- promote low carbon solutions to implementing its action plan
- build on existing investment and good practice
- outline the scale of funding required to implement the roadmap
- be regularly reviewed and updated over its lifetime to ensure its continued relevance and importance to the flood hydrology community

1.2 Structure of the roadmap

The flood hydrology roadmap has 5 main sections and numerous supporting appendices. This section gives a brief introduction to the roadmap and outlines the principles on which it has been based. Section 2 provides a narrative that highlights the importance and need for the roadmap. Section 3 presents the roadmap itself which comprises the roadmap vision, its action plan and intended outcomes (more detail on the roadmap action plan is presented in Appendix G). Section 4 describes how effective leadership and governance, the right level of funding and delivering actions through partnerships and collaboration are crucial to realising the roadmap vision. The final section of this report (section 5) briefly outlines how the roadmap was developed who’s been involved, how and when.

2 Why do we need a flood hydrology roadmap for the UK?

At its inception, the flood hydrology roadmap was intended to focus on developing a prioritised programme of applied research to underpin flood hydrology practice in England and Wales. Early consultation across the flood hydrology community quickly highlighted the need and desire to consider the long-term future of flood hydrology more broadly, both in terms of its spatial coverage and to look beyond applied research.

In response to these initial findings, the project to develop a roadmap for flood hydrology was broadened to cover the whole of the UK and to consider operational practice to fundamental science. The main drivers for developing the roadmap were:

- flood hydrology underpins billions of pounds’ worth of investment and activity in flood risk management across the UK
- flood hydrology should align with and support the implementation of flood risk management strategies across the UK
- the flood hydrology community can be disparate and not always working together to solve common problems
- the uptake and translation of flood hydrology science from academia to operations is often slow and very patchy
- there are known (and unknown) technical and methodological issues that need addressing in UK flood hydrology
- the climate is changing and flood hydrology data, methods, models and ways of working need to account for this
- to ensure that UK flood hydrology evolves and improves in a low carbon way

The following sections discuss each of these drivers of the flood hydrology roadmap.

2.1 Supporting investment in UK flood management

Flood hydrology and hydrological data underpin and enables many crucial flood risk management activities across the UK. These activities amount to billions of pounds’ worth of expenditure and include:

- design and maintenance of flood defences
- national flood risk assessment and mapping
- local flood mapping studies
- flood risk assessments for spatial planning
- strategic flood risk assessments for strategic planning
- design and operation of flood warning schemes
- design and operation of flood forecasting models
- reservoir safety (design and operation)
- real-time incident reporting
- post-flood event investigation

- design and operation of sustainable drainage systems
- evaluation of natural flood management measures
- infrastructure scheme design
- design of watercourse crossings for infrastructure (bridges and culverts)
- sizing of pumping stations in lowland catchments
- informing environmental permitting (formally flood defence consent)
- understanding the impact of climate change on flood risk
- flood risk modelling in the insurance industry

It’s hard to put a monetary value on the contribution of flood hydrology to each of these activities. However, the scale of funding for flood risk management activities as a whole highlights the level of investment that flood hydrology underpins. Spending on flood risk management varies across each of the 4 nations involved in the roadmap.

In England, between 2015 and 2021, risk management authorities invested £2.6 billion of government funding in flood and coastal risk management to better protect 300,000 homes. In the 2020 budget, the Chancellor announced a further £5.2 billion of capital funding to better protect 336,000 properties between 2021 and 2027 (Environment Agency, 2020b).

In Wales, the Welsh Government has invested more than £390 million in capital and revenue spending between 2016 and 2021 to help combat the risk of flooding and coastal erosion, benefitting over 45,000 properties.

In 2016, the Scottish Government committed to a capital investment programme for flood risk management of £420 million, over a 10-year period. This was supplemented in September 2020, when the Programme for Government in Scotland committed an additional £150 million over 5 years from 2021 to 2022 to support flood risk management actions.

In Northern Ireland, the total capital spend by flood risk management authorities from 2016-17 to 2020-21 was £91.5 million, with projected capital funding, for the period 2021 to 2027, to be around £280 million (Department for Infrastructure, 2020).

2.2 Supporting flood risk management strategies

Flood hydrology cannot claim to directly influence all the expenditure outlined above, however the outcome mapping presented in section 3.4 and Appendix H of this document clearly illustrates that flood hydrology is a fundamental part of achieving long-term flood risk management ambitions. For example, the National Flood and Coastal Erosion Risk Management Strategy for England (Environment Agency, 2020b) has 3 long-term ambitions:

1. climate resilient places
2. today's growth and infrastructure resilient in tomorrow's climate
3. a nation ready to respond and adapt to flooding and coastal change

The actions required to achieve these ambitions can be summarised as:

- build new flood defences to better protect homes and businesses
- avoid inappropriate development in the flood plain
- timely and effective flood forecasting, warning and evacuation
- operate flood defences to better protect homes and businesses
- use nature-based solutions to slow the flow of or to store flood waters
- all infrastructure investment is resilient to flooding
- all new development is resilient to flooding and enhances the environment
- a nation of people who understand their risk to flooding
- transform warning and informing services
- develop digital services that better communicate flood risk and raise awareness
- world leaders in researching and managing flooding
- help communities and local economies recover from flooding
- build back better after a flood with property flood resilience measures

Flood hydrology has a crucial role to play in achieving the vast majority of these actions (see section 3.4.12), again highlighting the fundamental importance that flood hydrology plays in helping achieve the long-term ambitions for flood risk management.

The National Strategy for Flood and Coastal Erosion Risk Management in Wales (Welsh Government, 2020) aims to reduce the risks to people and communities from flooding and coastal erosion. It has 5 main objectives:

- improving understanding and communication of risk
- preparedness and building resilience
- prioritising investment to the most at risk communities
- preventing more people becoming exposed to risk
- providing an effective and sustained response to events

All of these objectives require flood hydrology skills, methods, models and tools. For example, hydrological data and analysis are central to flood mapping, post-event reporting, the design and prioritisation of flood alleviation schemes and providing the right advice to planning consultations to avoid inappropriate development in the flood plain.

Likewise, flood hydrology underpins flood forecasting and flood warning, which is fundamental to preparedness for flooding and building resilience.

In Scotland, the Scottish Environment Protection Agency (SEPA) launched a consultation on its future flooding services strategy (SEPA, 2020). The strategy has many of the same themes as England and Wales, and again will be heavily underpinned by flood hydrology activities. The following elements of the strategy all have strong ties to flood hydrology:

- avoiding inappropriate development on the flood plain via its statutory consultee role on land use planning
- ensuring that urban, natural environment and flood plain assets are integral to flood resilience
- warning and informing people so they are prepared for flooding
- developing partnerships that support public sector transformation to meet the adaptation and mitigation challenges of climate change impacts on flood risk
- providing high quality, trusted information that people use to make powerful decisions, including maps, data and information

Northern Ireland has a long-term water strategy, where flood risk management is one of the 5 principles that the strategy focuses on (Department for Regional Development, 2016). The long-term vision is to 'manage flood risk and drainage in a sustainable manner'. It aims to achieve this through 5 policies:

- provide sustainable flood resilient development
- manage the catchment to reduce flood risk
- provide sustainable integrated drainage in rural and urban areas
- improve flood resistance and resilience in high flood risk areas
- be prepared for extreme weather events

Many of the policies rely on flood hydrology, such as avoiding development in flood prone areas, ensuring land-use planning decisions are informed to help minimise flood risk, and designing and using sustainable drainage systems (SuDS) and drainage infrastructure. The policies also highlight the importance of reservoir construction and maintenance, watercourse inspection and maintenance, developing and maintaining accurate information on flood risk, flood alleviation programmes and providing effective, efficient flood emergency information and communication systems. All of these are underpinned by flood hydrology data, methods and models.

The respective strategies across all 4 nations have common themes that rely heavily on flood hydrology, for example, avoiding inappropriate development, design and maintenance of flood defence schemes, flood warning and forecasting, communicating flood risk, and reservoir safety.

2.3 The flood hydrology community

In its broadest sense, inland flood hydrology is relevant to a range of specialisms, including hydrology, hydrometry, hydrometeorology, hydrogeology and geomorphology. It also covers a range of sources of flooding, including fluvial, pluvial, groundwater and reservoirs, where individuals, institutions and private companies can also specialise. This diverse nature of flood hydrology can lead to a disparate community working in silos, where common problems are not always solved through collaborative working, but rather tackled in a piecemeal way. The work of the BHS goes a long way to combatting this issue and providing a focus for the flood hydrology community.

This flood hydrology roadmap aims to build on the work of BHS (including the BHS working group on the future of UK hydrological research) and further develop the sense of community in flood hydrology by fostering collaboration and partnership working. The roadmap itself has been developed through multiple phases of consultation across the flood hydrology community, and it is intended that it will be implemented with increased emphasis on partnership and collaboration.

2.4 Translating science into practice

Many of the established methods used in flood hydrology were developed decades ago and are based on relatively old science. For example, the methods used to estimate the probable maximum flood (PMF) for reservoir spillway design date from the 1970s. The flood estimation handbook (FEH) was published in 1999 (Institute of Hydrology, 1999) and is still the industry standard for flood estimation in the UK. Parts of the FEH have been updated since its publication (for example, Kjeldsen, 2007; Environment Agency, 2008), but there is a case for a wholesale review of flood estimation methods based on the latest science, and the development of the next generation of open access operational models and methods. From a fluvial flood forecasting perspective, local forecasting services in the UK don’t use formal uncertainty methods or probabilistic forecasting approaches which could be developed using existing scientific knowledge (Arnal and others, 2020).

A second issue relating to the translation of science into practice is around the slow uptake of science. There can be a time lag of years and even decades between established and proven methods in academia being adopted by practitioners. A good example of this are the tools and methods to detect and account for non-stationarity in flood flow data used for flood estimation. These methods have been debated and developed in the academic world for many years (Milly and others, 2008; Gilleland and Katz, 2011), but have only just recently been incorporated into operational practice and guidance in England and Wales (Environment Agency, 2020a). There will always be a time lag between new science being developed and practitioners adopting it, often for good reason. However, the flood hydrology roadmap will seek to reduce this time lag and encourage the rapid uptake of new, proven science into practice. There are also many other developing areas of science that are yet to be exploited by practitioners, for example, integrated modelling, machine learning, artificial intelligence and data science.

One of the principles of the flood hydrology roadmap is to improve the translation of the science of flood hydrology into practice to overcome some of these long-standing issues and enable operational practice to keep pace with science.

2.5 Known technical and methodological issues

There are many areas of operational flood hydrology methods, models and data that have known limitations or issues that would benefit from improvement. For example, current industry standard flood estimation methods don't help practitioners account for climate or land-use change, don't use or report uncertainty information, and don't work well in small, urban or permeable catchments. Likewise, the performance of operational flood forecasting models can vary seasonally (with less certainty during summer convective storms), there is a lack of data assimilation, and forecasting is challenging in rapidly responding catchments. These are just a few examples of the known limitations and issues with current operational practice. The flood hydrology roadmap will identify these known limitations and issues through extensive consultation across the flood hydrology community and use this information to develop action plans to address and overcome these issues.

The National Flood Resilience Review (NFRR) (HM Government, 2016) also identified areas of flood modelling that would benefit from long-term improvement. All of these modelling issues have direct relevance to flood hydrology:

- develop a more integrated flood risk modelling approach to allow simulations to be run which link meteorology, hydrology and flooding across England
- carry out further work, including using information from historic sources (for example, newspaper reports, photographs, and sediments) to extend flood records and allow recent flood events to be set in a longer-term context, so as to improve assessments of the likelihood of extreme flood events happening somewhere in the country over different time periods
- develop further the statistical methods to reduce uncertainties in flood estimation, including taking account of long-term variability and trends
- flood risk and the associated impacts should be reviewed on a regular basis to take account of the latest science, the results of the next set of UK Climate Projections in 2018, and reflect any changes in the underlying assumptions

The Environment Agency and the Met Office have been working on these actions since the NFRR was published. However, they are long-term aspirations which will require new science and analytical techniques, and the development of "the next generation of integrated flood risk assessments" (NFRR, page 26). The flood hydrology roadmap has a significant role to play in realising these long-term aspirations, and addressing these areas has been central to its development.

2.6 Flood hydrology in a changing climate

The UK has experienced many extreme flood events in recent years. In England, widespread flooding affected around 55,000 properties in summer 2007. Repeat severe flooding was experienced in Cumbria in 2005, 2009 and 2015. 17,000 properties flooded in December 2015 and January 2016 over 3 successive storms (Desmond, Eva and Frank) and 2,900 properties flooded in February 2020 from Storms Ciara and Dennis. Severe flash flooding was also experienced at Boscastle (2004), Helmsley (2005) and Coverack (2017).

In Scotland, Storms Desmond, Eva and Frank resulted in in over 1,000 properties flooding, with a further 300 properties flooded from surface water in August 2020, combined with severe disruption to infrastructure (roads, railways, utility supplies and hospitals).

Storms Ciara, Dennis and Jorge caused flood water to impact 3,130 properties right across Wales, with record rainfall and river flows causing some of the most significant flooding impacts in Wales since the 1970s (Natural Resources Wales, 2020).

In Northern Ireland, 1,600 households were flooded in Belfast in June 2012. A series of storms in the winter of 2015 and 2016 resulted the flooding of more than 3,300 hectares of land and 174 properties (Strong, 2016). This was followed in August 2017 when 400 homes were flooded around Drumahoe and Eglinton (Department for Infrastructure, 2018).

While these observations of individual extreme events do not necessarily imply that long-term statistical trends of flood discharge are also increasing (Hall and others, 2014), recent flood event attribution studies have demonstrated that historical greenhouse gases have already made some individual flood events more likely than they would have been in a pre-industrial climate (Kay and others, 2018; Schaller and others, 2016). Furthermore, records of annual maximum peak flow across England and Wales show general, but not universal, evidence of an increase in flood peaks. Two-thirds of gauging stations in England and Wales show upward trends in peak flows, with 21% of these increases being statistically significant (Environment Agency, 2020a). Similar trends are seen across north-western Europe where about 69% of flow gauging stations show an increasing flood trend (Blöschl and others, 2019).

These observations of changes in river flow are set against a backdrop of changes in other climatic variables such as temperature and rainfall. A recent report shows that in 2020 Europe experienced its warmest year since 1850 by a considerable amount. The year 2020 also saw the UK reach its third highest annual average temperature, after 2014 and 2006 (Bissolli, 2021). UK Climate Projections 2018 (UKCP18) (Lowe and others, 2018) show evidence of increased annual average rainfall over the UK in the last few decades.

The recent Intergovernmental Panel on Climate Change (IPCC) 6th Assessment report (IPCC, 2021) confirms that human influence has warmed the climate at a rate that is unprecedented in at least the last 2,000 years. UKCP18 suggests that the UK can expect warmer, wetter winters and hotter, drier summers in the future. This is supported by a recent study which suggests that the record breaking average daily rainfall observed on 3

October 2020 might be 10 times more likely by 2100 due to climate change (Christidis and others, 2021).

The flood hydrology roadmap aims to provide the knowledge, methods, tools and expertise for flood hydrologists to detect, attribute and take account of hydrological variability, whatever its cause. However, as climate change becomes a reality, flood hydrology will have an even more important role to play in providing underpinning knowledge and science to enable the activities required to make the UK resilient to future flooding.

2.7 Flood hydrology and net zero carbon

In 2019, the government set a new target requiring the UK to bring all greenhouse gas emissions to net zero by 2050 (BEIS, 2019). The Environment Agency has set itself a goal to become a net zero organisation by 2030.

One of the principles of the flood hydrology roadmap is that any actions it identifies should be carried out using low carbon solutions. This principle should apply to all roadmap activities, ranging from desk-based studies to construction. Prior to any work starting to implement the roadmap or a roadmap action, that project or initiative should describe how the work will be done in a sustainable and low carbon manner. One way to do this would be to use appropriate carbon costing tools[3]. The project should also look for innovative approaches to minimise carbon emissions and ensure sustainable implementation.

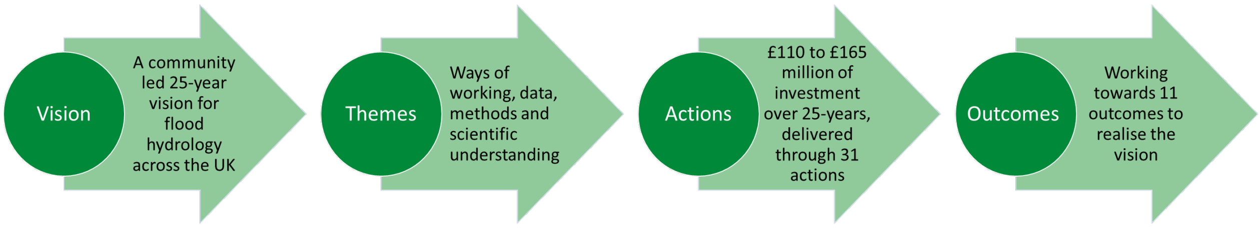
Those who are responsible for the long-term implementation of the flood hydrology roadmap (see section 4.1) should ensure that this is achieved using low carbon solutions, and be able to demonstrate its contribution to net zero targets across the UK.

[3] Environment Agency carbon planning tool [Last accessed 22 November 2021]

3 A roadmap for UK flood hydrology

The flood hydrology roadmap for the UK is built around a vision for the next 25 years developed by the flood hydrology community. This vision will be realised through 31 actions grouped into 4 thematic work areas of ways of working, data, methods and scientific understanding. Each action in the roadmap has been mapped to a desired outcome or outcomes where an outcome is defined as the result of change brought about to achieve the roadmap vision. The estimated funding required to carry out these actions is between £110 million and £165 million over the 25 year lifetime of the roadmap, which equates to an average of between £4.4 million and £6.6 million a year (see section 4.2). The high-level roadmap is shown in Figure 1.

Figure 1: The roadmap for UK flood hydrology



3.1 A vision for the next 25 years

A clear vision for the future of flood hydrology over the next 25 years is at the heart of the flood hydrology roadmap. This vision statement has been developed and refined through all stages of roadmap consultation described in section 5.

The overall vision for the UK flood hydrology roadmap is that:

- during the next 25 years society will have improved hydrological information and understanding to manage flood hazard in a changing world
- flood hydrology and whole-system process understanding will be underpinned by excellent evidence with quantified uncertainty
- leadership and collaboration are crucial to achieving this vision

3.2 Thematic work areas

Four thematic work areas have been identified to achieve the overall vision of the roadmap: ways of working, data, methods and scientific understanding. Each of these thematic work areas has a vision statement which was developed alongside the overall vision for the roadmap (above), and these are presented below.

3.2.1 Vision for ways of working

The vision for ways of working in UK flood hydrology over the next 25 years is:

- there is a representative UK group with a unifying overview as a lead voice for flood hydrology, to create more effective and efficient ways of working
- in the flood hydrology community, we work together with skilled teams and stakeholders, communicate clearly and use excellent, consistent technical guidance
- we engage across the UK and internationally, embracing and encouraging scientific and technological developments to continually improve efficiency and innovation in our field

3.2.2 Vision for data

The vision for data in UK flood hydrology over the next 25 years is:

- funding, knowledge, capability and resources exist to monitor the UK hydrological environment, particularly extremes
- new and historical data are communicated and shared openly, properly archived and centrally located to support all flood hydrology studies
- data are freely available for all carrying out flood hydrology studies
- data are of sufficient quantity and quality for each application; uncertainties are understood and communicated effectively

3.2.3 Vision for methods

The vision for methods in UK flood hydrology over the next 25 years is:

- flood hydrology methods for real-time, design and planning deal with all sources of flood risk
- methods are open-source, effective and regularly updated
- methods allow use of all information available and employ appropriate, best available tools that are consistent, accessible and peer reviewed
- impacts of future change and the calculation of uncertainty are included in decision-making as standard

3.2.4 Vision for scientific understanding

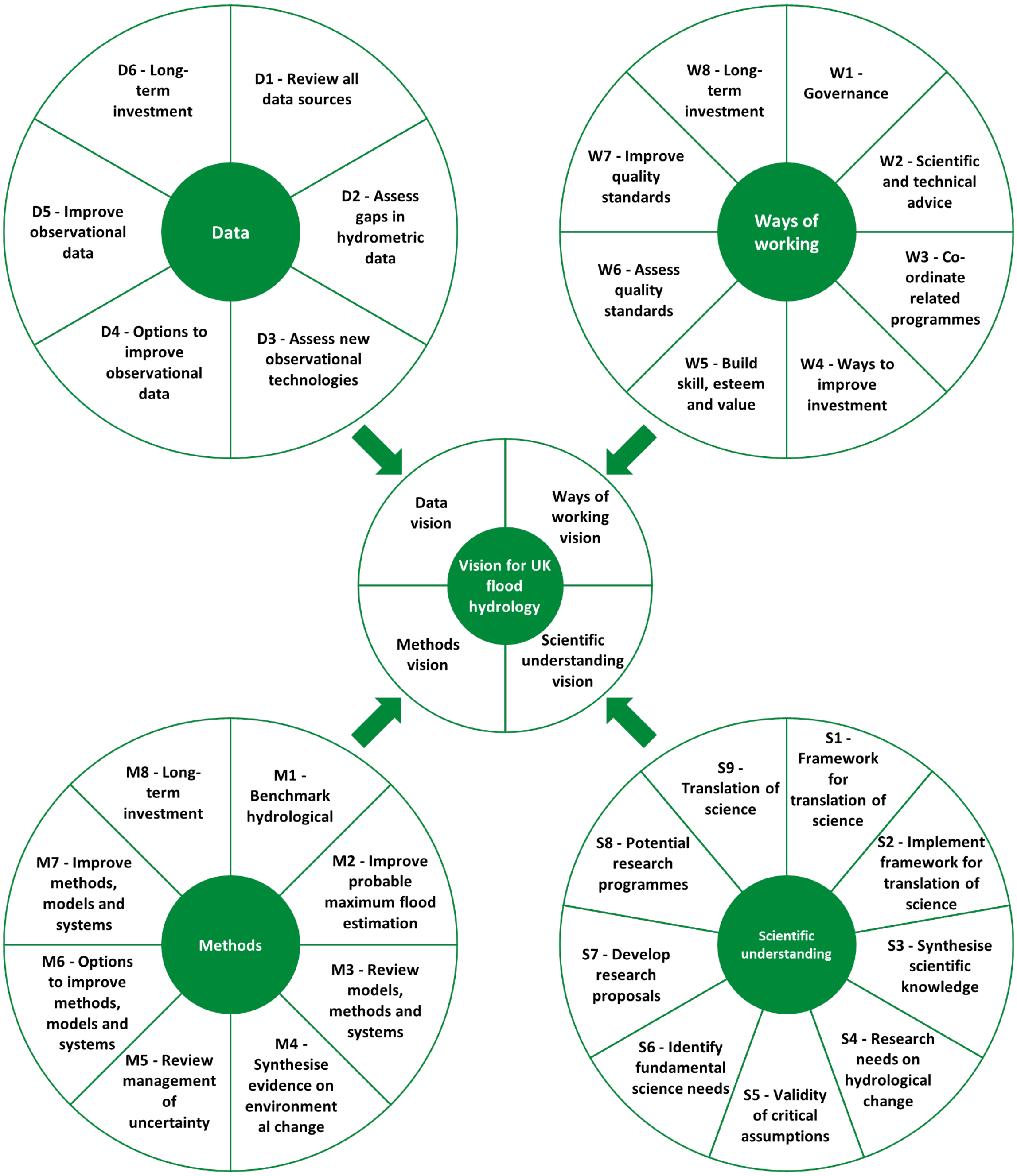
The vision for scientific understanding in UK flood hydrology over the next 25 years is:

- we continually improve our understanding of the processes governing all areas of flood risk (fluvial, fluvio-tidal, pluvial, reservoir and groundwater) with state-of-the-art science
- this science and knowledge is transferred into practical improvements in the efficiency and effectiveness of methods, ways of working and data

3.3 Action plans for thematic work areas

Each of the 4 themes in the flood hydrology roadmap has a detailed action plan which defines the collective actions required over the next 25 years to realise the roadmap vision. Figure 2 shows the 31 roadmap actions grouped around each theme. These actions have been developed from the 11 initiatives identified as part of the prioritisation process (see section 5.6) and then refined through consultation with the delivery partners group, the enablers group (see section 5.7) and the main roadmap steering group (see section 5.1.2). These actions should not be considered in isolation, there are many inter-dependencies which need to be identified and considered during delivery of the actions.

