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Working with natural processes to
reduce flood risk

R&D framework: science report

Report – SC130004/R2

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This report is the result of research commissioned by the Environment Agency's Evidence Directorate and funded by the joint Flood and Coastal Erosion Risk Management Research and Development Programme.

Published by:

Environment Agency, Horizon House, Deanery Road,
Bristol, BS1 9AH
www.environment-agency.gov.uk

ISBN: 978-1-84911-331-1

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Dissemination Status:

Publicly available

Keywords:

Natural processes, Flood and coastal erosion risk, Geomorphology, Ecosystem services, Research, Biodiversity, Water Framework Directive

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Project Number:

SC130004/R2

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The work of the Environment Agency's Evidence Directorate is a key ingredient in the partnership between research, guidance and operations that enables the Environment Agency to protect and restore our environment.

This report was produced by the Scientific and Evidence Services team within Evidence. The team focuses on four main areas of activity:

- **Setting the agenda**, by providing the evidence for decisions;
- **Maintaining scientific credibility**, by ensuring that our programmes and projects are fit for purpose and executed according to international standards;
- **Carrying out research**, either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available.

Miranda Kavanagh
Director of Evidence

Executive summary

The overall aim of the ‘Working with Natural Processes’ (WWNP) research framework project is to:

‘develop a comprehensive and prioritised programme of WWNP research, development and dissemination, which enables us to undertake FCERM sustainably, improving the environment for people and wildlife’.

The definition of WWNP in relation to flood and coastal erosion risk management (FCERM) that underpins the development of the framework is as follows.

‘WWNP means taking action to manage fluvial and coastal flood and coastal erosion risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts’.

The project was completed in 2013 to 2014 and had three stages. Stage 1 included a comprehensive review of WWNP research and development (R&D) and a stakeholder workshop to establish:

- what R&D had been carried out so far
- gaps in our knowledge
- future research needs

Stage 2 involved refining the research gaps, making links with other R&D programmes, and identifying and prioritising a set of potential R&D projects which could be undertaken by the Joint Programme, other risk management organisations, public sector bodies, non-governmental organisations, academic institutions and other research funders. Stage 3 was producing this report, which has been independently peer-reviewed.

Existing information and tools related to WWNP in a range of different topic areas were reviewed to help identify potential research gaps. A stakeholder workshop reduced the initial list to eight main gaps:

- understanding approaches to community and stakeholder engagement that would help to encourage WWNP by exchanging more knowledge and developing incentives
- understanding and changing cultural and institutional barriers to WWNP in flood risk management authorities that currently limit the promotion of WWNP approaches
- providing integrated guidance and/or training in WWNP for practitioners to help them bring together existing good practice and tools
- learning lessons from past and existing pilot/case studies to make use of existing knowledge and experience of WWNP
- undertaking new or continued studies to improve the WWNP evidence base, including collecting data about WWNP at a variety of catchment scales and in river, estuary and coastal locations
- completing a national-scale prioritisation of catchments and coastal cells where the most flood and coastal erosion risk benefits might be gained using WWNP
- collecting data about natural processes at a catchment scale

- developing more adaptive/resilient green engineering technologies to encourage their use as an alternative to traditional engineering

Building on these emerging research priorities, a long-list of project ideas that would help contribute to fulfilling these research gaps was identified using the earlier review of published data and evidence, ideas from the stakeholder workshop, and the project team's expert knowledge. A series of reviews and a priority scoring approach was used to reduce the final list to the 14 highest priority projects. The projects were scored based on:

- how much they would contribute to the overall objective of the WWNP research framework to help achieve WWNP in practice
- their potential to attract research and development funding
- whether they would help bring about the research priorities identified in the Living with Environmental Change (LWEC) flood research strategy
- how relevant the project outputs would be to stakeholders
- whether they would provide information that can be widely applied

The final list of projects included in the WWNP framework includes those that had high or medium priority from the scoring. Short business cases were written for these projects which form a basis for future R&D project proposals.

A series of projects in the final list involve trialling, testing and monitoring the effects of WWNP measures in a series of 'catchment laboratories' that will demonstrate how WWNP works in different environments. These would be long-term collaborative research projects. There would be a scoping stage to review existing catchment projects and to set objectives, identify locations, partnerships, timescales and funding.

The other projects in the final list include:

- national mapping to identify priority catchments where WWNP measures have most potential to produce flood and coastal erosion risk benefits
- modelling the effects of WWNP measures on flood and coastal erosion risk
- developing a 'blue-green engineering rating and design guide' for FCERM practitioners
- examining attitudes, cultural and scientific barriers to WWNP – do we need a cultural change?
- using the ecosystem approach for funding opportunities in WWNP
- developing operational guidance to achieve FCERM using WWNP
- joining up delivery of the Water Framework and Floods Directives
- assessing the costs and benefits of fish and eel screening measures at river and coastal engineering structures

The next steps are publicising the framework, obtaining funding for the projects from the Joint Programme, research councils or others, undertaking the research projects and monitoring progress of the framework. It will be important to communicate progress and results, and to make sure the outputs can be used by a wide audience. The framework should continue to link with existing Defra/Environment Agency R&D frameworks to join up research opportunities and to provide feedback for other R&D to benefit from the new evidence.