Figure 2: Summary of actions, themes and vision for the roadmap

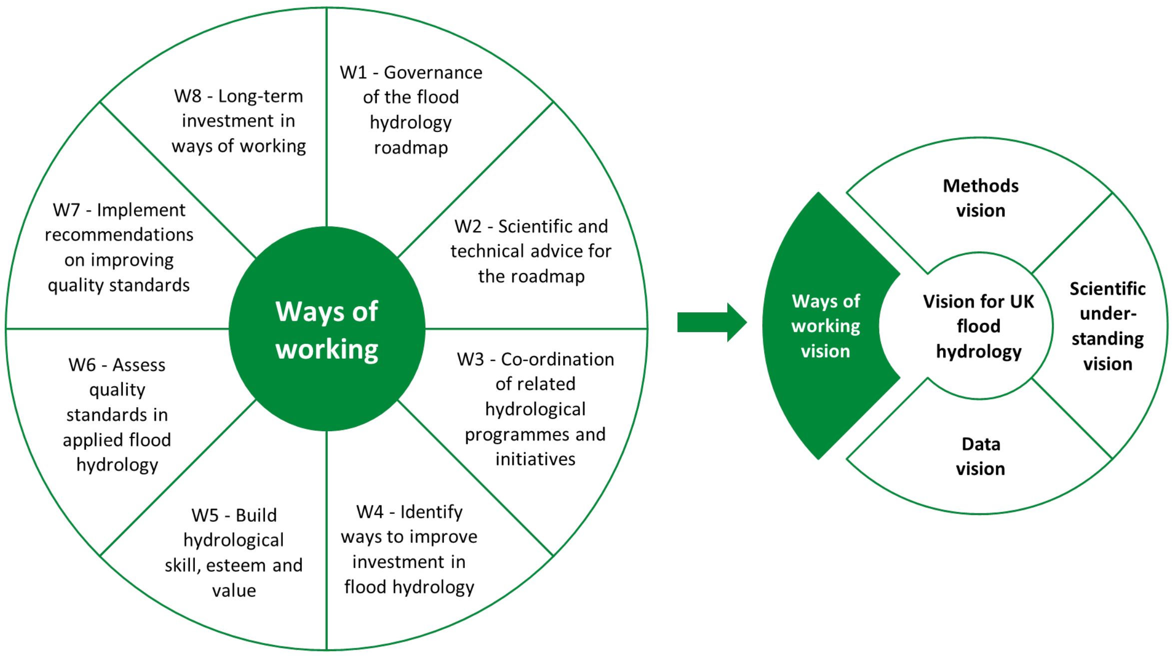


Each roadmap action has an objective, outline scope, intended outputs, intended outcomes and an estimated spend profile and duration. The action plan for each theme is described briefly below, with more detailed information given in Appendix G.

3.3.1 Action plan for ways of working

Eight actions have been identified to improve ways of working in UK flood hydrology, and these are summarised in Figure 3. These actions are aimed at achieving the vision for the ways of working theme described in section 3.2.1 and principally relate to how the flood hydrology community can work better together. Ways of working actions are numbered 1 to 8 with the prefix 'W' to denote ways of working.

Figure 3: Summary of actions on ways of working

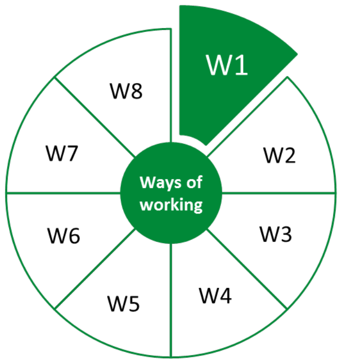


The actions identified in the ways of working theme are:

- W1: governance of the flood hydrology roadmap
- W2: scientific and technical advice for the roadmap
- W3: co-ordination of related hydrological programmes and initiatives
- W4: identify ways to improve investment in flood hydrology
- W5: build hydrological skill, esteem and value
- W6: assess quality standards in applied flood hydrology
- W7: implement recommendations on improving quality standards in applied flood hydrology
- W8: long-term investment in ways of working

These actions are outlined briefly in the section below and described in more detail in Appendix G of this report.

3.3.1.1 Action W1: Governance of the flood hydrology roadmap



It is likely that the initial members of the flood hydrology roadmap governance board will comprise potential funding organisations and the British Hydrological Society to represent the wider flood hydrology community:

- Environment Agency, England
- Scottish Environment Protection Agency
- Natural Resources Wales
- Department for Infrastructure, Northern Ireland
- British Hydrological Society

It is envisaged that it will take around 6 months to establish the governance board. The first task will be for each organisation to appoint an individual to the board to represent them. Each appointed representative should have sufficient seniority and authority to make decisions on behalf of their organisation that will contribute to achieving the roadmap vision.

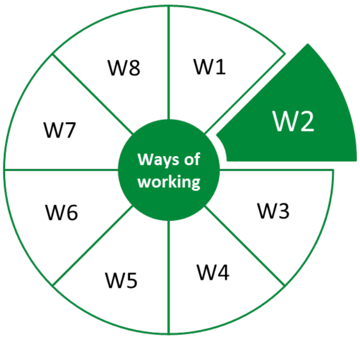
The board will need to make some early decisions, such as agreeing a formal name for the governance board and nominating an initial chairperson to lead the board. Other early activities will include developing terms of reference, establishing ways of working and developing a costed business plan for the ongoing operation of the board, including secretariat arrangements required to help the board function effectively.

One of the most important early actions for the governance board is to establish a scientific and technical advisory group (STAG) which will provide scientific and technical advice to the board to guide implementation of the roadmap. Suggestions on possible roles and responsibilities of the STAG and how it could be established and maintained are outlined in action W2.

Long-term responsibilities of the board are likely to include refinement and expansion of membership of the board. For example, it may be appropriate to invite UK Research and Innovation (UKRI) to join the governance board to help guide and advise on scientific actions in the roadmap. Members of the board will be encouraged to secure funding from their respective organisations to support delivery of the governance board business plan and implementation of the roadmap action plan.

One of the most fundamental responsibilities of governance board members will be to champion the roadmap and identify funding opportunities to help realise the flood hydrology roadmap vision. Other responsibilities of the board are likely to include developing a communications and engagement plan to encourage participation and investment in the roadmap and its action plan, and to report on the progress of roadmap implementation to the wider community. This could take the form of regular (annual) progress reviews of the flood hydrology roadmap action plan, with a formal published report on progress at least once every 3 years. These reviews should result in a refresh of the roadmap and action plan at appropriate intervals.

3.3.1.2 Action W2: Scientific and technical advice for the roadmap

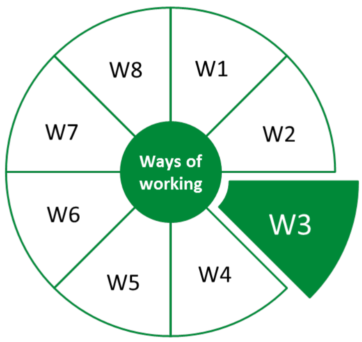


This action aims to establish a scientific and technical advisory group (STAG) to provide technical advice and steer to the governance board to help guide the implementation of the roadmap.

The flood hydrology roadmap governance board established in action W1 will lead on establishing the STAG. The main roles and responsibilities of the STAG could include helping to shape and scope projects and initiatives to implement the roadmap, provide scientific and technical advice and steer to in-flight roadmap projects, and provide peer review of project outputs prior to publication. However, it is for the governance board to define these responsibilities.

The governance board should champion and apply the principles of equality, diversity and inclusion (EDI) when establishing the STAG to ensure diversity of thought and background, so that discussions and decisions are informed by a diverse range of perspectives, including perspectives from underrepresented groups.

3.3.1.3 Action W3: Co-ordination of related hydrological programmes and initiatives



This action aims to ensure visibility, coordination and collaboration between programmes and initiatives related to flood hydrology across the UK.

This action should identify programmes and initiatives relevant to UK flood hydrology and create an open and accessible online catalogue detailing these activities. There should be appropriate resources and a clear process to keep the catalogue up to date as new programmes and initiatives emerge over time.

This action should also aim to facilitate and promote the coordination of outcomes across related programmes and initiatives to ensure that synergies can be maximised and duplication of work avoided. This activity should use low-carbon approaches to build understanding and collaboration between programmes and initiatives such as online workshops, events and knowledge exchange activities (linking to actions S1 and S2).

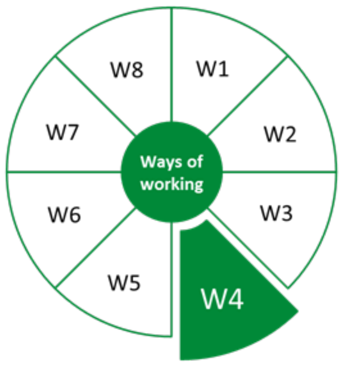
Both operational and scientific initiatives and programmes should be included in this action and encouraged to collaborate. Furthermore, there should be a review of international activities, groups and programmes related to UK flood hydrology. This review could aim to identify the potential benefits that could be achieved through international collaboration, and ensure the UK learns from global best practice and knowledge about flood hydrology.

It is likely that on completion of this action (estimated to take 12 months in Appendix G) the STAG would take ownership of longer-term co-ordination of related hydrological programmes and initiatives. The STAG should become the focal point for knowledge on collaboration in UK flood hydrology.

Examples of some high-profile UK programmes and initiatives that should be considered as part of this action are:

- NERC Flood Drought Research Infrastructure (FDRI) scoping study
- BHS working group on the future of UK hydrological research (see Beven and others, 2020; Wagener and others, 2021)
- NERC Hydro-JULES programme
- Scotland’s Centre of Expertise for Water (CREW)

3.3.1.4 Action W4: Identify ways to improve investment in flood hydrology

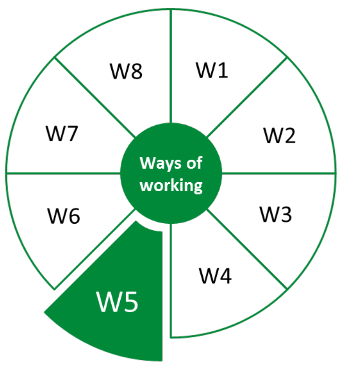


This action aims to make the case for investment in flood hydrology across the UK to ensure that future expenditure provides the greatest value to the economy, society and the environment.

This action will carry out activities that help demonstrates the value of investing in flood hydrology and hydrological data, for example by using approach such as value chain mapping (or dependency modelling). The work will need the expertise and knowledge of economists and will aim to quantify the contributions made by flood hydrology and hydrometric data to achieve flood risk management outcomes.

A report outlining the case for investment in UK flood hydrology will be published and used to help the governance board identify potential sources of investment and to focus engagement activities aimed at attracting investment in UK flood hydrology.

3.3.1.5 Action W5: Build hydrological skill, esteem and value



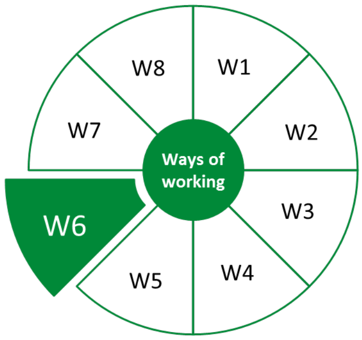
This action aims to strengthen the flood hydrology profession by quantifying the size and diversity of the skill base and developing the skills needed for the next 25 years.

Quantifying the flood hydrology workforce in the UK could take the form of a national survey to establish baseline data. For example, establishing the number of UK flood hydrologists, their salary, organisational position, level of education and diversity. The survey could also capture broader information on perceived skills gaps, now and in the future, higher education opportunities and vocational training opportunities open to flood hydrology professionals.

The findings of the survey should be published and used to inform a new skills and development framework for UK flood hydrology. This framework should aim to:

- raise the profile of flood hydrology as a profession
- ensure that flood hydrology is valued as a profession
- encourage a more diverse range of people into flood hydrology careers
- ensure that the UK flood hydrology community has the right skills, knowledge, training and development opportunities to tackle challenges over the next 25 years

3.3.1.6 Action W6: Assess quality standards in applied flood hydrology



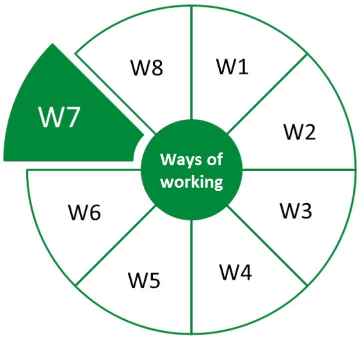
This action aims to assess where quality improvement and consistency is needed in flood hydrology, and to drive quality improvements.

Action W6 will examine where quality standards may be lacking or inconsistent in UK flood hydrology activities and understand the reasons for this. It will identify where there are recognised shortfalls in quality standards, examples of ‘good practice’ and the reasons why quality standards may not be adhered to.

The assessment will consider quality standards in flood hydrology models (for flood estimation and forecasting) and hydrometric data collection, processing and archiving. The assessment will also investigate what quality standards are required across the UK by commissioning agencies, how appropriate they are, and how rigorously they are being applied.

A report on this review of quality standards should be published which contains recommendations for improvements and a plan for implementation in action W7. This report could sit alongside a peer-reviewed journal paper on quality standards in UK flood hydrology.

3.3.1.7 Action W7: Implement recommendations on improving quality standards in applied flood hydrology

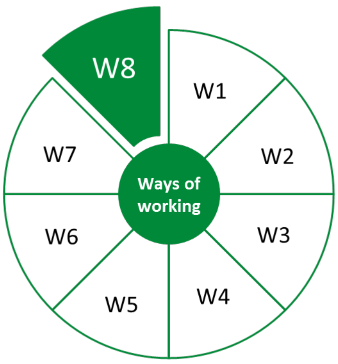


This action aims to implement the recommendations from action W6.

The detailed objectives, scope and intended outcomes of action W7 will be determined towards the end of action W6 and agreed by the flood hydrology roadmap governance board.

It is likely that this action will result in the development and implementation of new quality standards for UK flood hydrology.

3.3.1.8 Action W8: Long-term investment in ways of working



This action aims to carry out longer-term actions to achieve outcomes that will contribute to achieving the ways of working vison on the flood hydrology roadmap.

The detailed scope of long-term actions to improve ways of working in the roadmap will become clearer as implementation of the roadmap progresses, and will be informed by the findings and outputs of actions W1 to W7.

The following areas may be part of this long-term programme of work, but will be subject to change and review as part of the periodic refresh of the roadmap and its action plan (likely to be every 3 years), which will be led by the governance board:

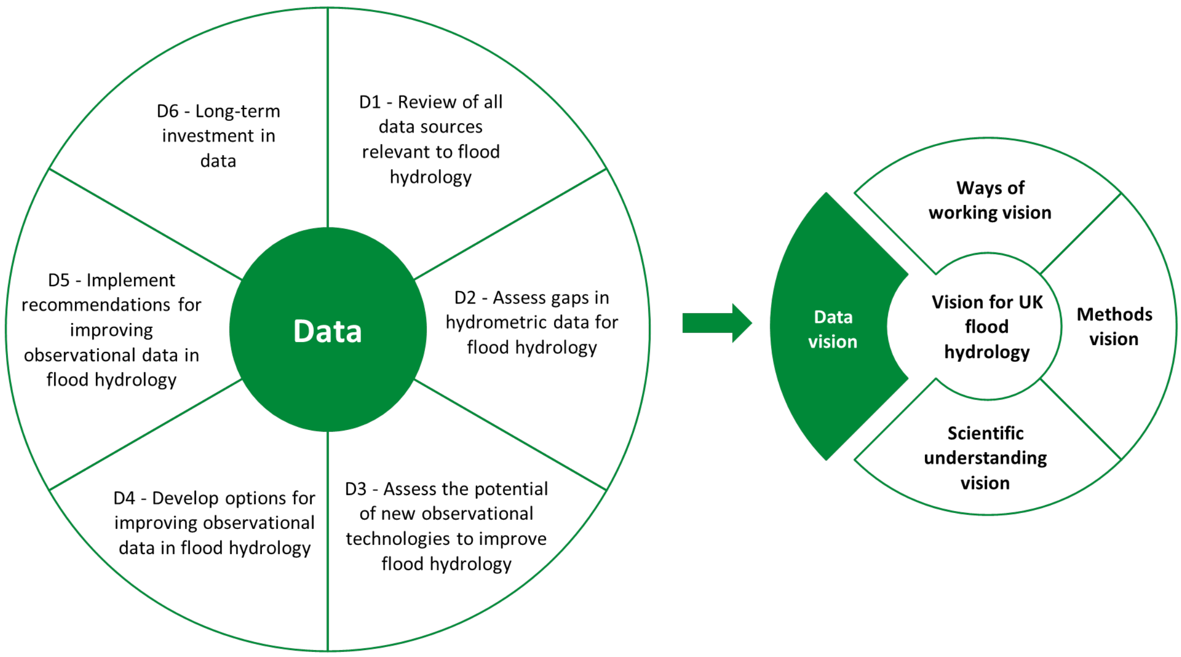
- periodic reviews of the purpose, membership and effectiveness of the STAG
- a review of the work done to improve coordination and collaboration between programmes and initiatives related to flood hydrology across the UK

- further work to demonstrate the value of UK flood hydrology and encourage longer-term investment
- periodic review of the survey of the flood hydrology community to help understand the impact of roadmap actions on the flood hydrology community
- reviewing and updating the strategy to improve diversity and promote equality of opportunity within the flood hydrology profession
- reviewing and updating the skills and development framework for UK flood hydrology
- a review of quality standards after a period of embedding and use
- communication and engagement activities to build on the sense of community and encourage uptake of roadmap outputs and outcomes

3.3.2 Action plan for data

Six actions have been identified to improve data in UK flood hydrology and these are summarised in Figure 4. These actions are aimed at achieving the vision for the data theme described in section 3.2.2 and principally relate to improving long-term data quality, quantity and accessibility. Data actions are numbered 1 to 6 with the prefix 'D' to denote data.

Figure 4: Summary of actions on data

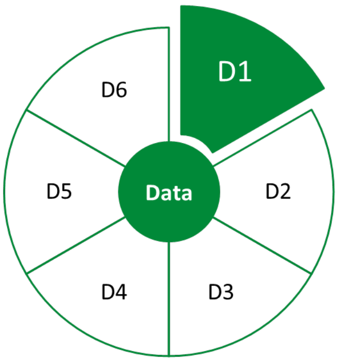


The actions identified in the data theme are:

- D1: review of all data sources relevant to flood hydrology
- D2: assess gaps in hydrometric data for flood hydrology
- D3: assess the potential of new observational technologies to improve flood hydrology
- D4: develop options for improving observational data in flood hydrology
- D5: implement recommendations for improving observational data in flood hydrology
- D6: long-term investment in data

These actions are outlined briefly in the section below and described in more detail in Appendix G of this report.

3.3.2.1 Action D1: Review of all data sources relevant to flood hydrology



This action aims to understand the status of flood hydrology data accessibility in the UK and set out options for improvement.

Action D1 will identify all sources of data relevant to flood hydrology in the UK and create an online register to capture this information, including hydrometric data such as river flows and levels, rainfall, groundwater level information and other sources of data that are of hydrological relevance[4]. The register will consider real-time and non-real-time data, data relating to all sources of inland flooding and data produced from operational and academic work. It will also establish a mechanism for maintaining and updating the register as new data becomes available.

The accessibility of data in the register will be reviewed and options and recommendations identified and published to improve the visibility and access to flood hydrology data sets,

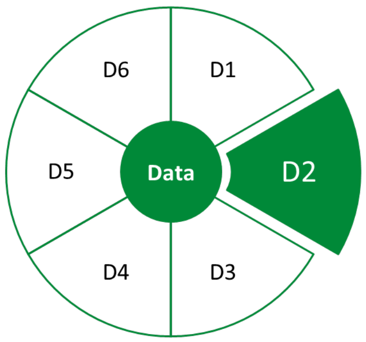
[4] There are many observations and data types that could be relevant to flood hydrology and the wider water cycle. For example, soil moisture, evaporation fluxes, snow, soils, geology, geomorphology and sediments, land cover, historic floods, paleo flood data, citizen science observations, documentary data sources, tracers, earth observations from space, topography, reanalysis and model outputs.

working towards the roadmap principle of open and free access to data, models and methods.

Identifying and reviewing flood hydrology data for the UK will require input from all bodies with responsibility for flood hydrology data, including measuring authorities, the UK surface and groundwater archives (SAGA) committee, and other data owners such as reservoir owners and operators. The review will also benefit from working with bodies that could advise on improvements to flood hydrology data (for example, the Geospatial Commission, the James Hutton Institute and the Centre for Environmental Data Analysis).

The findings, options and recommendations for improving access to UK flood hydrology data will be published alongside the online register.

3.3.2.2 Action D2: Assess gaps in hydrometric data for flood hydrology



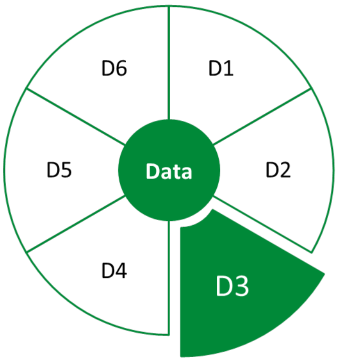
This action aims to assess gaps in hydrometric data and make recommendations for improving UK hydrometric data to better support scientific research and operational activities for flood hydrology.

Action D2 will assess where there are gaps in the UK hydrometric network and data set through a strategic review of national monitoring networks. The assessment will consider gaps from both a scientific and operational perspective and give special consideration to gaps and data needs in areas of future development outlined in local development plans, and in catchments where flood estimates and forecasts are known to be highly uncertain (for example small catchments, urban catchments and permeable catchments).

The assessment will make recommendations on improving high flow gauging, the availability and need for hydrometric data for reservoir inflow calculations, and consider what hydrometric data and infrastructure should be maintained long term (for example, the benchmark catchment network). It will also consider how data rescue (data that exists but is not easily available) could contribute to this action.

The assessment will also examine the long-term sustainability of the UK hydrometric network and provide a clear plan of the resources (people, money and infrastructure) needed to support such a network.

3.3.2.3 Action D3: Assess the potential of new observational technologies to improve flood hydrology



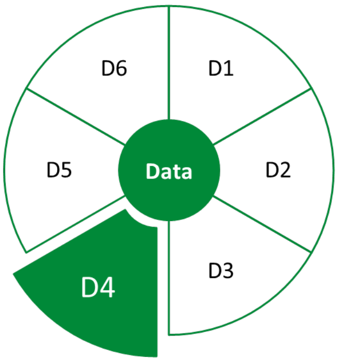
This action aims to assess the potential of new observational technologies to improve flood hydrology and identify options for implementation.

Action D3 will carry out an assessment of new observational technologies that could be used to gather data for real-time and non-real-time applications and for all sources of inland flooding. The assessment will:

- investigate opportunities for improving the characterisation of rainfall from weather radar, and the spatial measurement of rainfall, focusing on flood-generating rainfall events
- examine the opportunities for other data types to support flood hydrology, for example, information on soil moisture, evaporation, snow and snowmelt, and the use of geo-spatial data on soils, geology and other catchment descriptors to improve process understanding
- examine the potential of new technologies to enable the safe collection of reliable and accurate high flow gaugings during periods of high flow
- consider how technological advances in observational techniques, remote sensing, data processing, modelling, machine learning and artificial intelligence could improve UK flood hydrology
- examine new technologies and opportunities for citizen science data collection, storage and management and investigate the accuracy of citizen science and its quality control
- consider how new technologies could improve the efficiency of data collection
- consider the role of using existing technologies in different ways (for example, blended data sets)
- develop a mechanism for continued appraisal of new and emerging technologies beyond the life of this action

All of the above elements of this action should be informed by engagement and consultation with leading stakeholder groups (for example, hydrometry practitioners and researchers) and initiatives such as the FDRI project and the BHS working group on the future of UK hydrological research. The findings should be published alongside recommendations and options which outline the greatest potential for new observational technologies to improve flood hydrology.

3.3.2.4 Action D4: Develop options for improving observational data in flood hydrology



This action aims to develop a series of options to improve future accessibility, quantity and quality of flood hydrology data in the UK.

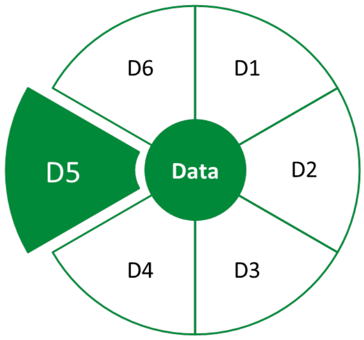
Action D4 will bring together the options and recommendations for improvement identified in actions D1, D2 and D3. It will develop a series of integrated options to improve observational data accessibility, quantity and quality, and embrace new technologies in flood hydrology.

The options should consider the creation of a discoverable portal or portals for all UK flood hydrology data which signposts users to relevant data sets. This portal could hold links to data sets rather than try to bring data together in one place and build on the online register creating in action D1. This action should also outline options that could achieve the roadmap principle of open and free access to all flood hydrology data, including the long-term hosting, funding and licensing of data. These options could be informed by international approaches to data access and by trying to answer the question, 'how do freely available flood hydrology data benefit society, the economy and the environment'.

Other elements that could be considered include examining opportunities for salvaging historical, non-digitised data and the development of a comprehensive 'local data' archive to host and make freely available data to enhance flood estimation such as local historical data, near-real time local data, palaeoflood and citizen science data.

The integrated options should be published in a report which considers needs for real-time and non-real-time data and examines all sources of inland flooding.

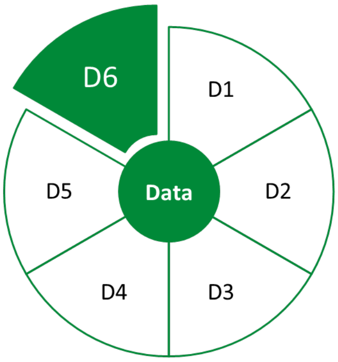
3.3.2.5 Action D5: Implement recommendations for improving observational data in flood hydrology



This action aims to implement the preferred options for improving future accessibility, quantity and quality of flood hydrology data in the UK.

The detailed objectives, scope and intended outcomes of action D5 will be determined towards the end of action D4 and agreed by the flood hydrology roadmap governance board.

3.3.2.6 Action D6: Long-term investment in data



This action aims to carry out longer-term actions to achieve outcomes that will contribute to achieving the data vison on the flood hydrology roadmap.

The detailed scope of long-term actions to improve flood hydrology data in the roadmap will become clearer as implementation of the roadmap progresses, and will be informed by the findings and outputs of actions D1 to D5. The following areas may be part of this long-term programme of work, but will be subject to change and review as part of the periodic refresh, and the roadmap and its action plan which will be led by the governance board:

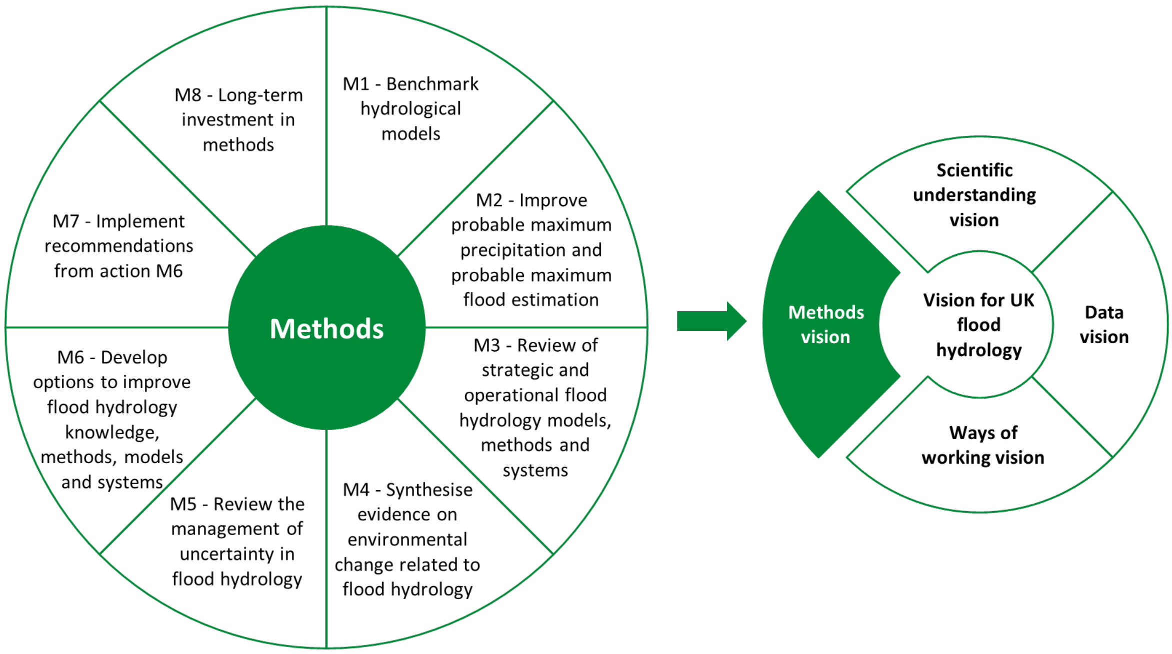
- the implementation of a national system that hosts the UK's flood hydrology data
- further work on improving the quality of high flow data using emerging technology
- ensuring that long-term hydrometric resources are sustainably funded
- improving the capture of data on extreme events in small and urban catchments
- periodic reviews of national data to ensure that the online register of flood hydrology data (from action D1) is up to date

The intended outputs from this action are yet to be defined and are dependent on the findings, recommendations, outputs and outcomes of actions D1 to D5.

3.3.3 Action plan for methods

Eight actions have been identified to improve methods in UK flood hydrology and these are summarised in Figure 5. These actions are aimed at achieving the vision for the methods theme described in section 3.2.3 and principally relate to improving flood hydrology methods, models and systems. Methods actions are numbered 1 to 8 with the prefix ‘M’ to denote methods.

Figure 5: Summary of actions on methods

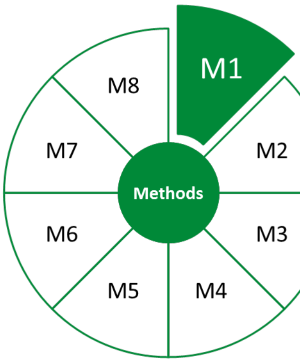


The actions identified in the methods theme are:

- M1: benchmark hydrological models
- M2: improve probable maximum precipitation and probable maximum flood estimation
- M3: review of strategic and operational flood hydrology models, methods and systems
- M4: synthesise evidence on environmental change related to flood hydrology
- M5: review the management of uncertainty in flood hydrology
- M6: develop options to improve flood hydrology knowledge, methods, models and systems
- M7: implement recommendations for improving knowledge, methods, models and systems (implement action M6)
- M8: long-term investment in methods

These actions are outlined briefly in the section below and described in more detail in Appendix G of this report.

3.3.3.1 Action M1: Benchmark hydrological models

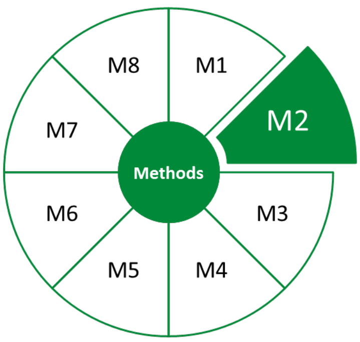


This action aims to develop benchmarking tests and data sets to test and compare the performance of hydrological models for operational use.

Action M1 will define the metrics that will be used to benchmark hydrological models, and identify the hydrological models and methods which will be benchmarked (which will include models used for real-time and non-real-time applications). This may involve identifying a selection of hydrologically diverse catchments to be used as 'labs' and developing and trailing benchmarking tests and data sets in a transparent and repeatable manner. This action will also need to ensure that appropriate benchmarks are developed for all sources of inland flooding and combinations of these sources.

A clear process should be established for benchmarking new models developed in the future, which states how new models should be compared to existing models that have already been benchmarked. The findings and the data, tests and benchmarking process should be published in a report and/or a peer reviewed scientific journal paper.

3.3.3.2 Action M2: Improve probable maximum precipitation and probable maximum flood estimation



This action aims to develop new methods and guidance for deriving reservoir flood inflow for extreme events up to and including the probable maximum flood (PMF).

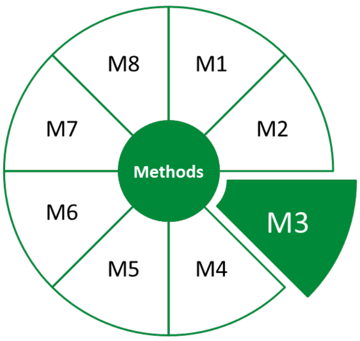
Action M2 is being taken forward by an Environment Agency research project called, 'Improving probable maximum precipitation (PMP) and probable maximum flood (PMF) estimation for reservoir safety' (FRS19222). Its primary purpose is to improve reservoir spillway flood hydrology in the UK.

The first phase of this project is underway at the time of writing (September 2021) and will collate and catalogue extreme historical rainfall and flood events, review state-of-the-art methods for estimating PMP and PMF, and develop options for improving PMP and PMF estimation in the UK.

The second phase of the project is likely to develop and implement new/updated methods and tools for estimating PMP and PMF in the UK which are freely available to all users. The new method should aim to take account of past and future non-stationarity and work alongside the climate change allowances used for flood and coastal risk projects, schemes and strategies[5] and flood risk assessments[6].

The ultimate goal of this work is to produce new freely available methods and guidance for estimating PMP and PMF which are based on the latest scientific understanding. A report and peer-reviewed scientific paper will be published detailing the new methods and their development.

3.3.3.3 Action M3: Review of strategic and operational flood hydrology models, methods and systems



This action aims to review strategic and operational flood hydrology models, methods and systems and make recommendations for improvement.

This review will consider all models, methods (process based, statistical and machine learning) and systems used in strategic and operational applications of flood hydrology covering both flood estimation and flood forecasting. It will consider the current state-of-art for models, methods and systems and define what is possible during the early part of the roadmap (around 6 years) and what may be possible over the 25 year life of the roadmap.

[5] Guidance on climate change allowances for FCRM projects and schemes [Last accessed 22 November 2021]

[6] Guidance on climate change allowances for flood risk assessments [Last accessed 22 November 2021]

The review should aim to:

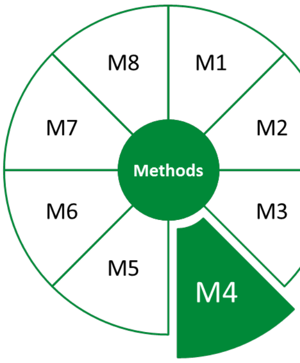
- identify models, methods, data and systems relevant to flood hydrology
- understand who benefits from and values flood hydrology models and data, including the research community
- understand the needs of end users
- investigate technology and software solutions to meet end user needs
- rapidly iterate outline plans for software and IT infrastructure solutions
- consider how community accessibility (with the aspiration of open and free access) to software could be improved
- identify where improvements to models, methods and systems would enable better uptake of (existing) scientific advances
- identify where new fundamental science is required to develop future models, methods and systems (feeding into action S6)
- identify opportunities to reduce uncertainty is small catchments, urban catchments and permeable catchments

One of the main elements for this review to consider is the future development of new approaches for modular, open access methods, models and systems for flood estimation and flood forecasting. Within this framework technical considerations include (a full list is given in Appendix G):

- new approaches for the detection and attribution of hydrological variability
- support for seamless approaches for modelling past and future climate change impacts
- translating model results into guidance and data that can be used for estimating future river flow and rainfall scenarios
- support for more flexible approaches to joint probabilities from all sources of flooding at multiple spatial and temporal (coherent) scales
- improving understanding of the role of flood volumes in assessment of risk
- improving understanding of long duration rainfall methods
- assessing the role of data-driven methods based on machine learning and artificial intelligence to augment or improve on hydrological methods and models
- assessing the scope for improvements to data assimilation methods applied in flood forecasting
- assessing the potential of more integrated hydro-meteorological modelling
- methods and systems that would enable flood hydrology and geomorphological methods and models to be linked

It is anticipated that the outputs from this action are likely to be a detailed report reviewing the current state of flood hydrology models, methods and systems, with recommendations on how to improve based on user needs and the best scientific evidence and a number of open-source software/systems demonstrators and prototype designs.

3.3.3.4 Action M4: Synthesise evidence on environmental change related to flood hydrology



This action aims to synthesise existing evidence and knowledge on environmental change related to flood hydrology and identify knowledge gaps.

The synthesis of evidence for action M4 could take the form of a systematic review or rapid evidence assessment[7]. The primary question of the review could be:

- what knowledge and methods relating to environmental change are required to achieve the strategic ambitions of the flood hydrology roadmap?

Secondary questions for the review could be:

- what environmental changes can have an impact on flood hydrology?
- how has environmental change impacted flood hydrology over the last millennia?
- what can past environmental change tell us about future flood hydrology?
- how might future environmental change impact on flood hydrology?
- how might environmental change influence how we do flood hydrology?

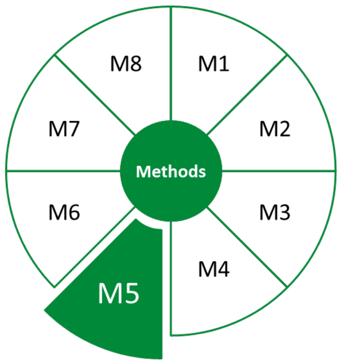
The review should consider past, present and future environmental change and the implications of each for flood hydrology practice and fundamental research. It should be complemented with additional work to identify a series of options and recommendations to:

- address knowledge gaps and answer important questions raised in the review
- improve operational practice relating to past, present and future environmental change
- identify opportunities to translate existing science into practice
- identify future research needs, ranging from fundamental research to near-operational research

The findings of the review should be published in a report and/or a peer-reviewed scientific journal.

[7] Guide on the production of quick scoping reviews and rapid evidence assessments [Last accessed 22 November 2021]

3.3.3.5 Action M5: Review the management of uncertainty in flood hydrology



This action aims to review the management of uncertainty in flood hydrology and make recommendations for improvement.

Action M5 will carry out a review of the rationale and motivation for the management of uncertainty in flood hydrology, clarifying the associated value (economic or otherwise) within FCERM. It should cover both real-time and non-real-time application and aim to establish clear answers to questions such as:

- why is uncertainty management important?
- who is uncertainty management important for?
- how do organisations use information about uncertainty?
- what are the sources of uncertainty in flood hydrology?
- which types of uncertainty are important?
- how can the uncertainty in future projections be included?
- can we use probabilistic approaches to help us quantify uncertainty?
- how should we communicate uncertainty in flood hydrology?

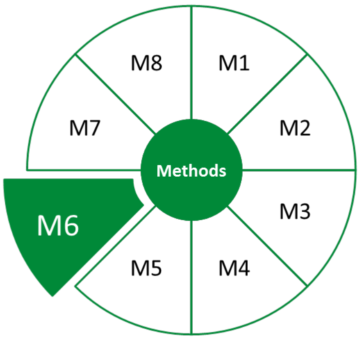
This review could consider the value of analysing uncertainty in the flood modelling chain and help answer questions like:

- what are the greatest sources of uncertainty in modelling for flood risk management?
- what is the relative importance of different assumptions/data sets that contribute to uncertainty?
- how much is the assumption of data stationarity important compared to other assumptions involved in estimating design floods?
- how can we present information on uncertainty to decision makers in a clear and informative way

This action could also help define the scope of new guidance for practitioners on the management of uncertainty in flood hydrology.

A report should be published which includes options and recommendations for managing uncertainty which can be further developed and implemented via subsequent actions M6 and M7.

3.3.3.6 Action M6: Develop options to improve flood hydrology knowledge, methods, models and systems



This action aims to develop integrated options to improve knowledge, methods, models and systems in UK flood hydrology.

Action M6 will build on and integrate options and recommendations identified in actions M3, M4 and M5. It will:

- set out clear (costed) plans to improve flood hydrology knowledge, methods, models and systems for flood estimation and flood forecasting over the next decade
- include costed options for maintaining any new methods, models and systems beyond initial development to enable continuous improvement through implementing new scientific advances
- produce a report with detailed project scopes and business cases for the preferred options to improve flood hydrology knowledge, methods models and systems

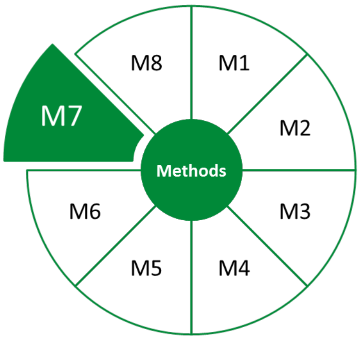
Methodological, modelling and system options for improvement could include:

- new open source, freely accessible modular approaches to flood estimation and flood forecasting
- seamless modelling of the past and future
- quantification and communication of hydrological variability over multiple space and time scales
- further development of methods and models to detect and attribute non-stationarity in hydrological variables
- complementary application of physics-based and statistical approaches
- methods to assess the real-world hydrological effectiveness of natural flood management

Options to improve knowledge in flood hydrology could include:

- improving the accessibility of practitioner guidance
- new guidance for the management of uncertainty in flood hydrology
- attribution studies to examine the causative role of drivers of hydrological change on flood risk
- improved assessment of changing risk of prolonged rainfall extremes
- further development of future river flow and rainfall scenarios to improve flood risk management planning and strategy decisions

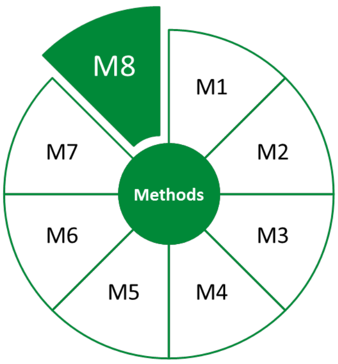
3.3.3.7 Action M7: Implement recommendations for improving knowledge, methods, models and systems



This action aims to implement the preferred options and recommendations to improve flood hydrology knowledge, methods, models and systems.

Action M7 will implement recommendations from action M6. It is likely that this action will include the implementation of new (next generation) methods, models and systems to underpin flood hydrology and flood risk management) for decades to come.

3.3.3.8 Action M8: Long-term investment in methods



This action aims to carry out longer-term actions to achieve outcomes that will contribute to achieving the methods vison on the flood hydrology roadmap.

The detailed scope of long-term actions to improve methods in flood hydrology will become clearer as implementation of the roadmap progresses and will be informed by the findings and outputs of actions M1 to M7.

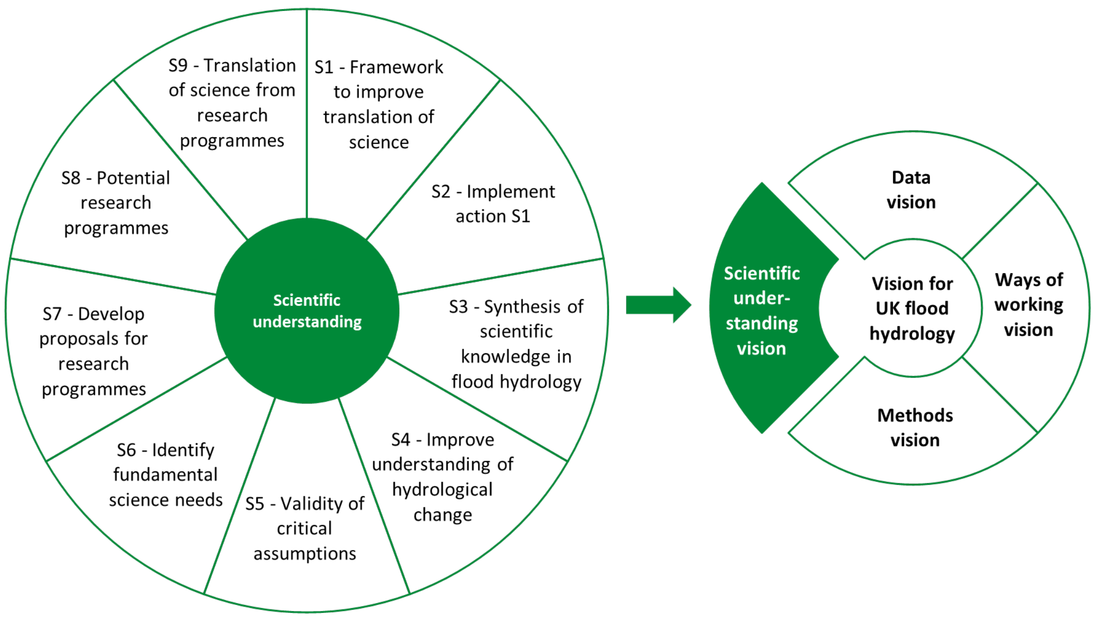
The following areas may be part of this long-term programme of work, but will be subject to change and review as part of the periodic refresh and the flood hydrology roadmap and its action plan led by the governance board:

- further development of the next generation modelling tools and systems from actions M6 and M8
- long-term investment in the digital infrastructure to support next generation modelling
- development and implementation of more integrated flood hydrology modelling

3.3.4 Action plan for scientific understanding

Nine actions have been identified to improve scientific understanding in UK flood hydrology and these are summarised in Figure 6. These actions are aimed at achieving the vision for the scientific understanding theme described in section 3.2.4 and principally relate to improving flood hydrology methods, models and systems. Scientific understanding actions are numbered 1 to 9 with the prefix ‘S’ to denote scientific understanding.

Figure 6: Summary of actions on scientific understanding

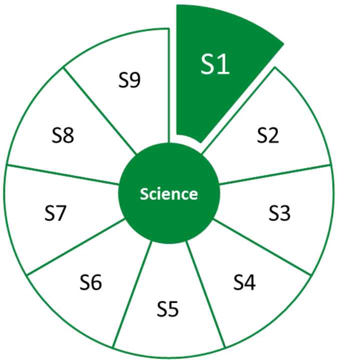


The actions identified in the scientific understanding theme are:

- S1: develop a framework to improve the rapid translation of new science into policy and practice
- S2: implement the framework to improve the rapid translation of new science into policy and practice (implement action S1).
- S3: synthesis of scientific knowledge in flood hydrology
- S4: identify research needs to improve understanding of flood generation processes and drivers of hydrological change
- S5: investigate the validity of critical assumptions made in operational flood hydrology
- S6: identify fundamental science needs in flood hydrology
- S7: develop proposals for research programmes
- S8: potential research programmes
- S9: translation of science from research programmes into practice

These actions are outlined briefly in the section below and described in more detail in Appendix G of this report.

3.3.4.1 Action S1: Develop a framework to improve the rapid translation of new science into policy and practice



This action aims to promote the rapid uptake of science into practice and also ensure that the science community has sight of the scientific and technical needs of practitioners.

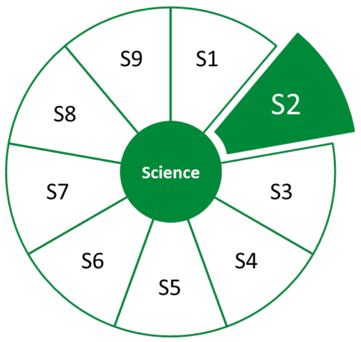
The development of a framework to improve the rapid translation of new science into policy and practice could be led by a group drawn from the science and practitioner community. The group could aim to identify gaps in knowledge exchange activities across the community, and identify novel and innovative ways to improve knowledge exchange between scientists and practitioners. The framework could have a 3-year reporting cycle where the report outlines how new science could be translated into practice based on a review of recent scientific developments in flood hydrology (from action S3) and expert opinion and judgment.

This framework could be complemented by more traditional knowledge exchange activities, which could include activities such as:

- knowledge exchange fellowships
- work placements/secondments for early career researchers, with an emphasis on improving diversity within the profession
- placements at academic institutions for practitioners
- promoting and organising workshops, meetings, conferences and other novel knowledge exchange methods
- delivering a series of presentations or webinars from practitioners and scientists via organisations such as the BHS, Institution of Civil Engineers (ICE), CIWEM, British Society for Geomorphology, British Dam Society, Royal Geographical Society and the Geological Society
- encouraging non-academic PhD supervision from the wider professional community
- developing collaborative awards in science and engineering (CASE) studentships with NERC and the Engineering and Physical Sciences Research Council (EPSRC)
- identifying better ways to engage with PhD and postdoctoral researchers
- increasing the visibility of ongoing academic research to the professional community

The framework will be published and contain a clear long-term plan to improve the rapid uptake of science into practice and also ensure that the science community has sight of the scientific and technical needs of practitioners. This plan will be implemented via action S2.

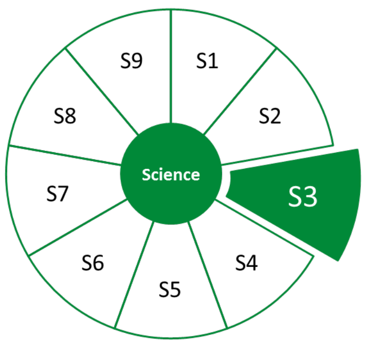
3.3.4.2 Action S2: Implement the framework to improve the rapid translation of new science into policy and practice



This action aims to implement the proposals for a framework to improve the rapid translation of new science into policy and practice.