Acknowledgements

The project was led by the Environment Agency: Lydia Burgess-Gamble (Project Manager) and Mark Ross (Project Executive), and the Project Sponsor was Alastair Driver. It was steered by a Project Advisory Group which included Andy Disney (Environment Agency), Greg Whitfield (Environment Agency), Jenny Mant (River Restoration Centre), John Oldfield (Bedford Group of Internal Drainage Boards and Association of Drainage Authorities), John Rees (Natural Environment Research Council and British Geological Survey), Nicola Rimington (Natural Resources Wales), Dr Peter Downs (British Society for Geomorphology and Plymouth University), Rob Cathcart (Natural England), Amy Shaw (Environment Agency), Ruth Ashton-Ward (Defra), Vicki Rhodes (Environment Agency and Living With Environmental Change) and Vince Carter (Forestry Commission).

The reports were peer-reviewed by Dr Mark Wilkinson (James Hutton Institute) and Professor Colin Thorne (University of Nottingham).

Thanks are given to individuals and organisations that contributed to this research including:

- Association of Drainage Authorities
- Bedford Group of Internal Drainage Boards
- British Geological Survey
- British Society for Geomorphology
- Chris Bown and Dr Emma Stevens (Black & Veatch)
- Professor David Sear, University of Southampton
- Department for Environment, Food and Rural Affairs
- Environment Agency
- Ece Ozdemiroglu (eftec)
- Economic and Social Research Council
- Professor Enda O'Connell
- Forest Research
- Forestry Commission
- Hutton Institute
- Living With Environmental Change
- Natural England
- Natural Resources Wales
- Natural Environment Research Council
- Dr Nicola Teague (Apem)
- Professor Philip James (University of Salford)
- River Restoration Centre

- Rivers Trust

Thanks are also given to those who attended and contributed to the Working with Natural Processes (WWNP) stakeholder workshop.

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1 Introduction

1.1 Overview

The Working with Natural Processes (WWNP) research framework is a cross-cutting research area within the Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management (FCERM) Research & Development (R&D) Programme (referred to subsequently in this report as the Joint Programme). The overall aim of this project is to:

‘develop a comprehensive and prioritised programme of WWNP research, development and dissemination, which enables us to undertake FCERM sustainably, improving the environment for people and wildlife’
(Environment Agency 2013a)

Figure 1.1 summarises the structure of this report and supporting documents.

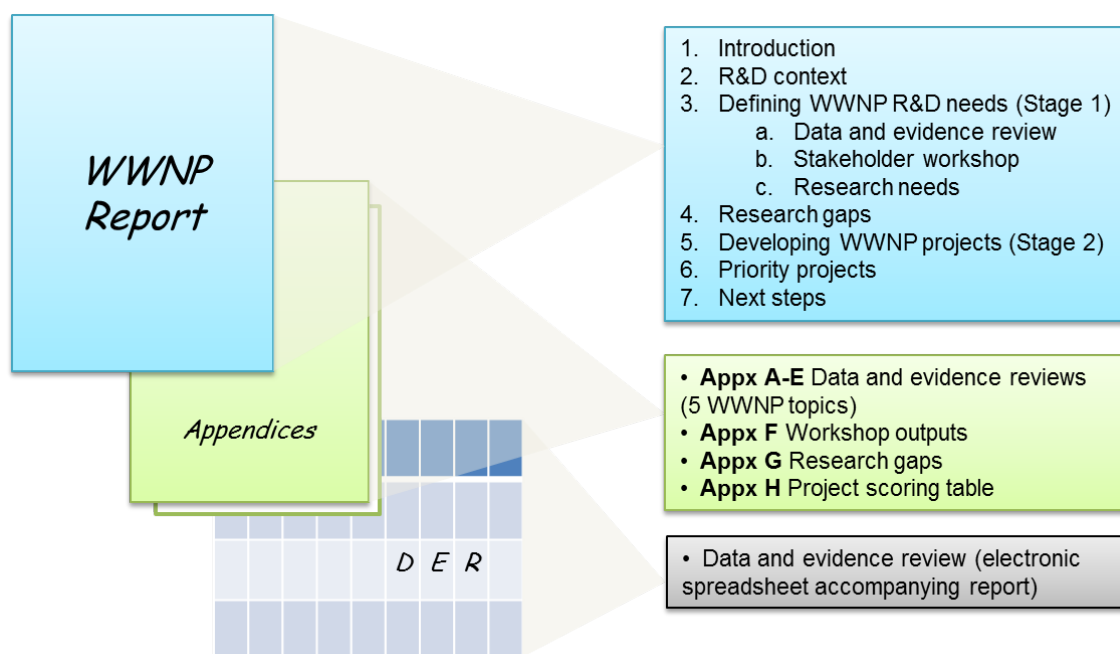


Figure 1.1 Structure of this report and supporting documents

There has never been a comprehensive review in England and Wales of WWNP research and development (R&D) to establish:

- what R&D had been carried out so far
- gaps in our knowledge
- future research needs

This project aims to answer these questions. Figure 1.2 shows the three stages of this project which include:

- Stage 1 – a review of existing data and evidence, a stakeholder workshop, and an analysis of emerging research needs and gaps
- Stage 2 – refining the research gaps, identifying and prioritising potential R&D projects

- Stage 3 – finalising the report and prioritised project list, including an independent peer-review

In this report, the term WWNP is used to refer specifically to ‘working with natural processes to reduce flood and coastal erosion risk’.