Action S2 will implement recommendations from action S1 to improve the rapid translation of new science into policy and practice.

3.3.4.3 Action S3: Synthesis of scientific knowledge in flood hydrology



This action aims to create and maintain an up-to-date comprehensive synthesis of the state of scientific knowledge in flood hydrology.

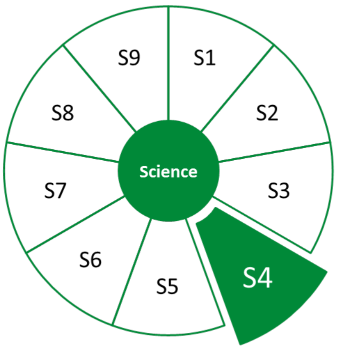
Action S3 will carry out a comprehensive synthesis of the state of knowledge in the science of flood hydrology, including process-based modelling, statistical modelling, machine learning and field and laboratory-based experiments. This could be in the form of an Intergovernmental Panel on Climate Change (IPCC) style report that can be periodically updated (for example, every 3 to 5 years). This report would aim to provide practitioners and academics with regular scientific assessments on the science behind flood hydrology, its implications and potential future risks and synthesise the latest scientific knowledge in the following areas:

- observational methods
- conceptual models of UK hydrology
- perceptual models of UK hydrology
- latest evidence on past environmental change and variability related to UK flood hydrology, including attribution to drivers of change
- analytical and modelling methods

- development of data-driven methods based on machine learning and artificial intelligence to augment or improve on hydrological methods and models
- transferability of knowledge from case studies across different catchments and environments
- latest evidence on future projections for flood hydrology variables
- latest developments in flood estimation
- latest developments in flood forecasting
- current understanding of hydrological processes
- the gaps between scientific knowledge and operational activities with implications for planning for future flood risk and for measuring authorities and practitioners
- future research needs (to feed into action S6)

The IPCC style report should be published periodically and accompanied by scientific journal publications and/or a special publication series.

3.3.4.4 Action S4: Identify research needs to improve understanding of flood generation processes and drivers of hydrological change



This action aims to provide a better understanding of the physical processes governing flood generation, in particular run-off generation, including surface water flooding, interactions with groundwater and extreme events.

Action S4 could issue a call for evidence structured around the BHS working group on the future of UK hydrological research[8] and a sub-set of the International Association of Hydrological Sciences' (IAHS) 23 unsolved problems in hydrology[9]. The call could be aimed at encouraging submissions and research proposals to UKRI on the topic of understanding the physical processes governing flood generation and driving hydrological change and variability. Areas of interest could include:

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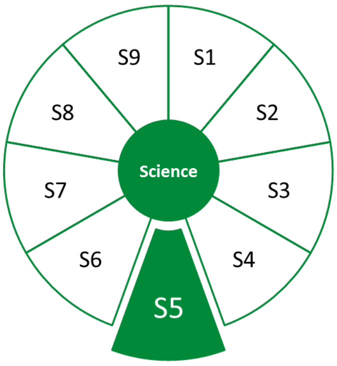
[8] BHS working group on hydrological futures [Last accessed 22 November 2021]

[9] IAHS 23 unsolved problems in hydrology [Last accessed 22 November 2021]

- reviewing physical process linkages framed within a rapid evidence assessment of perceptual models in flood hydrology
- considering processes in flood hydrology holistically, including those in urban systems, groundwater systems, interactions with coastal systems, atmospheric exchanges, co-evolution of vegetation and landscapes, and influences of anthropogenic activity
- including interactions between flood hydrology and ecological responses, water quality, hill-slope river coupling, woody debris, sediment transport, geomorphological change and sustainable drainage systems
- including past, present and future perspectives
- investigating how well models can represent flood generation processes
- assessing how flood generation processes might change in a changing climate

It is envisaged that a report will be published that identifies the research needs to improve understanding of flood generation and drivers of hydrological change, which will then encourage and enable the submission of research proposals in this area to UKRI.

3.3.4.5 Action S5: Investigate the validity of critical assumptions made in operational flood hydrology

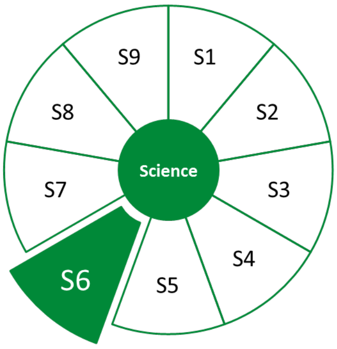


This action aims to provide better understanding of the validity of critical assumptions that are made in operational flood hydrology.

Action S5 could implement a project to capture critical assumptions made in current practice and design (conceptually) using a set of experiments that would test those assumptions. An example may be the structure of rainfall-runoff models, tested against evidence from observations, including both intensive field campaigns and remote sensing. This action could also develop case studies illustrating where critical assumptions in modelling and theory have and have not worked, with recommendations for improvement.

The findings of this working should be published in a report and ideally peer-reviewed papers describing the motivations, design and expected outcomes of the proposed experiments.

3.3.4.6 Action S6: Identify fundamental science needs in flood hydrology



This action aims to identify new scientific knowledge required in flood hydrology to deal with future environmental change.

Action S6 will build on and integrate fundamental research needs identified in actions S3, S4 and S5. It will also take account of research needs identified by the BHS working group on the future of UK hydrological research[10], and the IAHS 23 unsolved problems in hydrology[11].

Main challenges include:

- closure of water and energy balances over control volumes at multiple scales (for example, surface catchment, groundwater system)
- characterisation of uncertainty in fluxes and closures
- attribution and separation of changes in hydrological responses to local and large-scale drivers (for example, changes in river structures, land cover and climate)
- extrapolation of small-scale observations to larger-scale land cover changes
- integration of knowledge from empirical regionalisation and local dynamic model-based studies
- information management and computational frameworks to allow competing perceptual and predictive models to be compared, debated and rejected

Ambitions for the programme of work may include:

- development of an evolving, open-access perceptual model of UK flood hydrology
- a system for linking and accessing heterogeneous data sources, with a particular focus on data collected routinely for operational (rather than research) purposes by regulators, water companies and others

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[10] BHS working group on hydrological futures [Last accessed 22 November 2021]

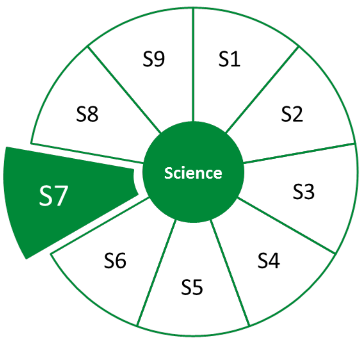
[11] IAHS 23 unsolved problems in hydrology [Last accessed 22 November 2021]

- national model ensemble linked to data assimilation and sensitivity analysis tools to enable uncertainty reduction and support hypothesis testing in the presence of uncertainties (an 'observation-simulation system experiment')
- testing of hypotheses corresponding to place-specific perceptual models and data, including novel measurement techniques, merging statistical and process-based hydrology

These research needs will then be shaped into a proposal which can be presented to UKRI for funding opportunities (via action S7).

The intended outputs from this action are a report and other media (presentations, videos, events) outlining fundamental research needs in UK flood hydrology to shape proposals for research programmes.

3.3.4.7 Action S7: Develop proposals for research programmes



This action aims to develop proposals for a major fundamental research programme in the field of flood hydrology.

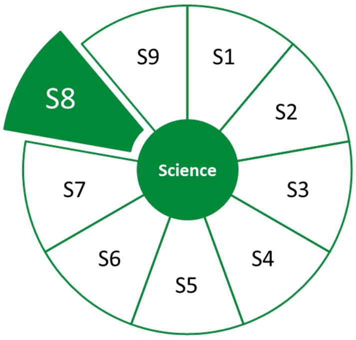
Action S7 will build on the research needs identified in action S6 and work across the academic and practitioner community to develop proposals for a number of major research programmes in the field of flood hydrology.

The proposal will ensure that it links to and utilises other UK research programmes such as FDRI and its potential capital investment in research infrastructure.

The proposal will also seek opportunities for multi-disciplinary research programmes (for example, through joint proposals with low flow (drought) hydrology and wider water research programmes.

The proposal(s) will be put to UKRI to discuss potential funding opportunities.

3.3.4.8 Action S8: Potential research programmes

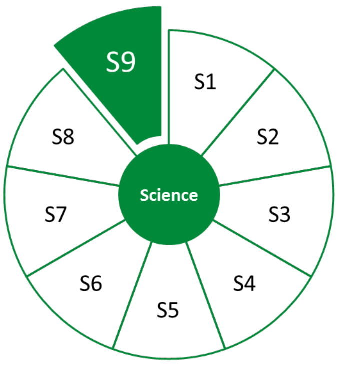


This action aims to attract funding for 3 research programmes related to flood hydrology over the next 25 years.

The detailed scope of research programmes related to flood hydrology will be defined by action S7. Action S8 will set out the aspirations of the flood hydrology community for 3 research council funded programmes over the 25 year lifetime of the flood hydrology roadmap. It is anticipated that these programmes may be part of other, larger multi-disciplinary programmes and not focused solely on flood hydrology.

The intended outputs from this action are multiple peer-reviewed publications of major scientific advances, new data, methods, models and knowledge of UK (and global) flood hydrology.

3.3.4.9 Action S9: Translation of science from research programmes into practice



This action aims to rapidly translate new science from research programmes into operational practice.

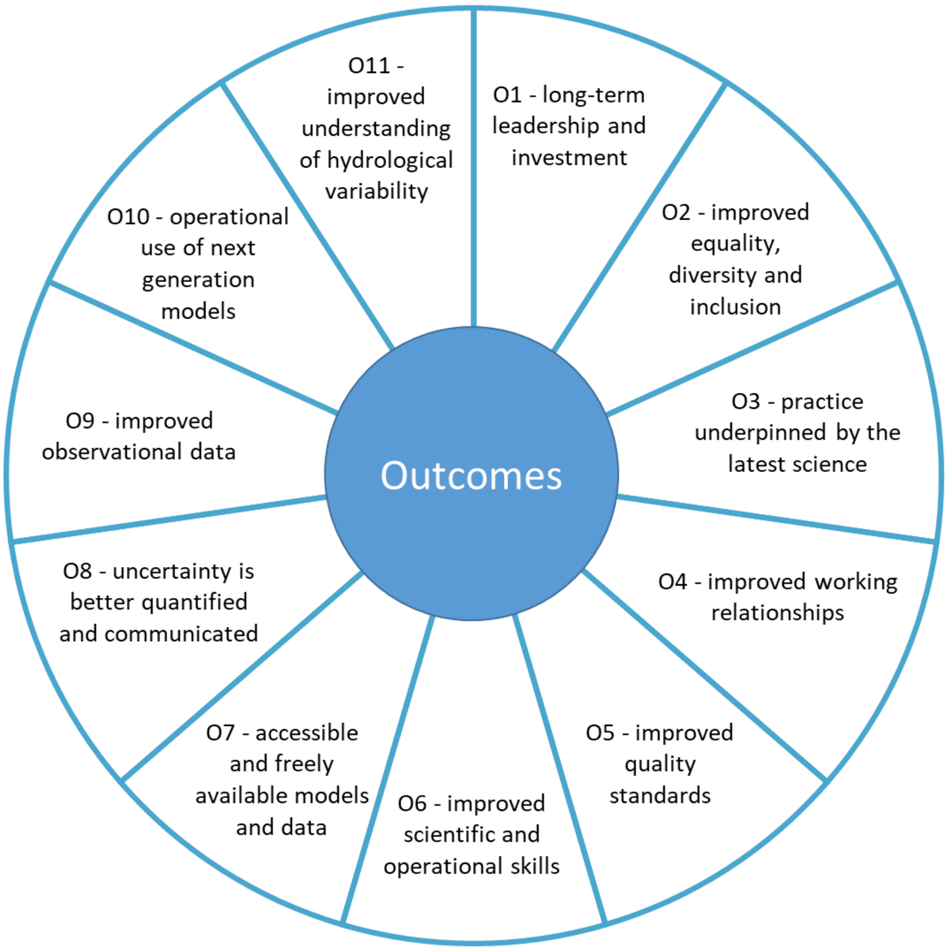
Action S8 outlines the aspiration to bid for funding for 3 major research programmes related to flood hydrology over the lifetime of the flood hydrology roadmap. Action S9 would focus on rapidly translating the new science from these research programmes into operational practice. It would use the framework developed by actions S1 and S2 and seek to improve that framework further.

The intended outputs from this action are rapid operational use of new scientific knowledge, methods and models and impact statements describing how new scientific knowledge, methods and models have been operationalised.

3.4 Outcomes for UK flood hydrology

The roadmap for UK flood hydrology has 4 main elements. The first 3 elements; the vision, the thematic work areas and the actions plans work together to achieve outcomes for UK flood hydrology, where an outcome is defined as a result of change brought about to achieve the roadmap vision. 11 desired outcomes have been identified for the UK flood hydrology roadmap which describe what the flood hydrology community want to achieve as a result of implementing the roadmap. The 11 desired outcomes are summarised in Figure 7 where each outcome is prefixed with the letter 'O'.

Figure 7: Summary of UK flood hydrology roadmap desired outcomes



This section describes each outcome and presents an outcome map which shows which roadmap actions contribute to each outcome. Each roadmap action can contribute to multiple outcomes, which can result in complex relationships. These more complex relationships are presented for each thematic work area in Appendix H.

3.4.1 Outcome 1: Leadership and investment

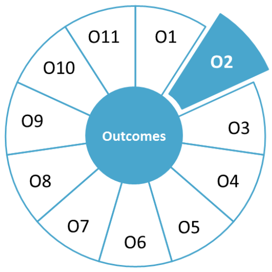
The desired outcome is for strong long-term leadership and investment for UK flood hydrology.

Outcome 1 will be achieved if:

- there is visible and effective leadership for UK flood hydrology
- the profile of UK flood hydrology is raised
- long-term investment in UK flood hydrology is increased
- research initiatives relating to flood hydrology are better targeted at achieving impact
- the value of investing in UK flood hydrology is clearly articulated
- there is improved scientific and technical steer for UK flood hydrology projects of national significance

The outcome map for outcome 1 is shown in Figure H-1 in Appendix H.

3.4.2 Outcome 2: Equality, diversity, and inclusion



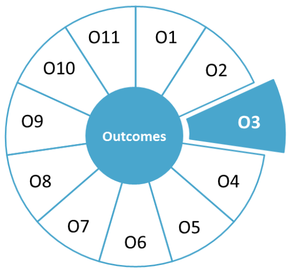
The desired outcome is for improved equality, diversity, and inclusion in UK flood hydrology.

Outcome 2 will be achieved if:

- the diversity of the UK flood hydrology community is better understood
- the flood hydrology workforce is more representative of the diverse communities it serves
- individuals and groups are treated fairly and have access to equality of opportunity
- there is improved diversity of thought and background in UK flood hydrology

The outcome map for outcome 2 is shown in Figure H-2 in Appendix H.

3.4.3 Outcome 3: Science and evidence



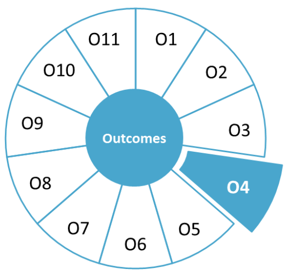
The desired outcome is that UK flood hydrology is underpinned by the latest science and evidence.

Outcome 3 will be achieved if:

- practitioners are more aware of, and better equipped to implement, scientific advances in flood hydrology
- improved decision-making in flood risk management where decisions are informed by the latest science and evidence from flood hydrology
- the latest scientific advances in flood hydrology are synthesised regularly for scientists and practitioners
- the speed of uptake of new science into practice is improved

The outcome map for outcome 3 is shown in Figure H-3 in Appendix H.

3.4.4 Outcome 4: Relationships and sense of community



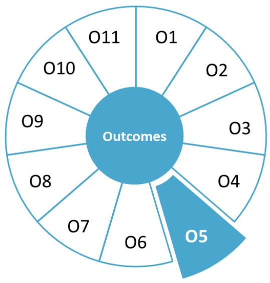
The desired outcome is for improved working relationships and sense of community across UK flood hydrology.

Outcome 4 will be achieved if:

- there is improved collaboration between flood hydrology scientists and practitioners
- the scientific needs of practitioners are more visible to the science community
- the visibility of flood hydrology programmes and initiatives across the UK is improved
- the coordination and collaboration between programmes and initiatives related to flood hydrology in the UK is improved

The outcome map for outcome 4 is shown in Figure H-4 in Appendix H.

3.4.5 Outcome 5: Quality standards



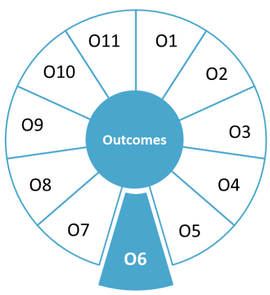
The desired outcome is for improved quality standards in UK flood hydrology.

Outcome 5 will be achieved if:

- the accuracy and reliability of UK flood hydrology data is improved
- there is improved decision-making in flood risk management where decisions are based on high quality data
- the confidence in hydrological estimates is improved
- the consistency of data and modelling approach across the UK is improved

The outcome map for outcome 5 is shown in Figure H-5 in Appendix H.

3.4.6 Outcome 6: Scientific and operational skills



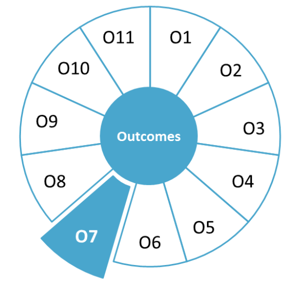
The desired outcome is for improved scientific and operational skills in UK flood hydrology.

Outcome 6 will be achieved if:

- there is a better understanding of the skills of the UK flood hydrology workforce
- flood hydrology skills are more valued
- professional esteem and the profile of flood hydrologists is raised
- flood hydrology skills in the UK are continuously improved and developed
- knowledge exchange and communication between flood hydrology researchers and practitioners is improved
- flood hydrology professionals feel valued and supported

The outcome map for outcome 6 is shown in Figure H-6 in Appendix H.

3.4.7 Outcome 7: Open source, accessible models, data and tools



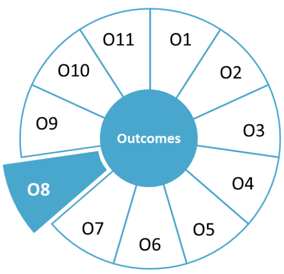
The desired outcome is that flood hydrology models and data are easily accessible and freely available.

Outcome 7 will be achieved if:

- the accessibility to flood hydrology data, models, software and tools is improved
- flood hydrology data and models are open source and freely available to all
- There is improved decision-making in flood risk management where decisions are made using the best available data, methods and tools
- there is greater access to data for scientific research and development
- the UK hydrometric data better supports scientific research and operational activities

The outcome map for outcome 7 is shown in Figure H-7 in Appendix H.

3.4.8 Outcome 8: Quantification and communication of uncertainty



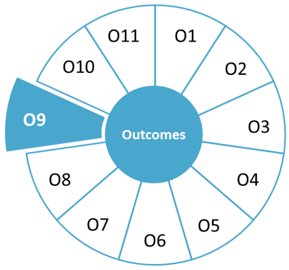
The desired outcome is that uncertainty in UK flood hydrology data and models is better quantified and communicated.

Outcome 8 will be achieved if:

- flood hydrologists can better quantify uncertainties in flood hydrology data and models
- the uncertainties associated with flood hydrology data and models can be clearly communicated to a range of audiences
- there is improved decision-making in flood risk management where decisions are informed by a clear understanding of the uncertainties in flood hydrology

The outcome map for outcome 8 is shown in Figure H-8 in Appendix H.

3.4.9 Outcome 9: Observational data



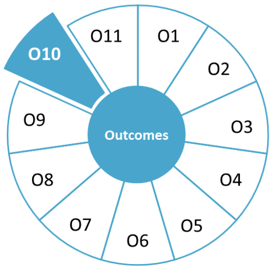
The desired outcome is for improved observational data to underpin UK flood hydrology.

Outcome 9 will be achieved if:

- there is a better understanding of how new observational technology can improve data quality and capture of high flows and floods
- there is a step change in the quantity of high flow data collected
- engagement with the public is increased through collecting and using citizen-derived observational data on floods
- the use of radar and rain gauge data is increased in flood hydrology research and projects

The outcome map for outcome 9 is shown in Figure H-9 in Appendix H.

3.4.10 Outcome 10: Next generation flood hydrology models



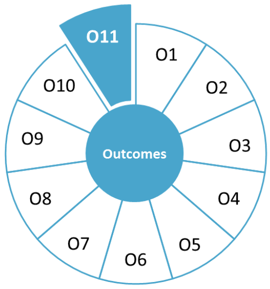
The desired outcome is that next generation flood hydrology models are used operationally.

Outcome 10 will be achieved if:

- there is community-wide buy-in for the models and systems needed for flood hydrology in a changing climate
- improved understanding of the hazards faced at UK dams and reservoirs due to extreme precipitation and river flow
- next generation flood hydrology models contribute to reducing risks to life and the economy
- there is improved understanding of flood risk from fluvial, pluvial, groundwater and reservoir sources in the UK

The outcome map for outcome 10 is shown in Figure H-10 in Appendix H.

3.4.11 Outcome 11: Flood processes and hydrological variability



The desired outcome is for improved understanding of flood processes and hydrological variability in the UK.

Outcome 11 will be achieved if:

- there is improved understanding of the potential impacts of future climate variability on flood hydrology and flood risk management operations
- there is improved decision-making in flood risk management where decisions are informed by the latest knowledge and science on environmental change and process understanding
- the uncertainties around future environment change are understood and communicated

The outcome map for outcome 11 is shown in Figure H-11 in Appendix H.

3.4.12 Outcomes for flood risk management

Flood hydrology underpins almost all inland flood risk management activities. It can be difficult to place a value (economic or otherwise) on the exact contribution of flood hydrology to flood risk management, but it is possible to show how the outcomes of the flood hydrology roadmap link to high-level flood risk management outcomes.

The national flood and coastal erosion risk management strategy for England (Environment Agency, 2020) has been used to identify high-level flood risk management outcomes. The strategy's long-term vision is for "a nation ready for, and resilient to, flooding and coastal change". This could be considered to be a desired primary outcome for flood risk management.

The strategy has 3 long-term ambitions, which are:

- climate resilient places
- today's growth and infrastructure resilient in tomorrow's climate
- a nation ready to respond and adapt to flooding and coastal change

These ambitions could be considered to be desired secondary outcomes for flood risk management.

To achieve the desired (primary and secondary) outcomes for flood risk management identified above, outputs are required, for example, building new flood defences to better protect homes and businesses. This action then contributes to helping to achieve climate resilient places, which, in turn, contributes to ensuring the nation is ready for, and resilient to, flooding (coastal change is not included here).

Figure 8 shows 13 flood risk management outputs that have been identified from the English strategy which need to happen to reach the ultimate desired outcome of a nation ready for, and resilient to, flooding. This figure also shows where the outcomes of the flood hydrology roadmap could contribute to these outputs.

Eleven of the 13 flood risk management outputs are underpinned by flood hydrology. An example of how flood hydrology roadmap outcomes contribute to flood risk management actions is show in Figure 9. In this example, 7 of the 11 flood hydrology roadmap outcomes have a clear line of sight to building new flood defences to better protect homes and businesses. This example, and the higher level outcome mapping (Figure 8) illustrate the importance of the flood hydrology roadmap in helping to implement the national flood and coastal erosion risk management strategy for England (Environment Agency, 2020).

The flood risk management outcomes identified in the strategy for England have relevance to the other nations across the UK. England is simply used as an example to highlight these links. A similar exercise could be done for the national strategy for flood and coastal erosion risk management in Wales (2020) or any other emerging flood risk management strategy.

Figure 8: High level outcome mapping showing links between flood hydrology roadmap outcomes and flood risk management outcomes

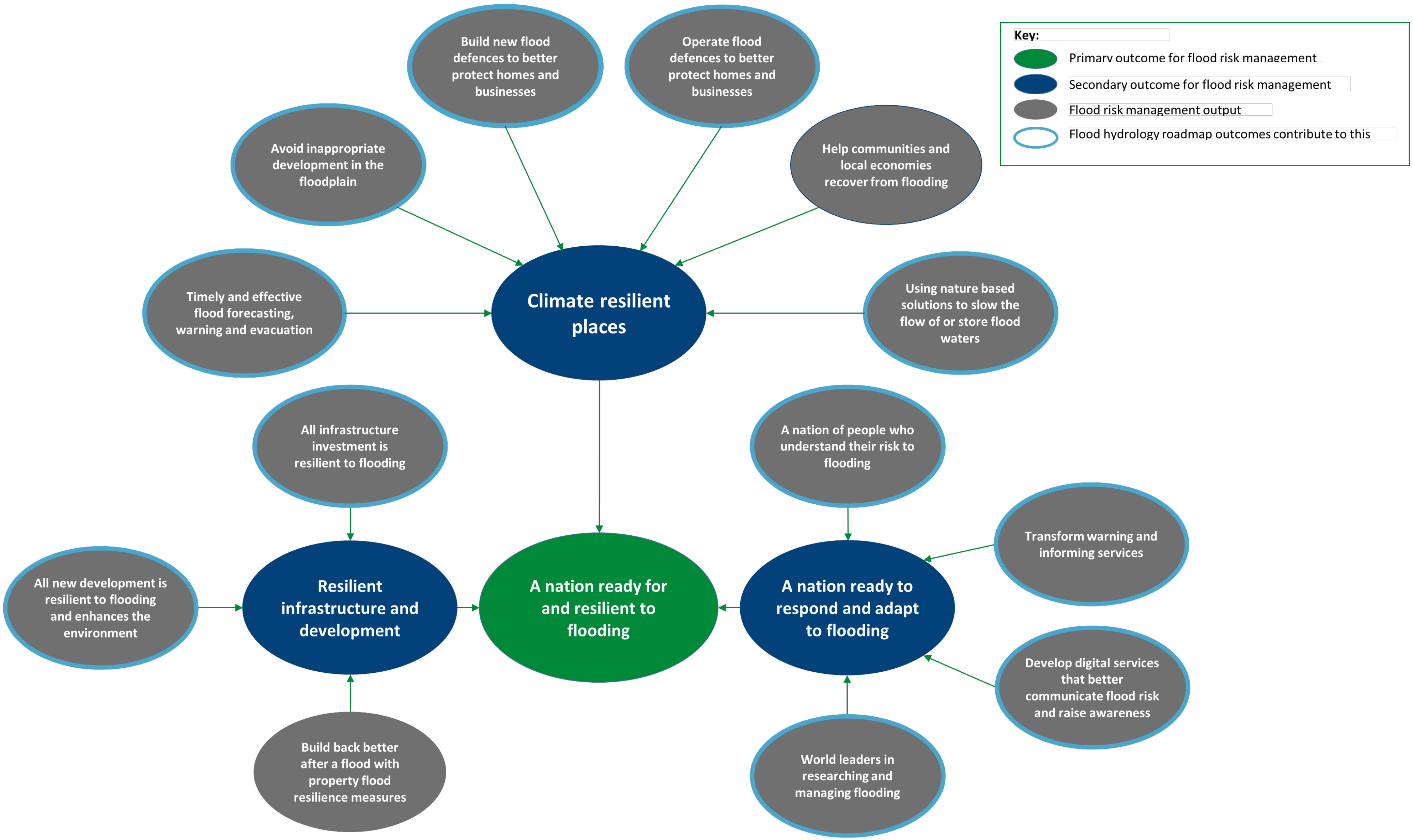
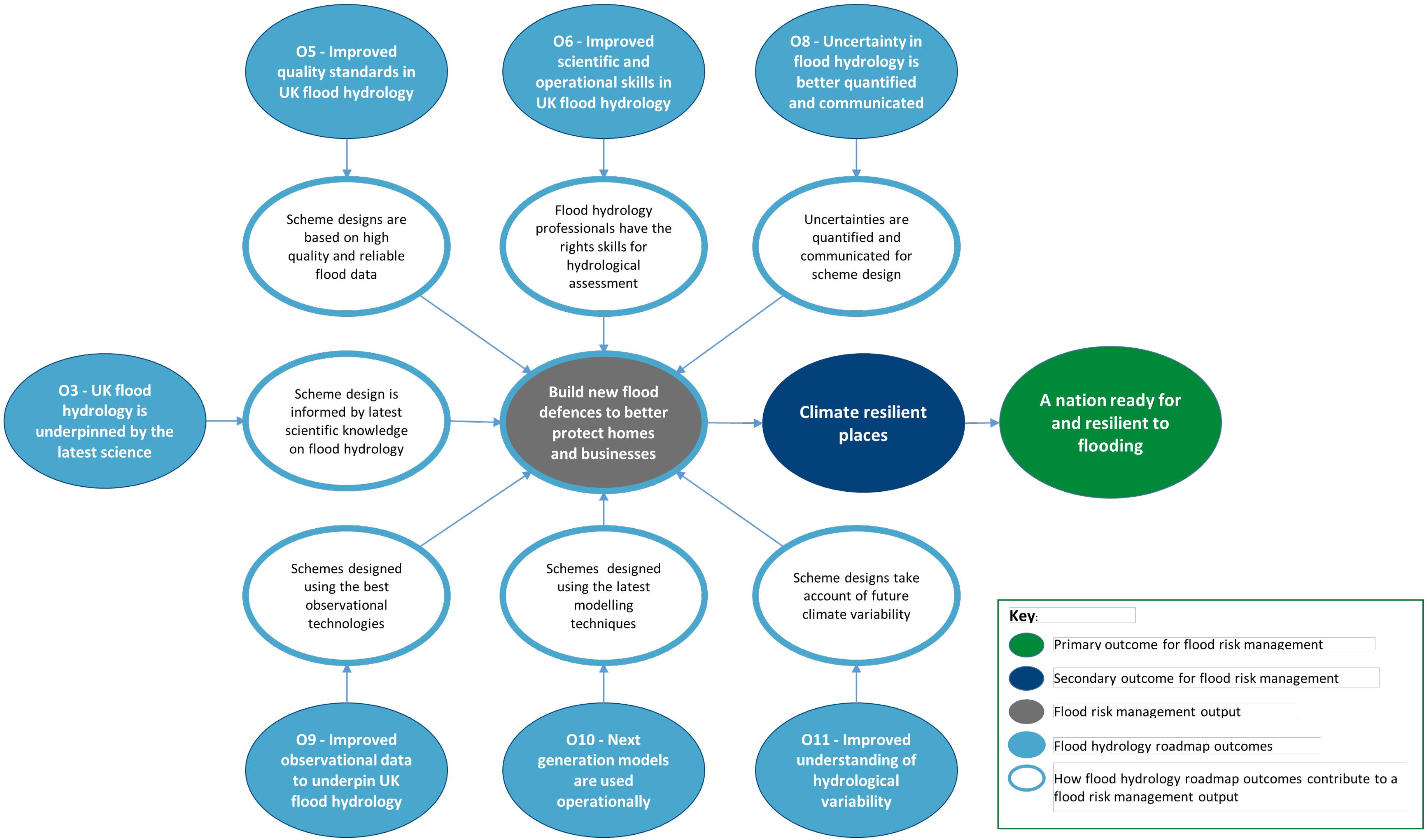


Figure 9: Case study example of how flood hydrology roadmap outcomes contribute to building new flood defences to better protect homes and businesses



4 Continuing the journey

This section describes the leadership, funding and partnership working required to deliver the UK flood hydrology roadmap over the next 25 years.

4.1 Leadership of the roadmap

The flood hydrology roadmap governance board established in action W1 will provide long-term leadership aimed at ensuring delivery of the roadmap vision. The governance board will initially be made up of government organisations who will potentially fund roadmap actions (the Environment Agency, Scottish Environment Protection Agency, Natural Resources Wales and the Department for Infrastructure, Northern Ireland) and the BHS who will represent the wider flood hydrology community in the UK.

Membership of the governance board is likely to expand as the roadmap develops and other sources of funding are identified. This is likely to include UKRI to enable discussion and shaping of bids for research funding to support the roadmap (actions S7 and S8).

The governance board will own the roadmap once the project to develop the roadmap is complete (on publication of this report) and will aim to:

- champion and promote the vision of the roadmap
- identify funding opportunities to implement the flood hydrology roadmap
- encourage participation and partnership working in the roadmap
- report on progress on implementation of the roadmap to the wider community
- refresh the roadmap and action plans at appropriate intervals
- ensuring that the roadmap is implemented using low carbon solutions
- champion the principles of equality, diversity and inclusion in all aspects of the roadmap

Scientific and technical leadership is expected to be provided by the STAG which will be established by the governance board in action W2.

The roles and responsibilities of the STAG are likely to include:

- helping to shape and scope projects and initiatives to achieve the roadmap actions and vision
- providing scientific and technical advice and steer to in-flight roadmap projects
- providing peer review of project outputs prior to publication

At the time of writing (September 2021), the governance board has been established and is considering how best to form the STAG.

4.2 Funding the roadmap

Each of the 31 actions identified in the roadmap has an estimated cost (see Appendix G and Figure 11), which cumulatively suggest that between £110 million and £165 million of funding is required over 25 to 37.5 years to implement the flood hydrology roadmap for the UK (this equates to £74 million and £111 million present value costs). The range of costs and timescales represent a lower best estimate which is based on experience of delivering similar projects and a higher estimate which accounts for optimism bias. Optimism bias is the systematic tendency to be over optimistic about the early assessment of key parameters of a project or strategy, such as costs, timescales, and benefits. The upper bound, or optimism bias factor for the flood hydrology roadmap is 50%. This has been calculated using a method outlined in the H.M Treasury "Green Book" (2018) and Annex 2 of Defra Guidance Document 'FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities' (March 2003). The calculation of the optimism bias factor is presented in appendix J. The optimism bias cost estimate is calculated by adding 50% to the best estimate cost. For example, a best estimate cost of £1 million would translate to an optimism bias estimate of £1.5 million, since 50% of £1 million is £0.5 million. The Green Book recommends that the initial optimism bias estimate should not be "locked in" but can be reduced as more detailed scoping work reduces uncertainty and the cost of specific risks are identified. Uncertainty around cost estimates increases further into the future, however, a constant optimism bias factor has been applied to all 25 years of the roadmap for simplicity rather than increasing this over time. The flood hydrology roadmap governance board (established in action W1 and described in section 4.1) should review the overall estimated costs of delivering the roadmap when they periodically refresh the roadmap and its action plan.

The timescale for delivery of the roadmap is also subject to uncertainty, particularly due to planned 25 year lifespan. Applying the 50% optimism bias factor to the best estimate of the time required to deliver the roadmap gives us a range of between 25 and 37.5 years for delivery. Again, this timescale should be reviewed by the flood hydrology governance board as the roadmap progress, timescales shorten, and uncertainties reduce. For the purposes of presentation, a 25 year timescale is referred to throughout the roadmap document, but readers should be aware that this may well be an optimistic estimate of the time required to fully deliver the roadmap.

Figure 10 shows the annual estimated spend and the cumulative spend required to implement the roadmap over its 25-year lifetime. The grey shading on the plots represents additional expenditure required (above the best estimate) when taking optimism bias into account. Planned expenditure increases steadily from year 1 to a peak in year 10 (starting April 2030), which coincides with the planned implementation of new (next generation) data, methods, models, and systems developed earlier in the roadmap. The peak annual expenditure is estimated to be in the range of £9.9 million to £14.9 million.

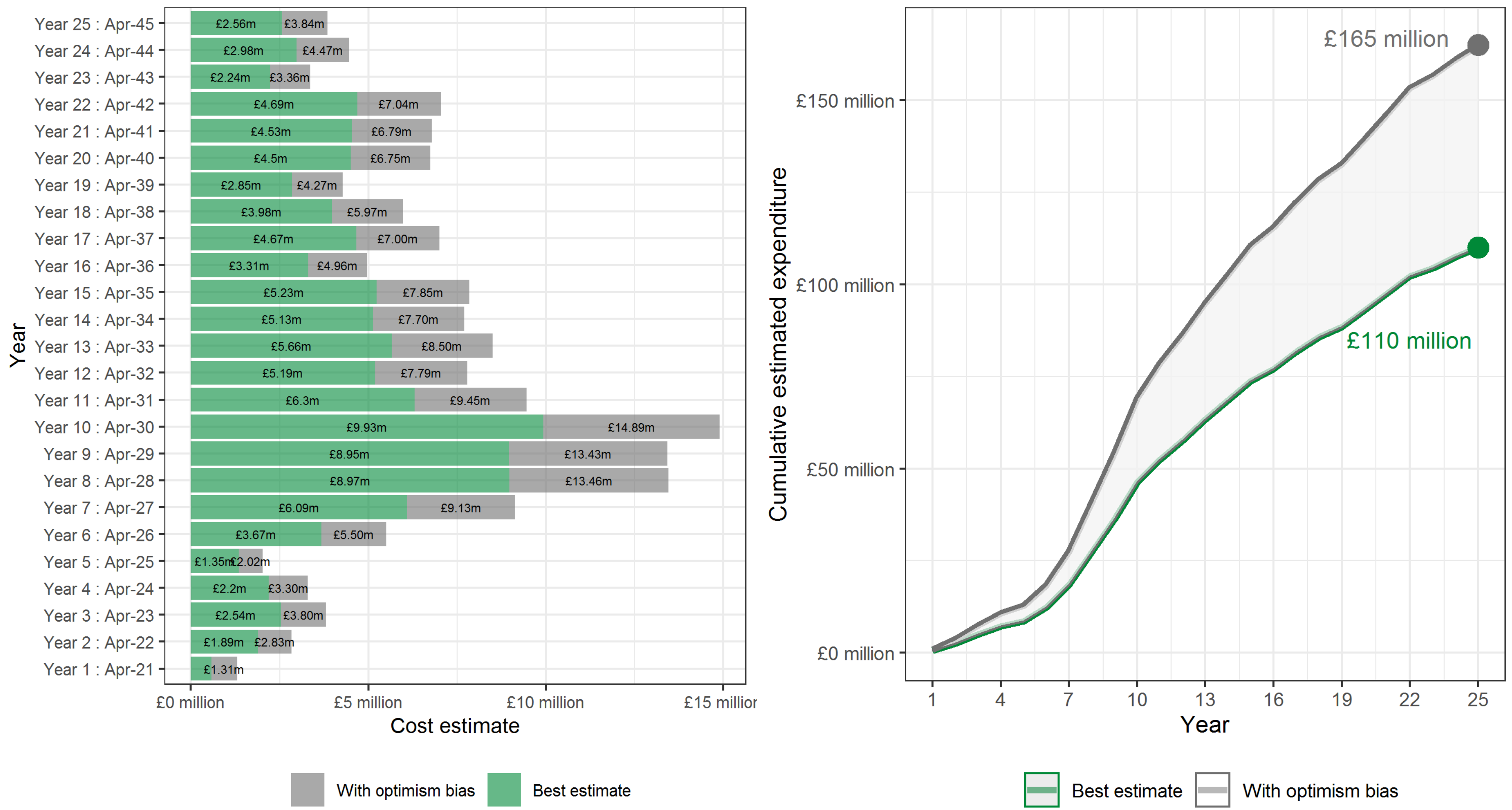
The estimated spend for each thematic area is shown in Figure 12 to Figure 15. The total estimated spend for each thematic area over 25 years is:

- £11.2 million to £16.8 million for ways of working
- £19.7 million to £29.6 million for data
- £39.9 million £59.8milion for methods
- £39.2 million to £58.8 million for scientific understanding

It is envisaged that the Environment Agency, Natural Resources Wales, the Scottish Environment Protection Agency and the Department for Infrastructure, Northern Ireland will bid for funding within their respective organisation to help implement the UK flood hydrology roadmap. At the time of writing (September 2021), the Environment Agency has preliminarily allocated £6.9 million of funding over 6 years (from April 2021) to help start implementation of the roadmap. It is envisaged that the other organisations listed above will use this document as a basis for business cases and funding bids to supplement the Environment Agency funding. The governance board will also be looking for funding opportunities outside government bodies to help implement the roadmap.

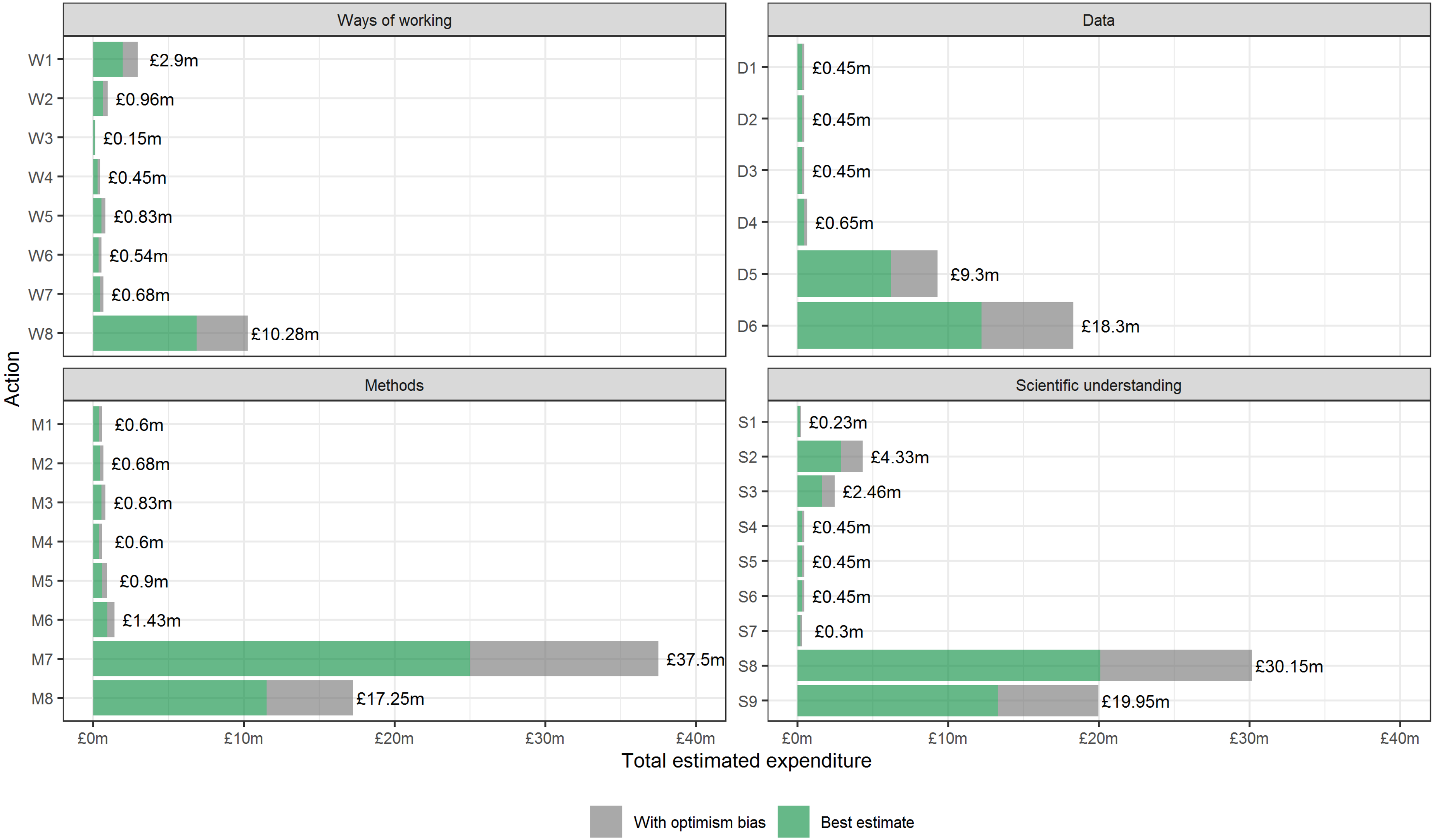
From a scientific perspective, the flood hydrology roadmap has an ambition to attract funding from UKRI for a number of research programmes related to flood hydrology (see actions S7 and S8). The success of these funding bids is seen as a central element of the roadmap to ensure that UK flood hydrology is underpinned by the latest science and evidence. Any UKRI funded programmes also need to attract a similar level of funding from more operational organisations for translation of new science into policy and practice.

Figure 10: Annual estimated spend (left) and cumulative estimated spend (right) required to implement the flood hydrology roadmap over 25 years.



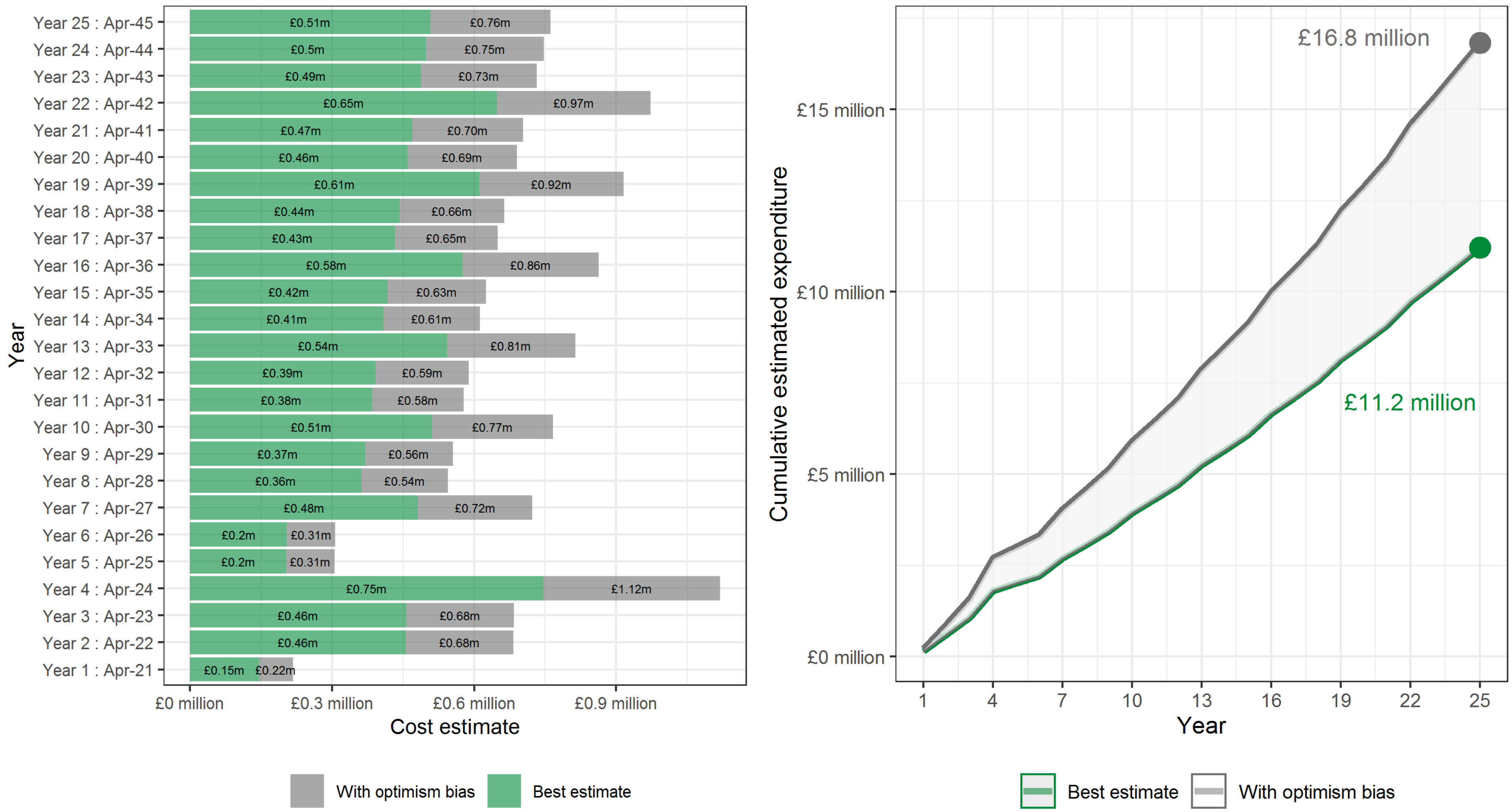
Note: where only 1 number is labelled on the individual bars (left hand plot) it represents the optimism bias estimate (the best estimate not plotted due to space constraints). The green and grey points labelled on the cumulative estimated expenditure plot (right hand plot) represent the total cumulative spend over 25 years for the best estimate and optimism bias estimate respectively.

Figure 11: Total funding required for each action in the flood hydrology roadmap, by theme.