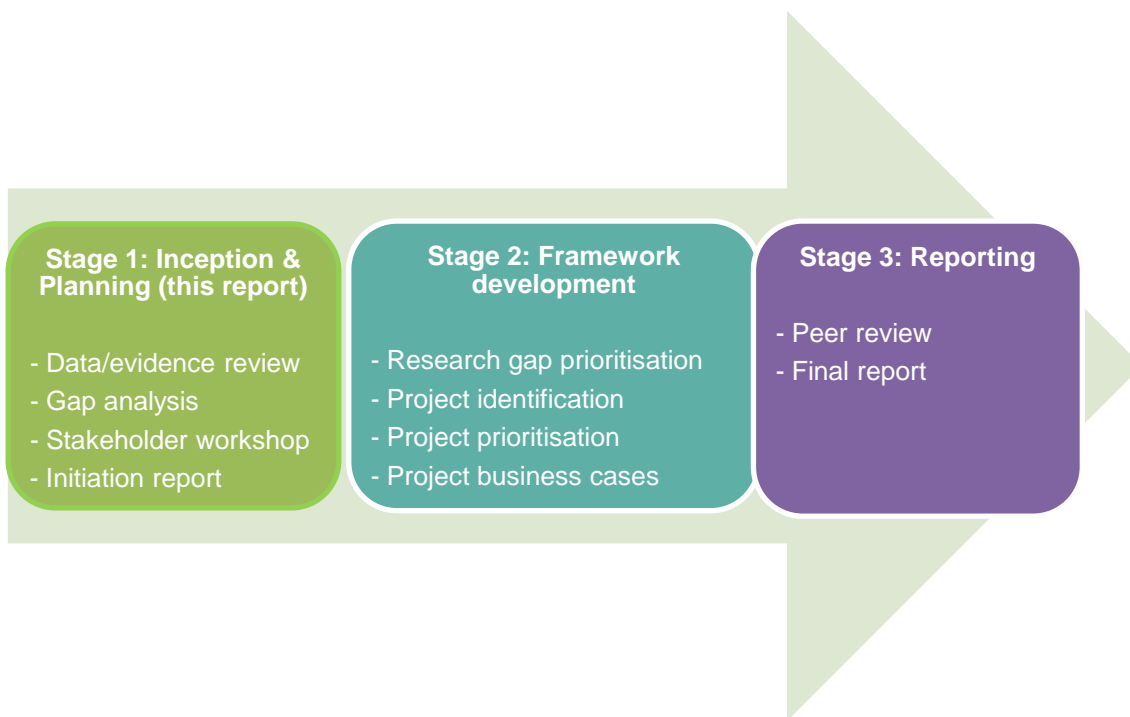


Figure 1.2 Stages in WWNP framework development

1.2 Definition

A multi-agency working group established by the Department for Environment, Food and Rural Affairs (Defra) defined WWNP as follows:

‘Working with natural processes means taking action to manage fluvial and coastal flood and coastal erosion risk by protecting, restoring and emulating the natural regulating function of catchments, rivers, floodplains and coasts’ (Environment Agency 2012a, p. 10)

For the purpose of this study WWNP includes the following topics:

- **ecosystem services** – including the ecosystem approach¹
- **fluvial and coastal geomorphology** – including sediment management and restoring natural processes
- **green engineering** – including mitigation measures and sustainable alternatives to ‘grey’ engineering²
- **habitat and species management** – including vegetation management, meeting biodiversity targets, fish and eel passage
- **natural flood management** – including catchment land management

¹ The ecosystem approach integrates the management of land, water and living resources and aims to balance conservation of biodiversity, sustainable use and equitable sharing of benefits.

² In this report, ‘green’ engineering means soft engineering/bioengineering and ‘grey’ engineering means hard defences.

WWNP takes many different forms, and can be applied in urban and rural areas, and on rivers, estuaries and coasts. For example, it might include:

- reducing the use of materials such as concrete by using sustainable drainage systems (SuDS) in urban areas
- restoring floodplains to store more water in rural areas
- creating managed flood storage areas along rivers, estuaries and coasts

Table 1.1 lists various WWNP measures and some of their potential flood and coastal erosion risk management (FCERM) benefits. Examples of the use of WWNP are shown in Figure 1.3.

Table 1.1 WWNP measures

WWNP measure	Potential FCERM benefits
Field-scale land and soil management (tree shelter-belt planting, reduced stocking levels, cover crops, contour ploughing, soil retention, manage tracks, fencing/stock access)	<ul style="list-style-type: none"> • Hold back or slow surface flows to reduce local flood peaks • Reduce excessive sediment input from soil run-off and stock trampling banks
Moorland grip-blocking or field drain and under-drainage blocking	<ul style="list-style-type: none"> • Slow flow by increasing storage in bogs or on pasture • Blocking under-drainage (mole and tile drains) in 'improved' upland pasture
Woody debris	<ul style="list-style-type: none"> • Slow flow within channel • Local effect
Land use change (for example, arable to pasture) or buffer strips	<ul style="list-style-type: none"> • Improve water storage in soils and reduce run-off • Catch and slow run-off and sediment
Floodplain woodlands	<ul style="list-style-type: none"> • Slow overland flows • Increase infiltration and interception of rain • Slow speed of water into rivers
Changes to vegetation and sediment management (maintenance)	<ul style="list-style-type: none"> • Natural processes help self-regulation of rivers • Can have positive or negative effects on flood risk depending on location
Floodplain reconnection (remove, set back or lower embankments)	<ul style="list-style-type: none"> • Increase water stored on floodplain to reduce downstream flow, including constructed washlands
River bed raising/ riffles (for example, in previously dredged sections)	<ul style="list-style-type: none"> • Improve natural processes and in-channel flows • May also help reconnect floodplains
Scrapes, swales and wetlands/ rural sustainable drainage	<ul style="list-style-type: none"> • Local flow storage • Catch run-off and sediments and slow water before reaching rivers
Flood storage areas (online or offline)	<ul style="list-style-type: none"> • Hold water within channel or by taking offline – may be engineered structures or relatively natural features
Two-stage channels	<ul style="list-style-type: none"> • Increase capacity of channels to move water

WWNP measure	Potential FCERM benefits
Removing redundant in-stream structures or re-engineer essential structures that restrict flow	<p>during floods but keeping a normal flow channel and features like berms to slow flow</p> <ul style="list-style-type: none"> • Reduce risk of blockage • Remove constraints to flows which may raise water levels • Depends on location as to whether it reduces flood risk
Urban flood corridors	<ul style="list-style-type: none"> • Opportunities may be linked to redevelopment for 'making space for water' along urban rivers through creation of floodways with room to store and convey flood water
Re-meandering straightened rivers or reconnecting historic meanders	<ul style="list-style-type: none"> • Helps re-link floodplains • Slows flow by reducing river slope and increasing length
Managed realignment (breach or removal of walls or embankments in estuarine/ coastal areas)	<ul style="list-style-type: none"> • Increases area for water to flow into • Helps improve natural flood/ erosion defences like saltmarsh by giving space to evolve to sea level rise
Protect natural estuarine and coastal defences (saltmarshes, sand dunes and shingle ridges, and beaches). Remove defences that disrupt natural processes	<ul style="list-style-type: none"> • Helps reduce wave energy and erosion and reduce overtopping of defences • Allows the coast to erode in some places for benefits of natural sediment features as defences in other areas
SuDS – urban	<ul style="list-style-type: none"> • Including water storage in developing urban areas to slow water flow • Including within buildings such as green roofs or ponds and open areas

Notes: Adapted from Environment Agency (2010)