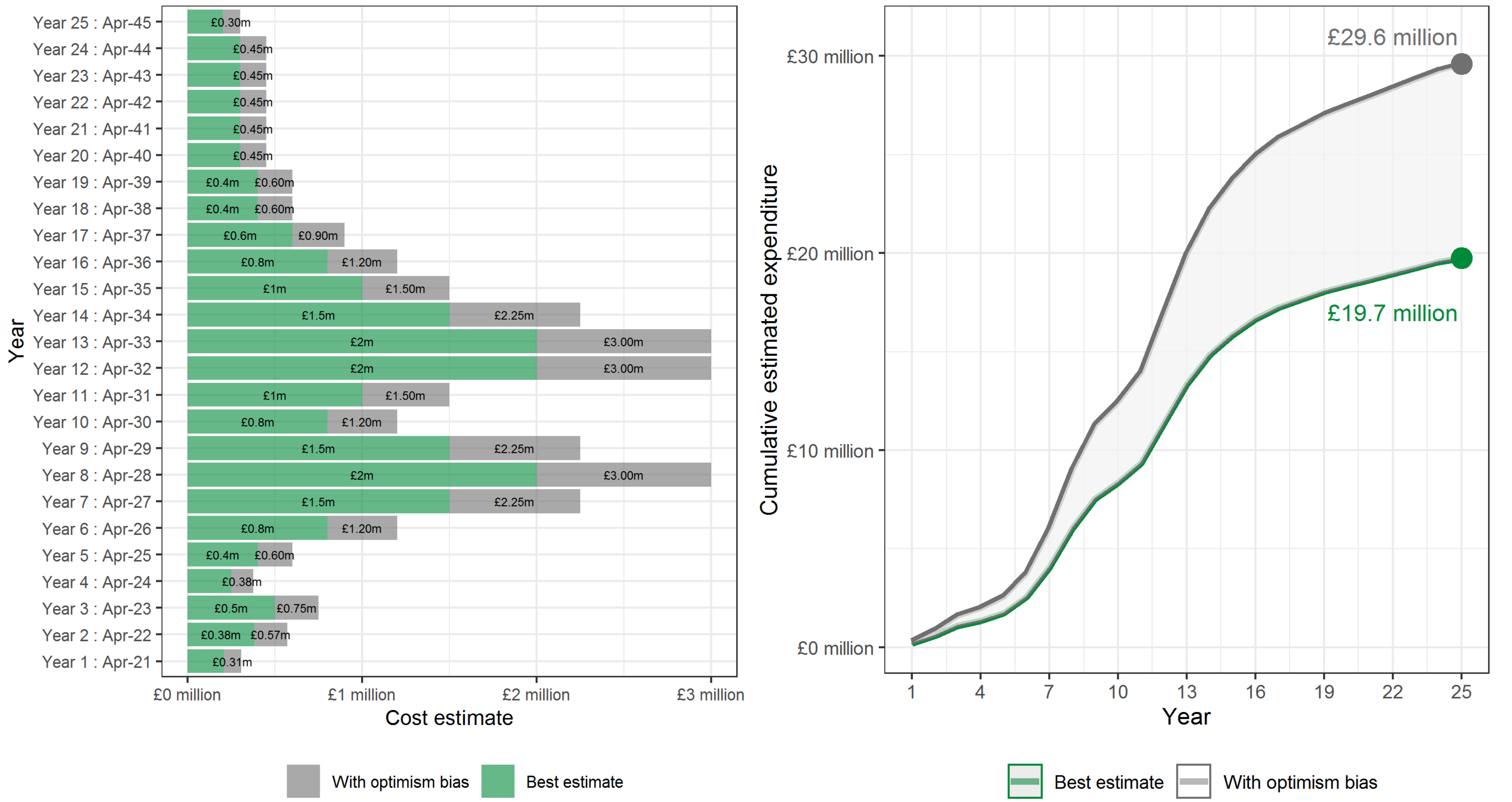
Note: the cost estimate labels on the bar chart above represent the optimism bias estimate (that is the higher cost estimate) for each roadmap action.

Figure 12: Annual estimated spend and cumulative estimated spend required to carry out **ways of working** actions over 25 years.



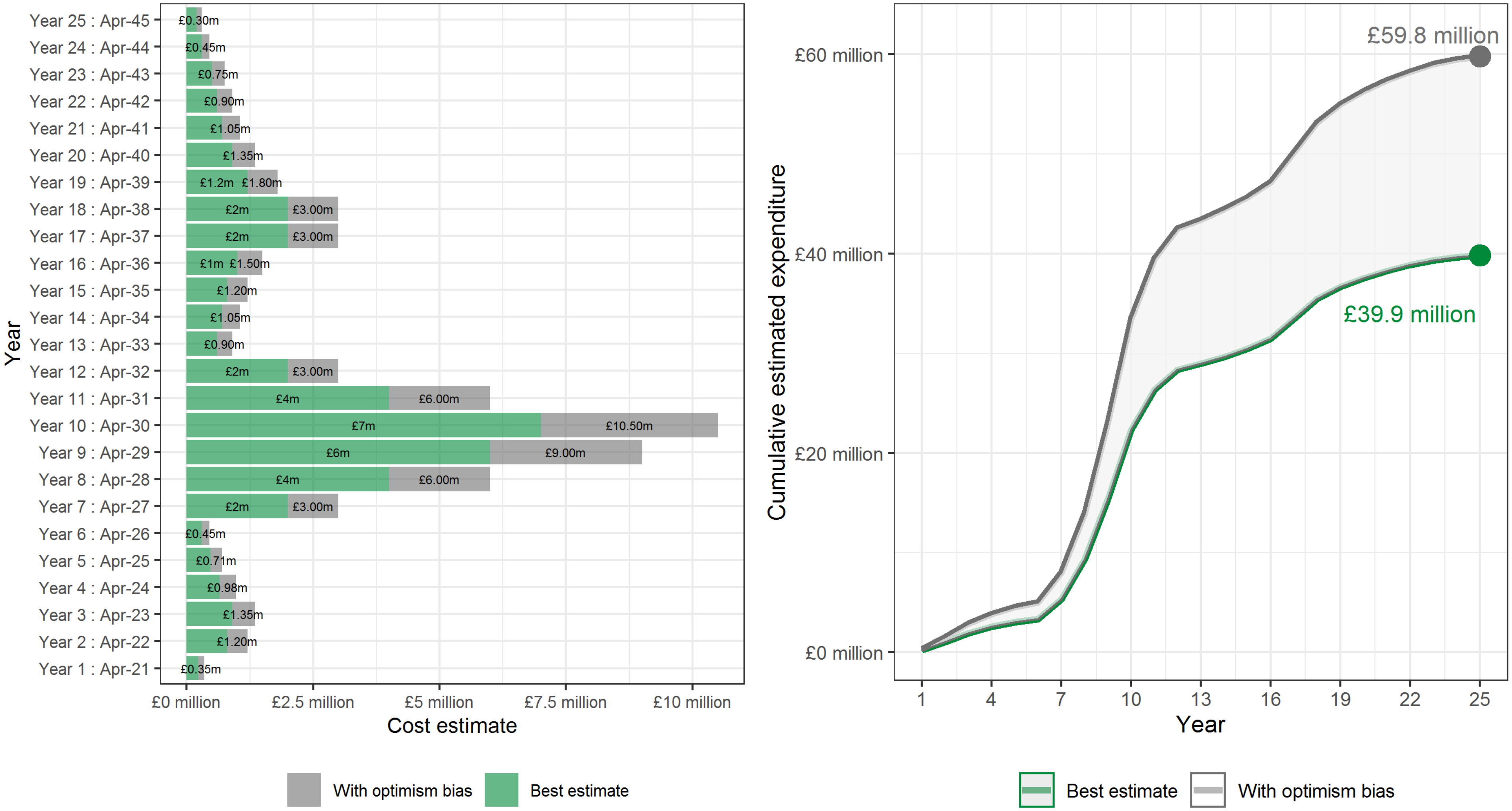
Note: where only 1 number is labelled on the individual bars (left hand plot) it represents the optimism bias estimate (the best estimate not plotted due to space constraints). The green and grey points labelled on the cumulative estimated expenditure plot (right hand plot) represent the total cumulative spend over 25 years for the best estimate and optimism bias estimate respectively.

Figure 13: Annual estimated spend and cumulative estimated spend required to carry out **data actions** over 25 years.



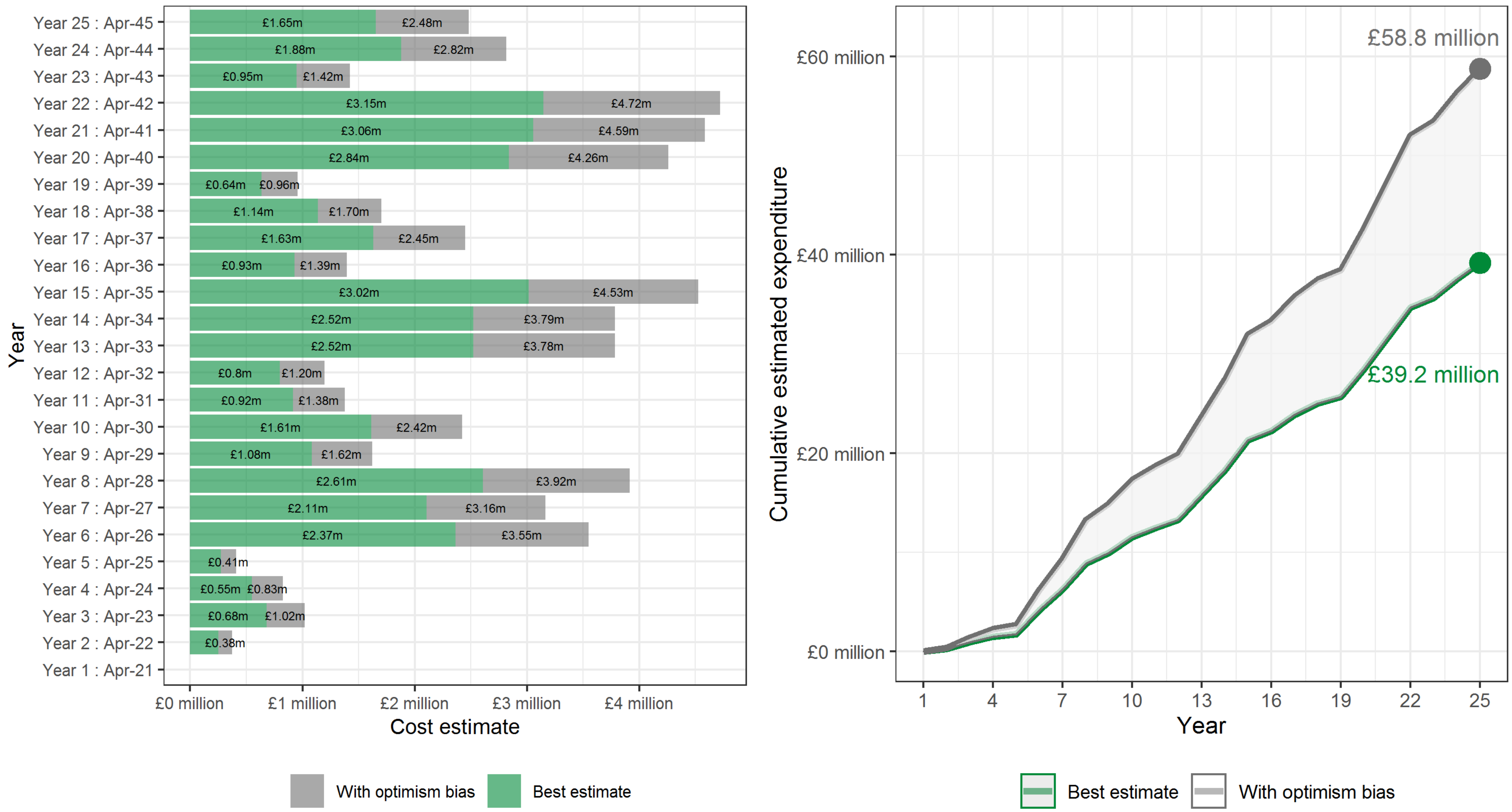
Note: where only 1 number is labelled on the individual bars (left hand plot) it represents the optimism bias estimate (the best estimate not plotted due to space constraints). The green and grey points labelled on the cumulative estimated expenditure plot (right hand plot) represent the total cumulative spend over 25 years for the best estimate and optimism bias estimate respectively.

Figure 14: Annual estimated spend and cumulative estimated spend required to carry out **methods actions** over 25 years.



Note: where only 1 number is labelled on the individual bars (left hand plot) it represents the optimism bias estimate (the best estimate not plotted due to space constraints). The green and grey points labelled on the cumulative estimated expenditure plot (right hand plot) represent the total cumulative spend over 25 years for the best estimate and optimism bias estimate respectively.

Figure 15: Annual estimated spend and cumulative estimated spend required to carry out **scientific understanding actions** over 25 years.



Note: where only 1 number is labelled on the individual bars (left hand plot) it represents the optimism bias estimate (the best estimate not plotted due to space constraints). The green and grey points labelled on the cumulative estimated expenditure plot (right hand plot) represent the total cumulative spend over 25 years for the best estimate and optimism bias estimate respectively.

4.3 Working in partnership

One of the principles of the roadmap is that it will be implemented through partnership working and collaboration. For the roadmap to be successful and achieve its desired outcomes, funding organisations will need to work together, pool resources and avoid duplication of effort. This may require semi-formal or formal agreements to be established such as a memorandum of understanding or collaborative agreements for individual projects.

There also needs to be partnership working at a technical level, particularly between scientists and practitioners to ensure roadmap actions have impact and are embedded in operational activities. Multi-disciplinary teams will be required to carry out roadmap actions with the right blend of knowledge and experience to cover flood estimation and flood forecasting and consider all sources of inland flooding.

4.4 Keeping the roadmap live

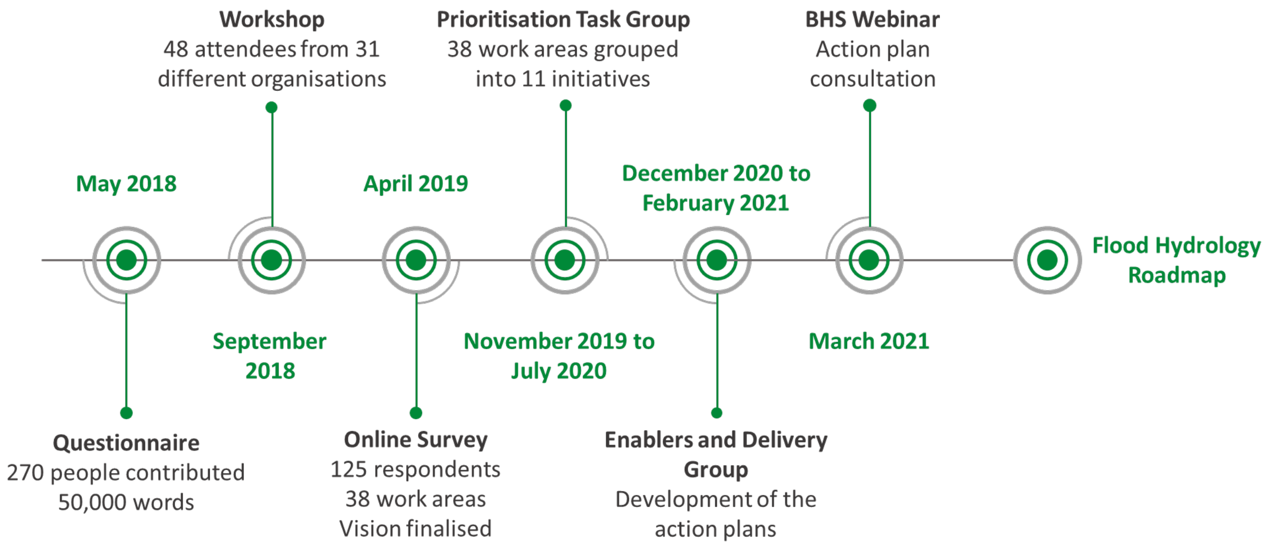
The scope of some roadmap actions is more certain than others. For example, there is less certainty about the scope of longer-term actions such as W8, D6 and M8 and for actions where that will implement options and recommendations from earlier actions, such as D5 and M7. Clarity around the scope of these actions will emerge as the roadmap progresses, which is why there is a need for regular reviews of progress on implementing action plans. These progress reviews should include periodic revision, refresh and reissue of the flood hydrology roadmap action plans to reflect greater certainty on the scope of the roadmap.

Likewise, given that the roadmap is intended to achieve its vision over the next 25 years, there will undoubtedly be drivers and demands on flood hydrology that change and evolve over time. The process for reviewing, refreshing and reissuing the roadmap will be owned by the governance board and should aim to keep pace with changing drivers and demands on UK flood hydrology.

5 Development of the roadmap

The flood hydrology roadmap has been developed through multiple phases of consultation with the flood hydrology community in the UK. Figure 16 shows the timeline for the development of the roadmap. There were 6 stages of consultation between May 2018 and March 2021 that have made significant contributions to the development of the roadmap. This section describes the governance for the roadmap project and each phase of consultation.

Figure 16: Timeline of the development of the flood hydrology roadmap



5.1 Governance of the roadmap project

The governance arrangements for the flood hydrology roadmap project are summarised in Figure 17. An Environment Agency project board was established to oversee the project in late 2017. This board was supported by an external steering group of recognised experts in flood hydrology, which has also run for the lifetime of the roadmap project. Other groups, including the current practice task group, the prioritisation task group, the enablers group and the delivery partners group were only temporary and set up to fulfil a specific task, as described in the following sections.

5.1.1 Environment Agency project board

The project to develop the flood hydrology roadmap has been led by the Environment Agency on behalf of the UK flood hydrology community. A project board was established at the start of the project with overall responsibility for the successful delivery of the project. This board comprised of a:

- **project sponsor** - the recognised owner of the overall business change being provided by the project
- **project executive** - accountable to the project sponsor for implementing the project as set out in the business case
- **project manager** - responsible for running the project on a day-to-day basis on behalf of the project executive and project board
- **senior users** - represents the interests of the users who will benefit from the project's products and deliverables

The following people carried out these roles on the Environment Agency project board, although it should be noted that the individuals who undertook these roles changed over the lifetime of the project. This configuration comprised the project board in the latter half of the project:

- Craig Woolhouse - project sponsor
- Dr Sue Manson - project executive
- Dr Sean Longfield - project manager
- Anita Asadullah - senior user
- Dr Mike Vaughan - senior user

5.1.2 Steering group

The Environment Agency project board was supported by several other groups (shown in Figure 17), most notably the steering group that has provided advice and direction to the project board since the start of the project. The steering group was made up of a range of experts from organisations external to the Environment Agency:

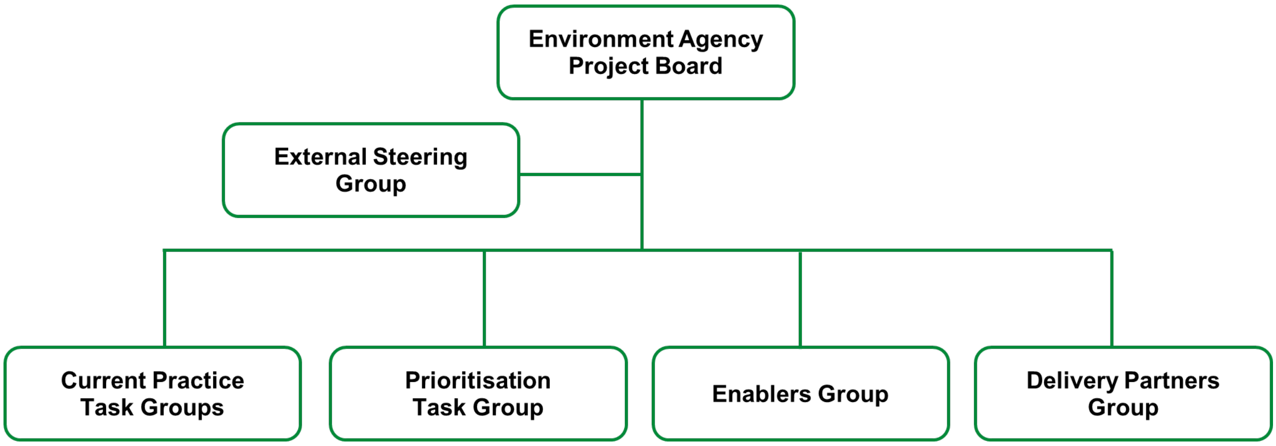
- Prof Hannah Cloke - University of Reading
- Prof Rob Lamb – Jeremy Benn Associates (JBA) Trust and Lancaster University
- Dr Charlie Pilling - Flood Forecasting Centre
- Nick Reynard - UK Centre for Ecology and Hydrology
- Owain Sheppard - Natural Resources Wales

5.1.3 Task groups

Four different task groups were established at various points in the roadmap project to tackle specific issues and provide technical expertise and advice or to help steer decisions by the project board. These were:

- the **current practice task group** - described in section 5.5
- the **prioritisation task group** - described in section 5.6
- the **delivery partners group** - described in section 5.7.1
- the **enablers group** - described in section 5.7.2

Figure 17: Governance arrangements for the flood hydrology roadmap project



5.2 Questionnaire

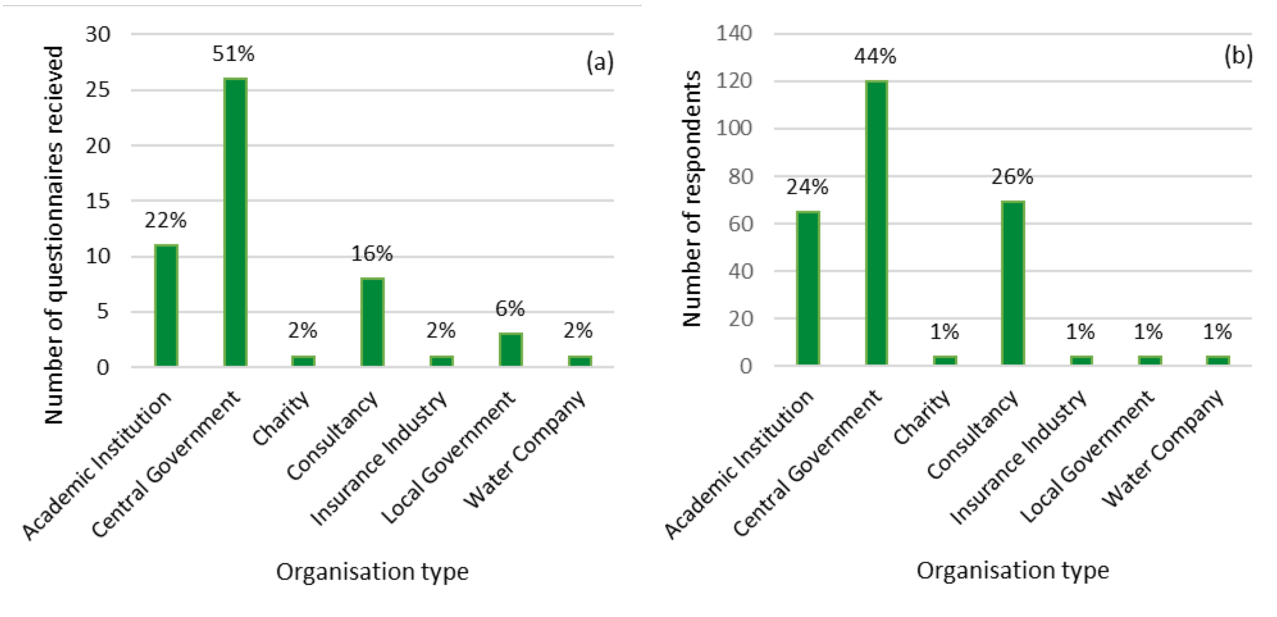
The first task for the roadmap project was to gather initial ideas and perceived needs for the future of flood hydrology from across the UK flood hydrology community. To achieve this, a questionnaire was sent to 52 individuals in May 2018. Each respondent was asked 7 questions. The full text of the questionnaire is presented in Appendix A.

5.2.1 The respondents

52 questionnaires were sent out to stakeholder groups across the flood hydrology community. 51 responses were received. Figure 18 (a) shows that of the 51 questionnaires received, more than half (51%) were from central government bodies. 22% of questionnaires came from academic institutions (10 institutions in the UK, and one based in Europe). 16% of questionnaires were completed by private consultancy businesses with an interest in flood hydrology. Local government organisations returned 6% of questionnaires, with charities, the insurance industry and water companies each accounting for 2% of responses (one questionnaire each).

Multiple individuals often contributed to an organisation’s questionnaire response. Central government, consultancies and academic institutions accounted for 94% of the 270 individuals who contributed to a questionnaire response. 120 people from central government bodies, 65 academics and 69 consultants contributed to a questionnaire response. 16 individuals from local government, water companies, the insurance sector and a charity made up the remaining responses (Figure 18 [b]).