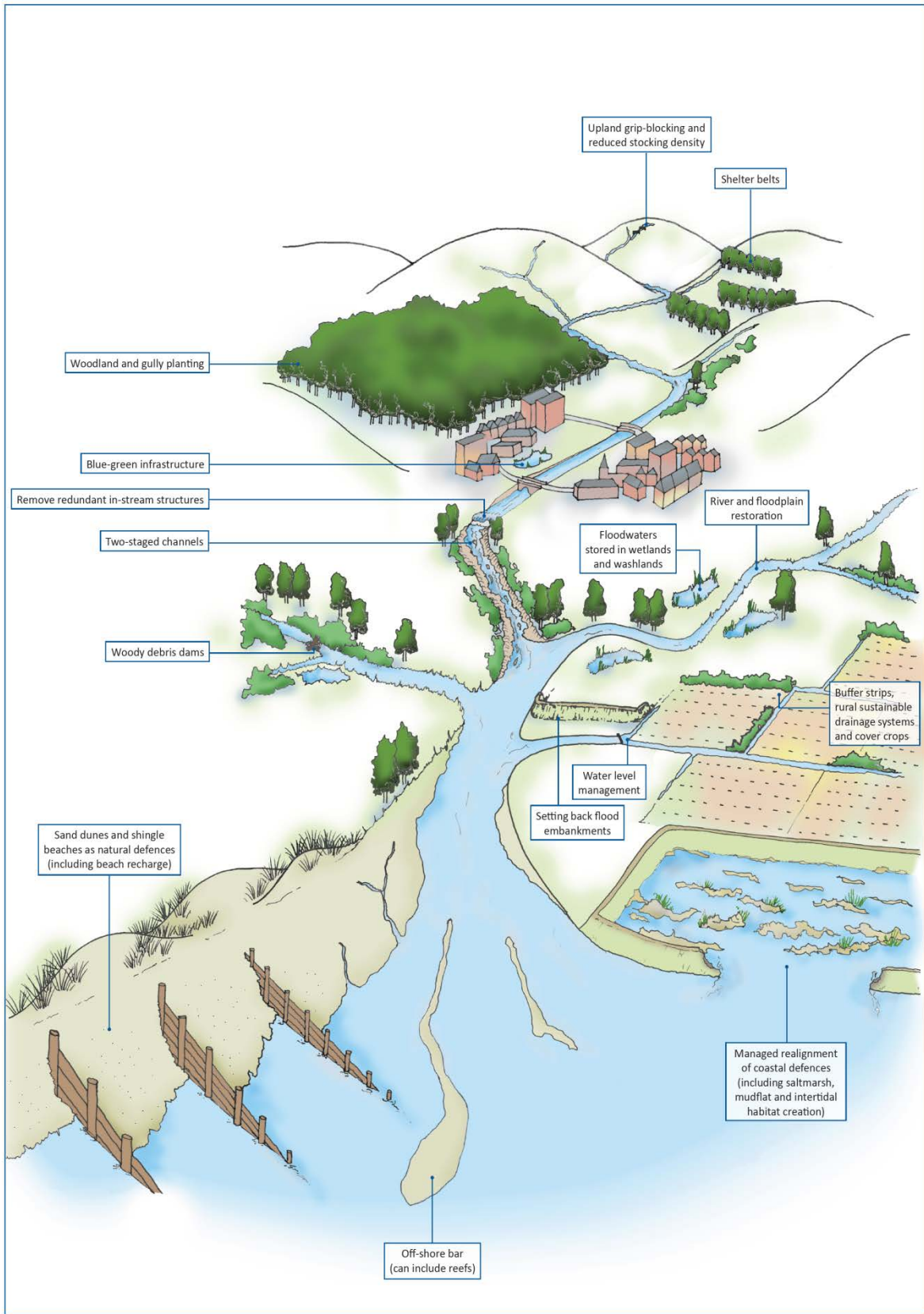


Figure 1.3 Examples of WWNP to reduce flood and coastal erosion risks in a conceptual catchment–estuary–coastal system

1.3 Why WWNP?

The Pitt Review, undertaken after the flooding in summer 2007, concluded that flooding from a range of sources can no longer be managed by building ever higher, lengthier and heavier defences in urban and rural areas. The review emphasised the need to 'work with natural processes' as part of integrated portfolios of responses to flooding and coastal erosion (Pitt 2008). Recommendation number 27 states that:

'Defra, the Environment Agency and Natural England should work with partners to establish a programme through Catchment Flood Management Plans and Shoreline Management Plans to achieve greater working with natural processes'.

To respond to this recommendation, Defra set up three catchment pilots to demonstrate a series of multi-objective flood management schemes, each of which included WWNP measures particularly focused on catchment land use management. The pilots were:

- Pickering, North Yorkshire (Slowing the Flow) – led by Forest Research
- Holnicote, Somerset (Source to Sea) – led by National Trust
- Upper Derwent, Derbyshire (Moors for the Future) 'Making Space for Water' – led by Environment Agency

These projects aimed to demonstrate how land management, working with natural processes and partnership working, could contribute to reducing flood risk locally while providing wider benefits to the environment and communities. Although they have provided an excellent basis for testing some WWNP approaches, these pilots are limited in scale and scope. They leave a number of questions to be answered about the benefits of natural flood management and WWNP at larger scales and with more combinations of measures.

WWNP can be complementary to traditional flood and coastal defences, as part of the full range of measures that risk management authorities can use to reduce the risk of flooding and coastal erosion to people, property, businesses and infrastructure. WWNP will help ensure that FCERM is undertaken sustainably and as cost-effectively as possible, by reducing future maintenance costs and maximising the wider benefits to society and the economy – for example by improving water quality, enhancing human well-being and providing opportunities for relaxation and recreation. WWNP can help improve the environmental condition of rivers, wetlands and coastal areas in urban and rural areas, and provide economical local solutions to smaller scale flood problems. WWNP can also help to mitigate and adapt to the impacts of climate change such as sea level rise and more extreme weather events.

WWNP can help meet the requirements of legislation (see section 1.4) and achieve broader environmental benefits by:

- reducing flood risk sustainably (that is, in terms of cost efficiency, social equity and environmental quality)
- providing opportunities for local stakeholder engagement and community participation
- conserving, creating and restoring habitats
- enhancing biodiversity
- capturing carbon

- reducing excessive sediment inputs or managing sediment more sustainably
- improving water quality

1.4 Legislation and policy background

The main policies and legislation that currently encourage the use of WWNP in FCERM are summarised in Figure 1.4.