Figure 18: Summary of stakeholder organisation type: (a) shows the number of questionnaires received from each organisation type, (b) shows the number of individuals who contributed to the response from each organisation type. Note percentages are rounded to the nearest whole number.



Central government bodies who responded to the questionnaire were made up of the Environment Agency, the Met Office (MO), Natural Resources Wales (NRW), the Scottish Environment Protection Agency (SEPA), the Department for Infrastructure, Northern Ireland (DfI), and the Natural Environment Research Council (NERC). This group also includes the Incident Management and Modelling Theme Advisory Group (IMM TAG) which advises the Environment Agency/Defra Joint Flood and Coastal Erosion Risk Management (FCERM) research and development programme. The Environment Agency accounted for 62% of all central government responses, and Natural Resources Wales for 15% (Figure 19 [a]). A total of 120 individuals from central government contributed to responses, with 73 from the Environment Agency, 15 from Natural Resources Wales, 10 from the IMM TAG, and the remaining 22 people spread across the other organisations (see Figure 19 [b]).

Figure 20 shows the spatial interests of the organisations that responded to the questionnaire. The majority of organisations (43%) had interest in the whole of the UK (many will also have international interests, but that is not represented here). 27% of organisations were focused on England, 8% focused on Wales and 2% on Scotland and Northern Ireland (1 organisation each). 12% of organisations had a regional interest (local government, Area Environment Agency staff and a water company). This equates to 6 organisations, all of which had a regional/local remit in England. Two international organisations also submitted questionnaires (one from Europe, and one from Australia).

Figure 19: Summary of central government bodies: (a) shows the number of questionnaires received from each central government body, (b) shows the number of individuals who contributed to the response from each central government body. Note percentages are rounded to the nearest whole number. [Abbreviations: Met Office (MO), Environment Agency (EA), Bureau of Meteorology, Australia (BoM), Incident Management and Modelling Theme Advisory Group (IMM TAG), Natural Resources Wales (NRW), Department for Infrastructure, Northern Ireland, Scottish Environment Protection Agency (SEPA), Natural Environment Research Council (NERC)].

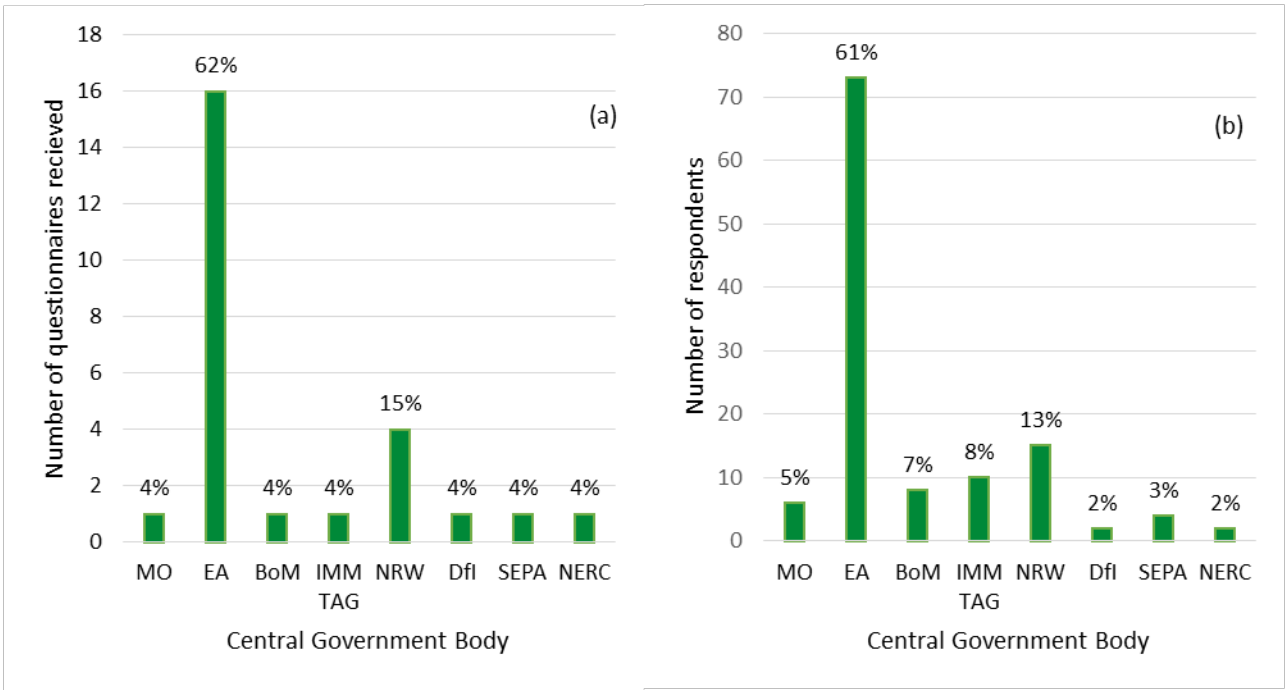
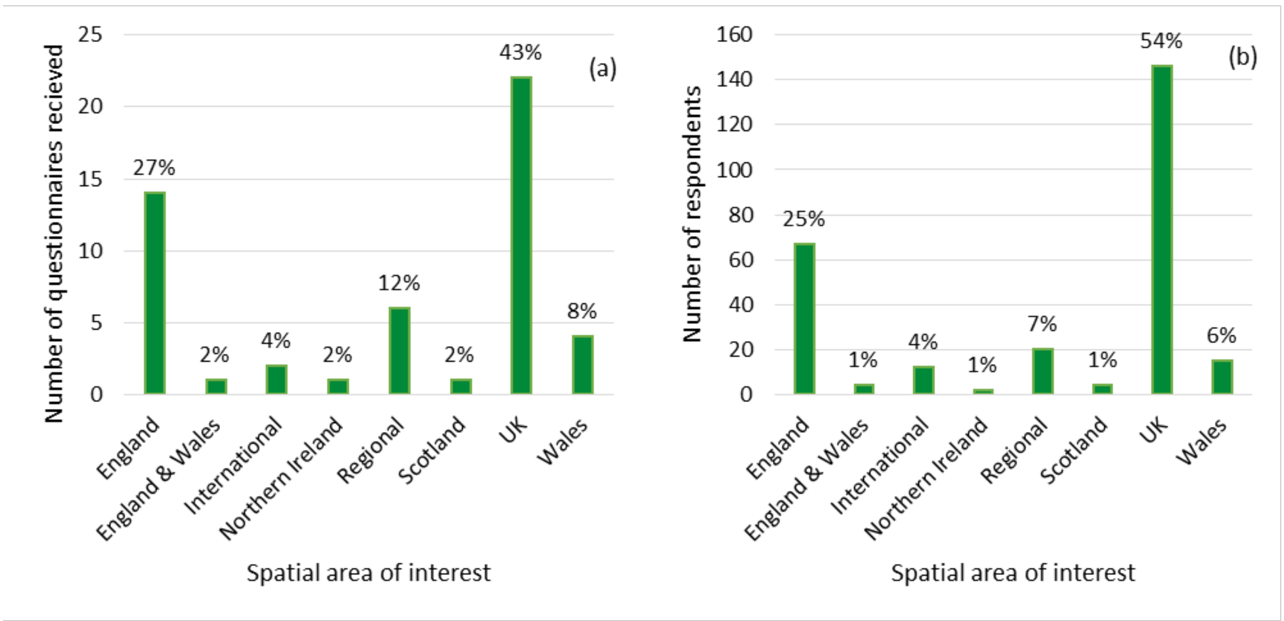


Figure 20: Summary of spatial interests of questionnaire respondents: (a) shows main spatial area of interest of questionnaires received from each central government body, (b) shows the main spatial area of interest of individuals who contributed to the response from each central government body. Note percentages are rounded to the nearest whole number.



5.2.2 Questionnaire responses

This section describes the responses to questions 2, 3 and 4 from the questionnaire. The responses to questions 1, 5, 6 and 7 are not shared to comply with General Data Protection Regulation (GDPR). The responses to the questionnaire are available in a file called FRS18196-A2-Flood hydrology roadmap - questionnaire.xlsx published on GOV.UK alongside this report. The content of this file has been anonymised to protect individual and organisational identity. Square brackets [ ] in this file indicate locations where text has been removed or changed.

Question 2 – The vision

Question 2 asked:

"We will develop a joint vision for flood hydrology 10 to 20 years from now. Please imagine you are in the future and that things are working well. Please describe what flood hydrology work looks like. We're not asking for any suggestions of solutions but rather short descriptions of what the future could provide. Please write as many future vision statements as you'd like."

A total of 488 vision statements were identified by respondents to the questionnaire and used to draft early versions of the vision statements.

Question 3 - The problems today

Question 3 asked:

- what are the inadequacies in current approaches?
- what are your team's biggest challenges in flood hydrology?
- what do you think are the wider challenges in flood hydrology?
- how urgent are they and how big are the impacts?
- how well known are the problems?

Respondents were asked to score each problem, challenge or opportunity they identified above for 3 criteria:

- urgency scale – score from 1 to 5, with 1 being "It will make things better, but there is no inherent urgency" and 5 being "We have already missed a key deadline"
- impact scale – score from 1 to 5, with 1 being "It has a locally important impact" and 5 being "It affects how we do things fundamentally, impacting everything and almost everyone (forecasting, long-term flood risk, all sources of flooding)"
- topic maturity – score from 1 to 5, with 1 being "We don't know much about the issue at all" and 5 being "Knowledge of the issue is known and updated, it needs translating into practice"

Respondents identified 396 areas of challenges and opportunities in UK flood hydrology.

Figure 21: Word cloud generating using the short name/title of problems, challenges and opportunities in question 3 of the flood hydrology roadmap questionnaire.

Figure 21 shows a word cloud generated using the ‘short name/title’ given for each response (column B of the ‘Question 3’ tab in the Excel file FRS18196-A2-Flood hydrology roadmap - questionnaire.xlsx). This visualisation gives prominence to words used most frequently by respondents in their description of problems, challenges, or opportunities. Unsurprisingly, the words ‘flood’ and ‘hydrology’ are most prominent, but other words stand out, such as data, estimation, uncertainty, risk, and modelling.

Figure 22 shows the frequency of respondents’ scores for all 396 problems, challenges and opportunities identified in question 3 of the questionnaire. 10% of responses were classified in the most urgent category (score of 5), with the majority (68%) scoring 4 or 3 for urgency. In contrast, 26% of responses were classified as having the most impact (score of 5), with 66% scoring 4 or 3. The maturity scores were more differently distributed, with 68% of responses scoring 3 or less (least mature).

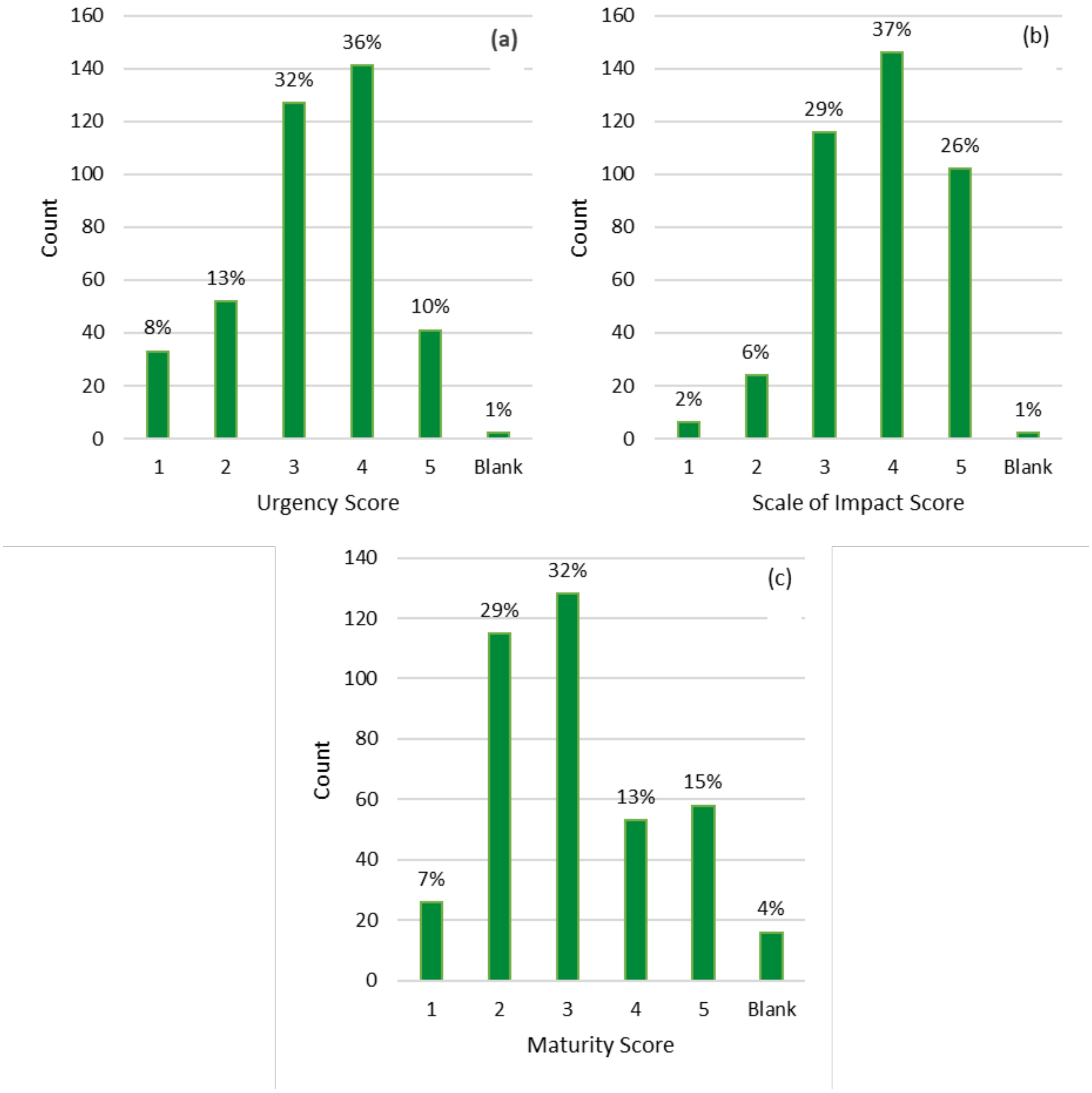
Question 4 – Prioritisation method

Question 4 asked:

“We will receive lots of suggestions of what we can do to improve things. We will need to prioritise these needs/ ideas for projects to know where to concentrate our efforts. Which criteria/questions do you think we could use to decide where to focus our efforts?”

160 ideas for prioritisation methods were received which are contained in the FRS18196-A2-Flood hydrology roadmap - questionnaire.xlsx file.

Figure 22: Scores for urgency (a) impact, (b) maturity and (c) for problems, challenges, and opportunities identified in question 3 of the flood hydrology roadmap questionnaire (all scores are from 1 to 5, with 5 being the most urgent, highest impact and most mature



5.3 Workshop

The findings from the initial questionnaire (above) were used to inform a face-to-face 2-day workshop in Birmingham in September 2018. The main aim of the workshop was to build ownership of the roadmap among leading stakeholders, and to start to create its content in terms of a vision for the future, perceived needs and actions required.

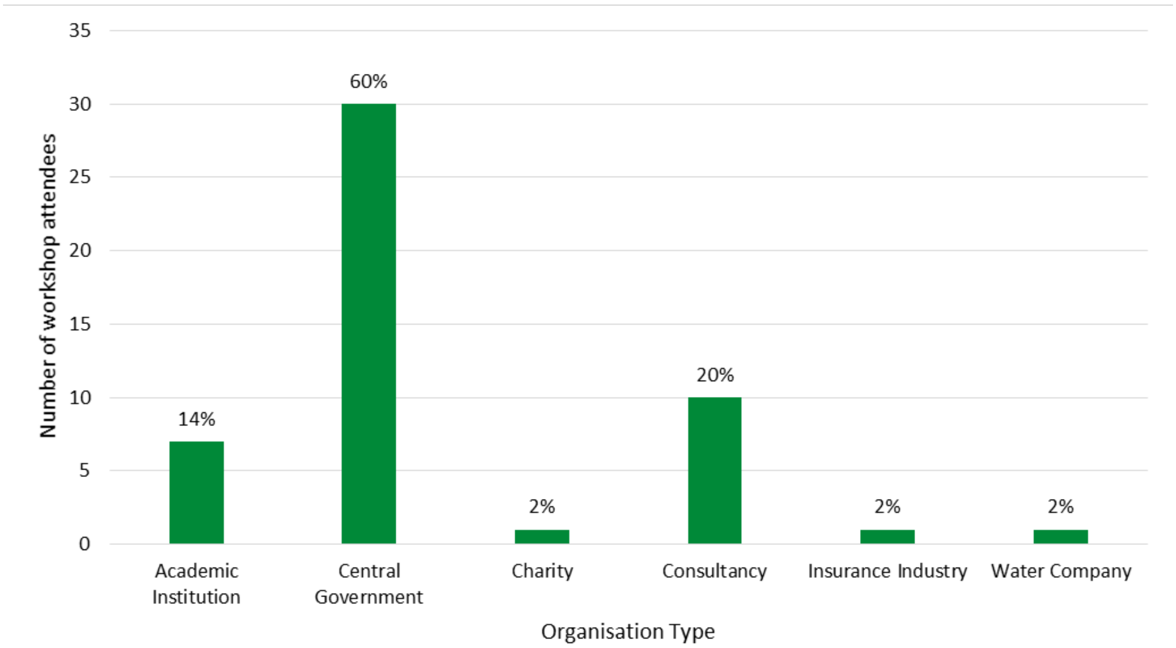
5.3.1 Attendees

The workshop was attended by 50 participants from 27 different organisations (summarised in Figure 23). The majority of attendees (60%) are classified as being from central government organisations, which include the Environment Agency, Scottish Environment Protection Agency, the Met Office, Northern Ireland Rivers Agency, the Flood Forecasting Centre, the British Geological Survey and the Natural Environment Research Council.

Consultancy companies accounted for 20% of the attendees from 9 different organisations. Representatives from 7 academic institutions attended (14% of attendees), including Reading University, Newcastle University, Bristol University, Hull University, the University of Bath, the European Centre for Medium-Range Weather Forecasts and the UK Centre for Ecology and Hydrology.

The remaining 6% of workshop attendees represent one person from a charity (the Chartered Institution of Water and Environmental Management, [CIWEM]) and one person each from the insurance industry and a water company.

Figure 23: Summary of workshop attendees by organisation type



5.3.2 Creating a vision for the future of flood hydrology

Part of the first day of the Birmingham workshop was focused on creating a collective vision statement for the future of flood hydrology in the UK. Two groups each created a draft high level vision statement presented below:

Vision statement - Group one

Our vision is that in 25 years all (flood) hydrology is aligned with best available and continuously improving whole system process understanding, underpinned by excellent data and evidence to quantify uncertainty and other characteristics and its sources, tailored to each location, time scales and application in a consistent, sustainable and open way to enable robust decision-making. Recognising that leadership, championing and collaboration are key to delivery of this vision.

Vision statement - Group two

In 25 years, through working together, society will have the best hydrological information and understanding to manage the impacts of flooding from all sources, at all scales in a changing world.

Each group also started to develop more detailed vision statements on other issues such as data, methods, uncertainty, accessibility and scientific understanding. These are presented in Appendix B of this report.

These draft vision statements represent the starting point for the final vision statements presented in section 3.1.

5.3.3 Examining the current situation

Workshop participants were also asked to explore and record the current situation in relation to flood hydrology for flood forecasting and planning (flood estimation). This was done for 4 different sources of flooding; fluvial, groundwater, pluvial and reservoirs.

The following questions were asked:

- Which data sets are currently used (underlying and processed data sets)?
- What are the current methods and technical approaches?
- Who does what?
- Who is ultimately responsible?
- What are the current knowledge gaps?
- What are the current challenges?
- What works well?
- Any obvious links to water courses or the coast?
- What are the general issues?

Tables were produced to capture this information and common themes across the sources of flooding identified. The detailed tables have been used to inform the current practice tables presented in Appendix E.

5.3.4 Action planning

The second day of the Birmingham workshop was devoted to action planning, where groups identified specific actions that could be taken to improve flood hydrology in the UK.

A total of 73 potential actions were identified and grouped around 16 main headings. The main headings were:

1. develop a decision-making under uncertainty framework
2. create a working group to look at monitoring issues holistically
3. better process understanding
4. developing methods which address climate change implications
5. new improved methods for reservoir flood estimation
6. further research of groundwater flooding
7. removing obstacle to academics working with government bodies and consultancies
8. improve access to flood hydrology data
9. improve skills and knowledge of flood hydrology practitioners
10. quantifying relative uncertainties in our flood hydrology methodologies
11. build a plan of actions based on recommendations of the National Flood Resilience Review
12. review and implement scientific developments to improve real-time forecasting
13. global network and collaboration
14. update the Flood Estimation Handbook
15. sediment data monitoring in the UK
16. training standards for hydrometric data collection and archiving

The full list of 73 actions with a short description can be found in Appendix C of this report.

These actions helped shape the online survey that was used to engage with the wider flood hydrology community described in the next section.

5.4 Online survey

An online survey was carried out in April 2019 which received 125 responses. The purpose of the online survey was to test developing vision statements and potential future work areas that had been identified from the earlier questionnaire and workshop. The responses to the online questionnaire are available in a file called FRS18196-A3-Flood hydrology roadmap - survey responses.pdf which is published on GOV.UK alongside this report.

A brief overview of the survey is presented here, rather than an in-depth analysis of the responses. The responses from this survey were used to refine the vision statements and develop a comprehensive set of actions required to achieve the roadmap vision.

The respondents to the survey were asked to classify their primary interest in flood hydrology, as flood forecasting, flood estimation or both. Figure 24 shows that more than half of survey respondents had a primary interest in flood estimation, 14% had a primary interest in flood forecasting, and 30% had an interest in both.

The survey also asked respondents about their interest and expertise in the 4 main sources of inland flooding (groundwater, surface water, reservoirs and fluvial flooding) and whether that related to flood forecasting or flood estimation. Figure 24 shows that primary expertise and interest in fluvial flooding was highest among survey respondents and lowest in groundwater (forecasting and estimation). Secondary interest or experience in sources of flooding was more evenly distributed among respondents.

Figure 24: **Primary interest of online survey respondents**

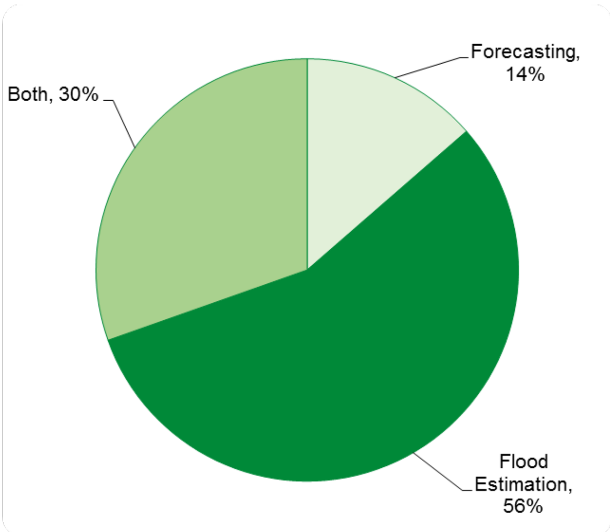
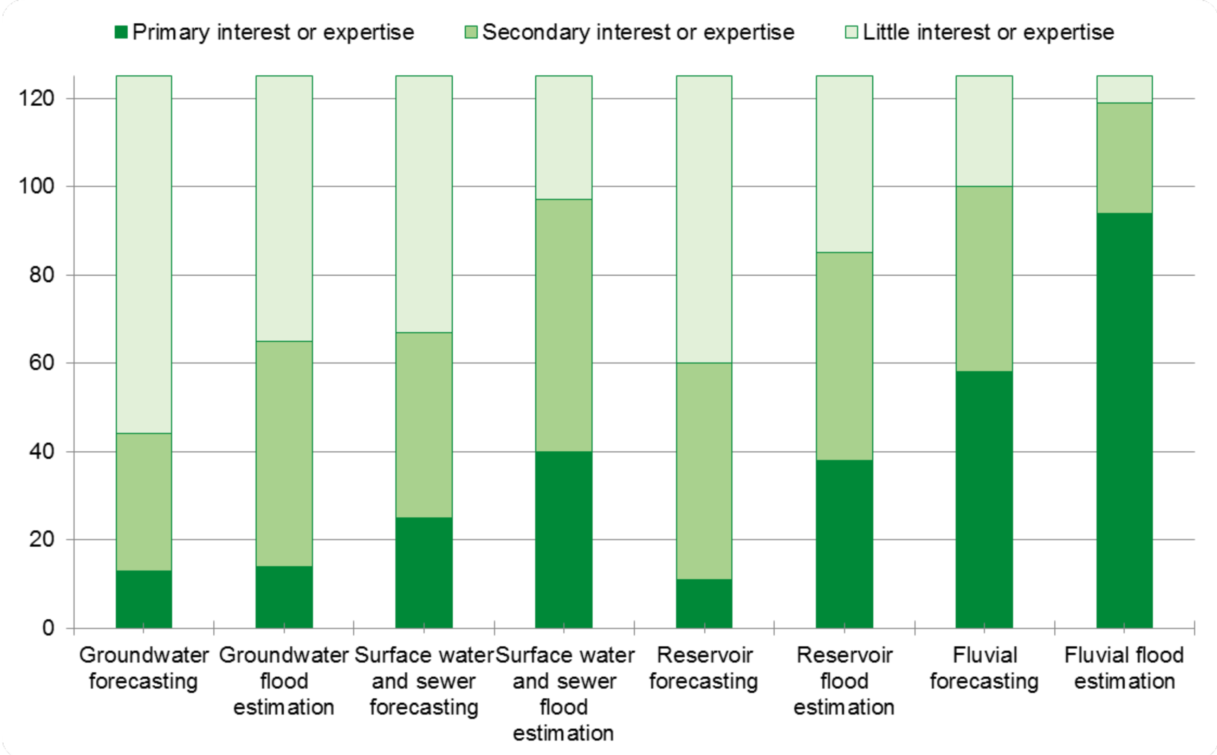


Figure 25: Summary of survey respondents' interest in sources of inland flooding



Questions in the online survey were arranged in 4 thematic work areas[12] which were identified after the Birmingham workshop:

- ways of working
- data
- methods
- scientific understanding

Vision statements were presented for comment, which included an overall vision for the roadmap and vision statements for each of the thematic work areas. The text based responses to these questions can be found in the FRS18196-A3-Flood hydrology roadmap - survey responses.pdf file.