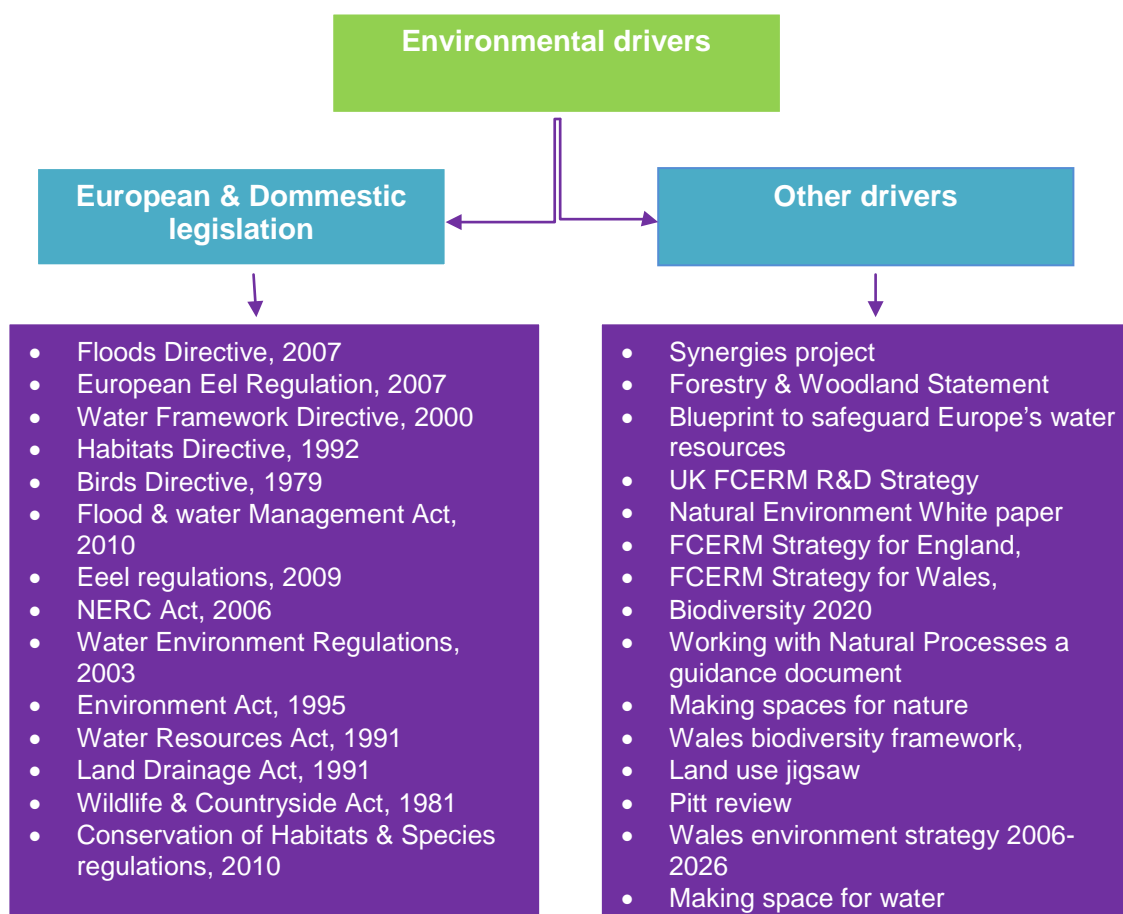


Figure 1.4 Main legislative and policy drivers of WWNP in FCERM

WWNP contributes to the Environment Agency’s ambition to develop an integrated programme to achieve more environmental benefits with its FCERM activities (Environment Agency 2013b). This includes:

- joining up river basin management plans, flood risk management plans, shoreline management plans and catchment flood management plans
- achieving a catchment-based approach
- providing a unified planning approach to meet the requirements of the Water Framework Directive (WFD), Habitats Directive, Floods Directive and Eel Regulations

During the early stages of development of the WWNP framework, Defra was working on a project called ‘Synergies’ (Hardiman and Cathcart 2013), looking at how to

integrate the delivery of Biodiversity 2020, the Water Framework Directive and the Flood and Coastal Erosion Risk Management programmes. The recommendations from the Synergies project include three specific areas where WWNP could contribute:

- a common evidence base to help agree objectives and inform decision making at a range of spatial scales
- targeting on-the-ground measures to achieve multiple objectives
- developing funding, regulation, incentives and advice in a way that can be more flexibly applied

1.5 Recent floods and WWNP

While past flood events and their review have contributed to the development of WWNP as a concept for flood risk management, recent flooding has increased its profile further. During the development of the WWNP framework, significant river, coastal and surface water flooding occurred in England and Wales between December 2013 and February 2014. WWNP as a way of reducing flood risk featured highly in the media, with a mixture of positive and negative reactions in different situations and locations. Although there was some positive coverage, there was evident distrust of WWNP from some communities, leading to calls for a return to dredging and construction of major flood schemes. The need to consider alternative forms of flood management, including natural flood management and WWNP was discussed in parliament (Hartwell-Naguib and Roberts 2014).

The Chartered Institute of Water and Environmental Management (CIWEM) also published a position statement on FCERM in light of the winter 2013-2014 floods (CIWEM 2014). This states that:

‘FCERM should look to work with natural processes to reduce flood and erosion risk, benefit the natural environment and reduce costs of schemes’ (adapted from CIWEM 2014).

There is considerable momentum for WWNP to be used more widely, become more integrated into flood risk management practice, and the need to understand better when its use would be most effective.

1.6 WWNP successes and barriers

Perceptions of WWNP can be mixed. To look at how WWNP is viewed, attendees at a workshop held during this project (September 2013) were asked to identify words that might define successful WWNP and barriers to WWNP.

From the lists of words that groups came up with, ‘word clouds’ were produced for ‘successful WWNP (Figure 1.5) and barriers to WWNP (Figure 1.6). The size of words in the clouds is proportionate to the number of times they were referred to by the workshop groups. There was not a set number of words so there is only an implicit relationship.

- **Successful WWNP** was seen to be integrated, multi-functional, sustainable and resilient, and to include engagement, value and communication.
- **Barriers to WWNP** included funding, understanding, uncertainty, risk, policy, perceptions and institutional barriers.

2 R&D framework context

This section describes other R&D strategies and frameworks that link to WWNP. The WWNP research framework was developed in close collaboration with these other strategies and frameworks. Any research gaps and projects identified during the WWNP project were cross-checked against related research frameworks and strategies to ensure the project complemented rather than duplicated effort. This includes applied research in England and Wales.

2.1 The Joint Programme

The Joint Programme is a partnership between the Department for Environment, Food and Rural Affairs (Defra) and the Environment Agency, which serves all FCERM operating authorities and undertakes approximately £2.5 million of research each year. It was set up to ensure the government's investment in FCERM is based on reliable and sound evidence. It develops information and tools to help practitioners reduce and mitigate the impact of flooding on the UK economy and local communities.

The Joint Programme has three themes:

- Policy, Strategy and Investment
- Asset Management
- Incident Management

And four cross-cutting work areas:

- Local Flood Risk
- Coastal
- Reservoirs
- WWNP

The Joint Programme is an end-user oriented, applied research programme which is steered and peer-reviewed by relevant experts.

2.2 Living With Environmental Change

Living With Environmental Change (LWEC) is a partnership of 22 public sector organisations with representatives from the private sector forming part of a Business Advisory Board. LWEC aims to ensure decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from the effects of climate change.

LWEC has produced and is implementing the UK FCERM Research Strategy (Moores and Rees 2011), which identified FCERM research priorities for the next 20 years. It is vital that WWNP priorities are in line with these broader research areas.

The strategy identified broad research themes and scored them in terms of their 'maturity' and 'urgency'. Maturity considers the amount and type of research completed per theme and whether new research is needed to bridge knowledge gaps. Urgency considers how soon we need research to be completed. LWEC assessed their research needs and gaps against six PESTLE (**P**olitical, **E**conomic, **S**ocial,

Technological, Legal and Environmental) drivers. Section 3 explains how the LWEC strategy has been used to identify research needs and gaps in this project.

2.3 Coastal Research, Development and Dissemination Research Framework

The Coastal Research, Development and Dissemination (CoRDDi) research framework is a cross-cutting work area in the Joint Programme (Environment Agency 2012b). It sets out coastal flood and erosion risk research priorities for the next five years.

CoRDDi identified research gaps and needs in four themes:

- understanding whole-system behaviour
- valuing impacts and promoting innovative funding
- decision making and operational practice
- dissemination, education and training

Within these themes, 18 priority projects are proposed over a five-year period.

In collaboration with the Joint Programme, a major programme of research called 'Coastal Sediment Systems' has been funded and commissioned as part of the Natural Environment Research Council (NERC) Natural Hazards Theme. A number of the CoRDDi priority projects and the planned outcomes of the Coastal Sediment Systems programme have some overlap with the research needs relating to natural processes in coastal environments identified within this WWNP framework. Sections 3 and 4 of this report describe how similar research objectives between the CoRDDi and WWNP framework were identified and managed.

2.4 Local Flood Risk Research Framework

The Local Flood Risk Research Framework is a new cross-cutting work area in the Joint Programme. It will establish research priorities for local flood risk management approaches. The potential links between these areas were considered as the WWNP R&D needs and projects were developed through ongoing liaison between the framework theme managers.

2.5 Reservoir Safety Research Strategy

The Reservoir Safety Research Strategy is currently being updated. There are thought to be few direct links with WWNP, with the exception of a project currently underway that aims to produce guidance on the design of flood storage areas. Some WWNP measures may need to consider the implications of the Reservoirs Act if they store volumes of water larger than 10,000 m³.

2.6 SEPA natural flood management mapping

In 2013 the Scottish Environmental Protection Agency (SEPA) completed a national scale mapping of opportunities for natural flood management (NFM) across Scotland in 2013 to provide information for developing flood risk management strategies (SEPA 2013). The five general approaches include:

- run-off reduction
- floodplain storage
- sediment management
- estuarine surge attenuation
- wave energy dissipation

Similar tools may be required to help implement WWNP in England and Wales.

3 Defining R&D needs

This section summarises how existing research in WWNP was reviewed and remaining R&D needs were examined. This was the first stage of the project (June 2013 to November 2013), which included the tasks shown in Figures 3.1 to 3.4.