The online survey then presented potential work areas which had been identified and refined from the questionnaire and Birmingham workshop, and invited respondents to score each potential work area from 1 to 5, where 1 would be the lowest priority and 5 the

[12] These thematic work areas were identified by examining the responses from the first questionnaire (section 5.2) by the project steering group. A parallel analysis was carried out by Lancaster University and the JBA Trust using machine learning methods, which concluded that the machine learning interpretation of the questionnaire responses was consistent with the choice of themes made by the steering group. A brief description of the machine learning work is given in Appendix I.

highest priority. A total of 38 potential work areas were presented in the survey (see Appendix D).

Figure 26: Average priority score for each work area in the online survey (range from 1 to 5, where 1 = low priority and 5 = high priority)

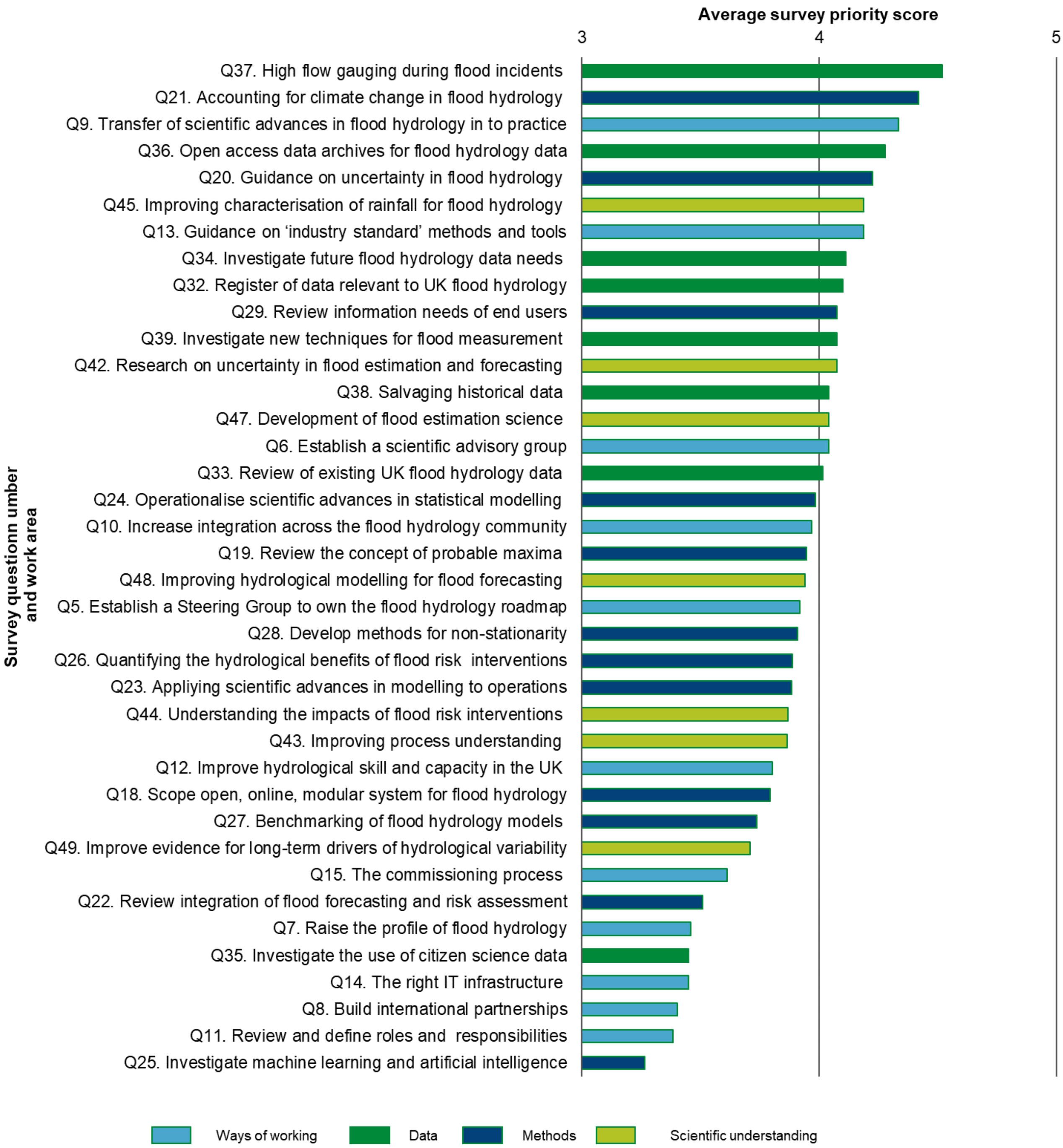
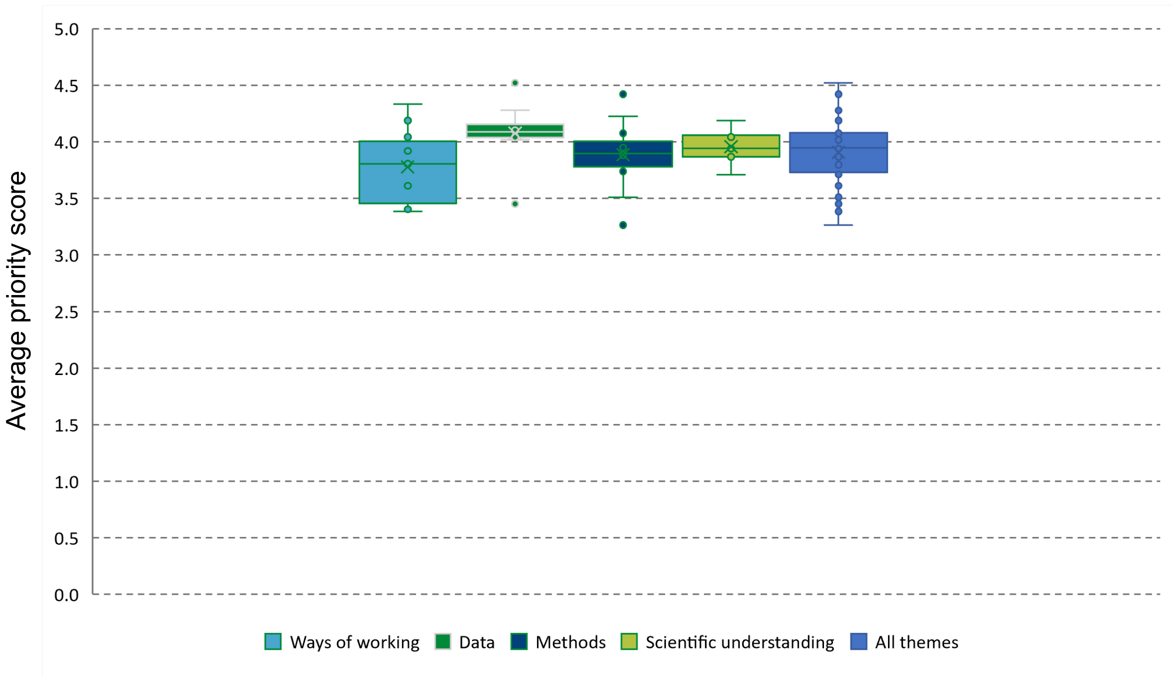


Figure 26 shows a summary of the average priority score for each work area in the online survey. The average priority score for all questions was 3.9, with a range between 3.26 and 4.52, which suggests that none of the potential work areas were seen as low priority by the survey respondents. This data is summarised in Figure 27 which presents boxplots of the average scores for each work area grouped by theme. This plot shows that collectively, potential actions on data were considered the highest priority, followed closely by scientific understanding and methods. Scores for potential ways of working actions had a much wider range of average priority scores, although still scoring above 3.3 for all actions. Although this analysis appears to favour data actions, the average priority scores for all potential work areas scored quite highly considering the 1 to 5 range.

The project team and the prioritisation task group used the results from the online survey to start to form the final actions plans for the roadmap. The work of the prioritisation task group is described in section 5.6.

Figure 27: Boxplot of average priority scores for each potential work area in the online survey by thematic work area (range from 1 to 5, where 1 = low priority and 5 = high priority)



5.5 Current practice task group

The current practice task group was established for several months from March 2019, with the aim of summarising current practice in flood hydrology for reservoirs, groundwater, surface water and fluvial flood risk for both forecasting and planning perspectives. This information was then used as a baseline to help develop proposals for future improvement.

The group comprised 27 volunteers from across the UK flood hydrology community. There were 4 sub-groups:

- fluvial led by Phil Raynor from Jacobs
- pluvial and sewers led by Bridget Woods-Ballard from HR Wallingford
- groundwater led by Dr Mark Whiteman from the Environment Agency
- reservoirs led by Dr Thomas Kjeldsen from the University of Bath

The outputs form the current practice task group are presented in Appendix E.

5.6 Prioritisation task group

Following the online survey in April 2019, a prioritisation task group (PTG) was established with the aim of identifying a prioritised plan of work to inform the roadmap. 27 individuals from across the UK and one from the Netherlands were represented on the PTG. The range of organisation types represented on the PTG, shown in Figure 28(a), indicates that there was a broadly even distribution of individuals working with the regulator/operational sector, research sector and consultancy sector.

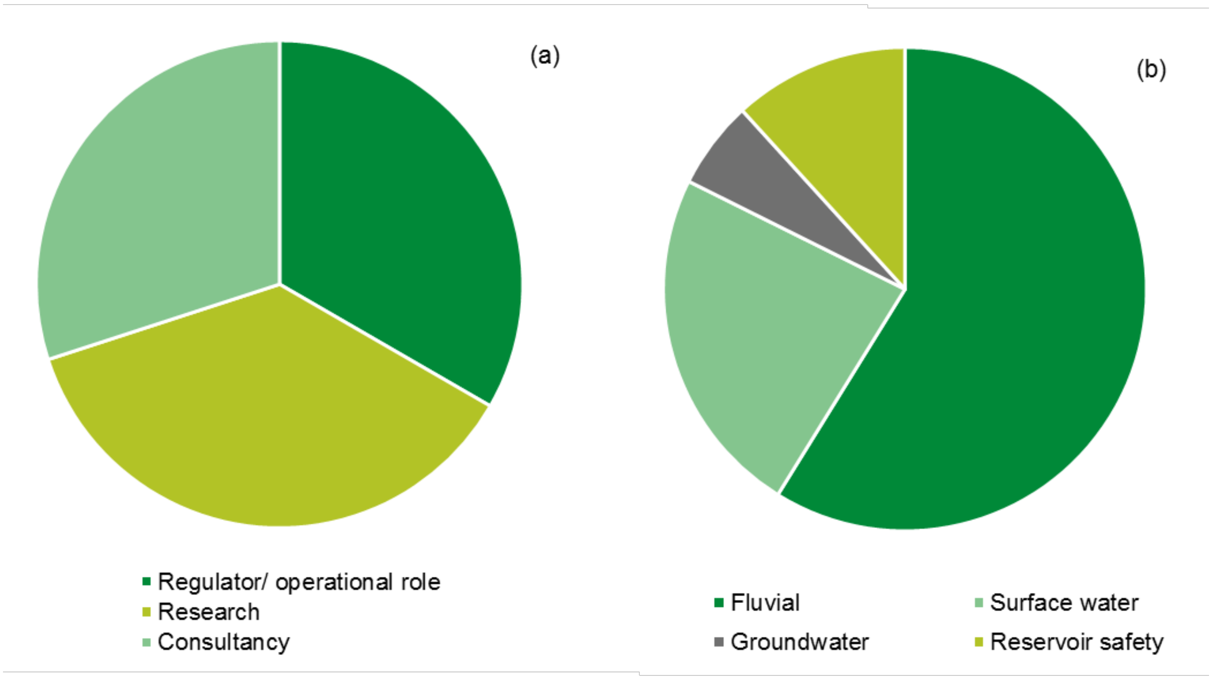
The technical expertise represented on the PTG is shown in Figure 28(b). The majority of expertise and experience covered fluvial flood hydrology, although many individuals also had experience in other technical areas such as surface water, groundwater and reservoir safety.

The PTG initially examined the 38 work areas identified in the online survey (section 5.4) and attempted to evaluate each work area against the following criteria:

- likely to result in reduced risk to life
- likely to result in reduced economic impact of flooding
- likely to result in other improvements to flood impacts or scheme design, for example, environmental benefits
- leads to something readily implementable by practitioners
- results in improved hydrometric data quantity or quality
- chances of the work area not succeeding are low (low risk)
- results in reduced uncertainty/increased confidence
- increases efficiency and effectiveness of future flood studies or operational flood management
- increases or shares knowledge and expertise

- quick win that builds on existing work
- significant step forward in scientific understanding with potential wider application, for example, overseas or other sectors
- already done or underway
- unlikely to be affordable

Figure 28: Organisational and technical representation of the prioritisation task group



Due to the complex nature of the resulting 'matrix' from the initial evaluation and the interdependence between many of the individual works areas, the project team took a decision to group all 38 priority work areas into a shorter number of 'initiatives'. This set out the scope of work required in a broader work area. The PTG then reviewed and commented on these initiatives, rather than strictly prioritising them.

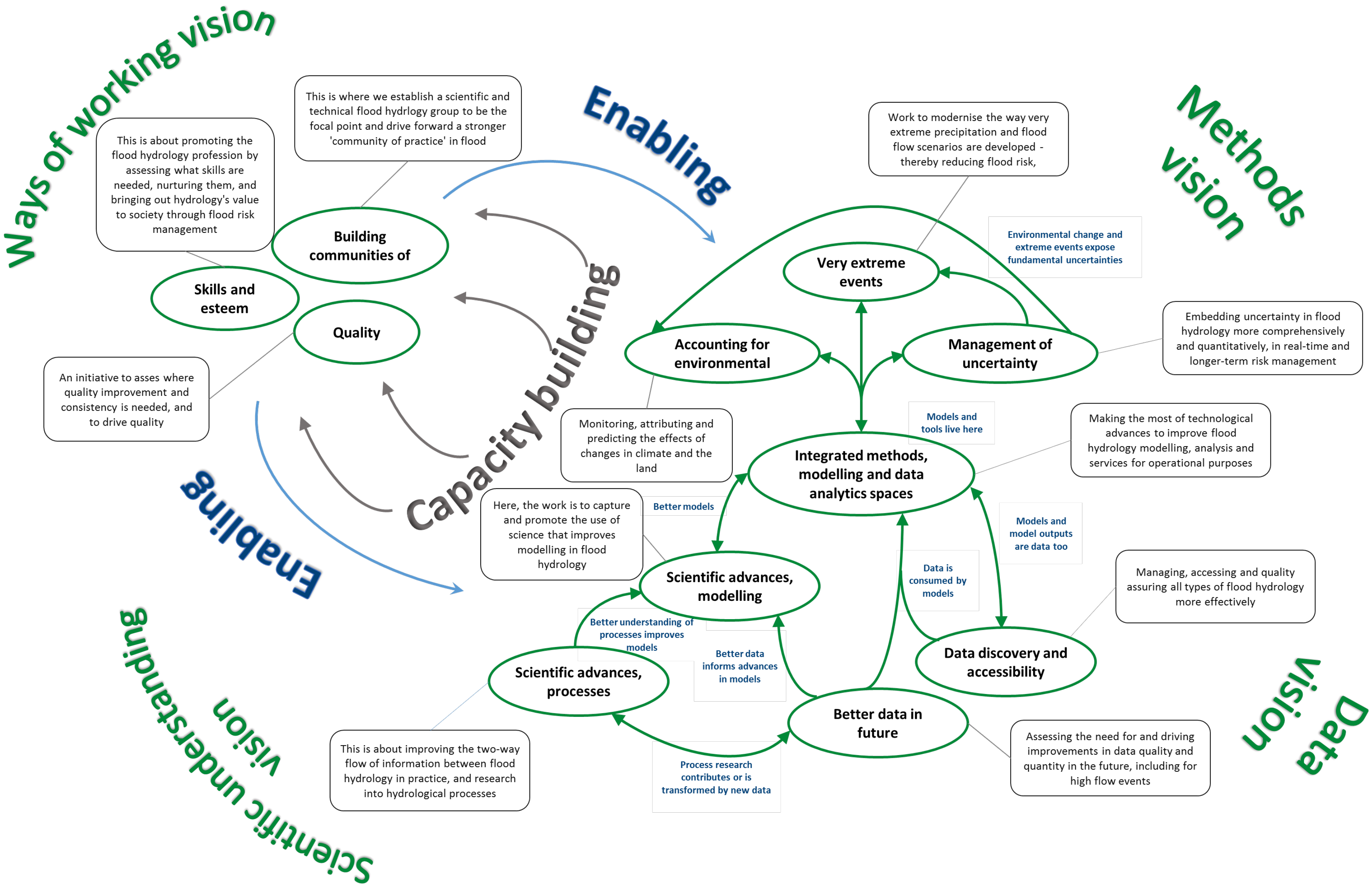
11 initiatives were developed containing information on context, objectives of the initiative, expected benefits and outputs, drivers and the risk of not carrying out the work. The detailed initiatives are presented in Appendix F and their interrelationships summarised in Figure 29. The 11 initiatives are:

1. better data in future
2. building communities of practice
3. data discovery and accessibility
4. integrated methods, modelling and data analytics spaces
5. management of uncertainty
6. monitoring, attributing and predicting the effects of environmental change
7. quality assurance

8. scientific advances in modelling
9. scientific advances in process understanding
10. skills, esteem and value
11. very extreme events

The content of these initiatives was used to develop a detailed action plan for the roadmap, discussed in section 3.3.

Figure 29: Summary of initiatives (in green ovals) developed during the prioritisation process



5.7 Enablers and delivery partners group

The final step in the development of the flood hydrology roadmap was to establish action plans which clearly set out the actions required to achieve the vision of the roadmap.

Two groups were established to help the project team turn the 11 initiatives developed during prioritisation into action plans for the flood hydrology roadmap:

- the delivery partners group
- the enablers group

The project team developed draft action plans based on the findings of the online survey and the outcomes from the prioritisation task group, and presented them to the delivery partners group and the enablers group.

5.7.1 The delivery partners group

The delivery partners group was responsible for identifying when actions should be carried out and who might fund these actions (group members were budget holders and decision makers in their organisation). The main purpose of the delivery partners group was to:

- commit (as far as possible) their organisation to involvement in the prioritised projects to be included in the action plan
- co-ordinate engagement with the enablers group
- approve an action plan to put forward to the roadmap steering group

The organisations represented on the delivery partners group were:

- Environment Agency
- Natural Resources Wales
- Department for Infrastructure, Northern Ireland
- Scottish Environment Protection Agency
- Flood Forecasting Centre
- Met Office
- UK Research and Innovation
- European Centre for Medium-Range Weather Forecasts

5.7.2 The enablers group

The role of the enablers group was to advise the delivery partners on which organisations could help contribute to elements of the roadmap and ‘how’ that could be achieved to ensure that projects and activities take account of dependencies.

The main purpose of the enablers group was to:

- capture, prioritise and promote priority enabling topics from the prioritisation process
- support proposals to delivery partners

- formulate a plan to carry out the enabling activities
- build a community for sharing ideas and building concepts, including relevant parties outside flood hydrology
- be aware of the longer term future

Members of the enablers group were selected for their technical and scientific knowledge and represented the following organisations:

- Environment Agency
- Natural Resources Wales
- Department for Infrastructure, Northern Ireland
- Scottish Environment Protection Agency
- Canal and River Trust
- UK Centre for Ecology and Hydrology
- Flood Forecasting Centre
- Met Office
- British Hydrological Society
- CIWEM Rivers and Coastal Group
- CIWEM Urban Drainage Group

5.7.3 Workshops

Two workshops were held with the delivery partners (January and February 2021) and the enablers group (December 2020 and March 2021), which helped develop the final action plan presented in Appendix G.

These workshops marked the end of the process to develop action plans for the UK flood hydrology roadmap.

5.8 BHS webinar

The original plan for the roadmap project was to hold a follow-up meeting to the September 2018 workshop in Birmingham where the draft roadmap and action plan would be presented and refined after comments. Due to COVID-19 lockdown restrictions it was not possible to hold a second workshop. The project board decided that the draft roadmap should be presented to as wide an audience as possible. The vision and action plans were presented to an online audience of nearly 500 people via a BHS webinar[13] in March 2021.

The draft action plan was shared with participants on request, and comments were invited from the wider community. Incorporation of comments received after the webinar marked the end of the development of the roadmap.

[13] BHS webinar on the flood hydrology roadmap [Last accessed 20 September 2021]

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List of abbreviations

BEIS	Department for Business, Energy and Industrial Strategy
BHS	British Hydrological Society
BSG	British Society for Geomorphology
CASE	Collaborative Awards in Science and Engineering
CIWEM	Chartered Institution of Water and Environmental Management
CREW	Scotland's Centre of Expertise for Water
DfI	Department for Infrastructure, Northern Ireland
EDI	Equality, diversity and inclusion
EPSRC	Engineering and Physical Sciences Research Council
FCERM	Flood and coastal erosion risk management
FDRI	Flood Drought Research Infrastructure
FEH	Flood Estimation Handbook
GDPR	General Data Protection Regulation
Hydro-JULES	Hydro-Joint UK Land Environment Simulator
IAHS	International Association of Hydrological Sciences
ICE	Institution of Civil Engineers
IMM TAG	Incident Management and Modelling Theme Advisory Group
IPCC	Intergovernmental Panel on Climate Change
JBA	Jeremy Benn Associates
MO	Met Office
NERC	Natural Environment Research Council
NFRR	National Flood Resilience Review
NRW	Natural Resources Wales
PhD	Doctor of Philosophy
PMF	Probable maximum flood

PMP	Probable maximum precipitation
PTG	Prioritisation task group
SAGA	Surface and Groundwater Archives committee
SEPA	Scottish Environment Protection Agency
STAG	Scientific and Technical Advisory Group
SuDS	Sustainable drainage systems
UKCEH	UK Centre for Ecology and Hydrology
UKCP18	UK Climate Projections 2018
UKRI	UK Research and Innovation
WHO	World Health Organisation

List of appendices

Appendices to this report are contained in a separate document (published alongside this report) available on GOV.UK:

FRS18196-A1-Flood hydrology roadmap – appendices.pdf

The appendices contain the following information:

Appendix A – Questions in the questionnaire

Appendix B – Vision statements from the Birmingham workshop

Appendix C – Potential actions identified at the Birmingham workshop

Appendix D – Work areas in the online survey

Appendix E – Current practice tables

Appendix F – Initiatives

Appendix G – Action plan for thematic work areas

Appendix H – Outcome mapping

Appendix I – Machine learning interpretation of questionnaire responses

Appendix J – Optimism bias calculation

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