Figure 3.1 Stage 1 key tasks

For the purposes of this project, WWNP was split into five topics:

- ecosystem services – including the ecosystem approach (ESS)
- fluvial and coastal geomorphology (FCG)
- green engineering (GE)
- habitat and species management – including fish and eel passage (HS)
- natural flood management (NFM)

Dividing WWNP into specific topics helped make the review of this large work area more manageable. A range of experts and the Project Advisory Group (PAG), who have experience in one or more of these topics, independently reviewed work as it was completed.

3.1 Task 1 – Data and evidence review

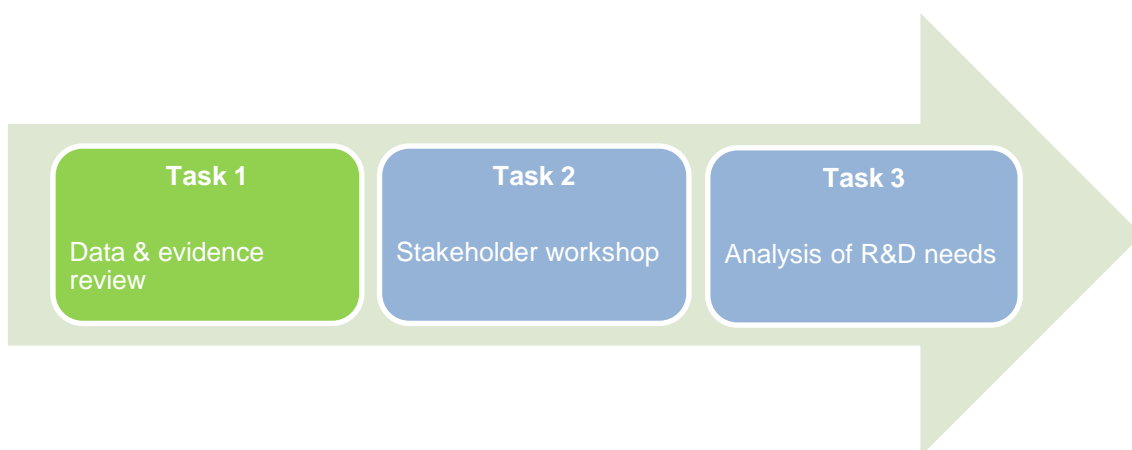


Figure 3.2 Task 1 – Data and evidence review

3.1.1 Purpose

The data and evidence review (DER) was completed between June and September 2013. Its aim was to:

- **collate and record** evidence for WWNP in FCERM produced in the UK and overseas during the last 20 years
- **identify and link** to evidence in other research programmes such as LWEC, CoRDDi, research councils and research institutes
- **produce** a spreadsheet listing each piece of evidence (see section 3.1.4)

'Evidence' includes published and draft research reports, papers, tools, data, guidance and ongoing or planned research projects.

3.1.2 Principles

The data and evidence review identified completed, ongoing and planned research relevant to both WWNP and FCERM by following these key principles:

- **Focus on quality over quantity** by identifying the most widely used documents and research.
- **Target** evidence published only in the last 20 years (1993 to 2013).
- **Apply a consistent methodology** across all topics – including shared and clearly defined parameters and definitions.
- **Use time efficiently and effectively** by reviewing at an appropriate level of detail.
- **Keep a transparent audit trail** for work done.
- **Consult** specific individuals within organisations to ensure comprehensive coverage.

3.1.3 Sources of evidence

Lists of completed, ongoing and planned research projects were provided by a number of organisations:

- Environment Agency
- Defra
- Economic and Social Research Council (ESRC)
- British Society for Geomorphology
- NERC
- Hutton Institute
- Centre of Expertise for Waters (CREW)
- Forestry Commission
- Forest Research
- River Restoration Centre (RRC)

This included published and draft research reports, papers, tools, data and guidance.

Online literature searches were also carried out and supplemented with information from topic leads – evidence used in everyday practice including reports, journal articles, guidance and manuals.

Stakeholders who attended the WWNP workshop also identified important references which they used. These were added to the data evidence register (see section 3.1.4).

The quality of the evidence collected and reviewed varies depending on the degree of peer review that each document has received. For example, published journal papers and reports are likely to have greater scientific credibility as they have been subject to a rigorous peer-review process.

3.1.4 Data and evidence register

As of 30 September 2013, a total of 525 pieces of evidence had been sourced, of which over 370 were considered relevant to both WWNP and FCERM. This evidence was recorded in the data and evidence register (DER), which is a Microsoft® Excel spreadsheet with three parts. Parts 1 and 2 are provided with this report ([Link to DER Excel version](#)) while Part 3 was part of the project working process (see section 3.3.2):

- **Part 1 – Describes** the evidence – for example, title, authors, year published, current status and a short abstract
- **Part 2 – Categorises** the evidence – for example, data type, spatial application, policy relevance and target audience
- **Part 3 – Cross-references the evidence against identified research needs** – for example, R&D needs identified in LWEC's FCERM Strategy, CoRDDi or at an internal Environment Agency workshop

The DER was reviewed by the PAG and senior reviewers from academia and other consultants in the project team. Appendices A to E explore in detail the evidence that was collected for each of the five topics.

3.2 Task 2 – Stakeholder workshop

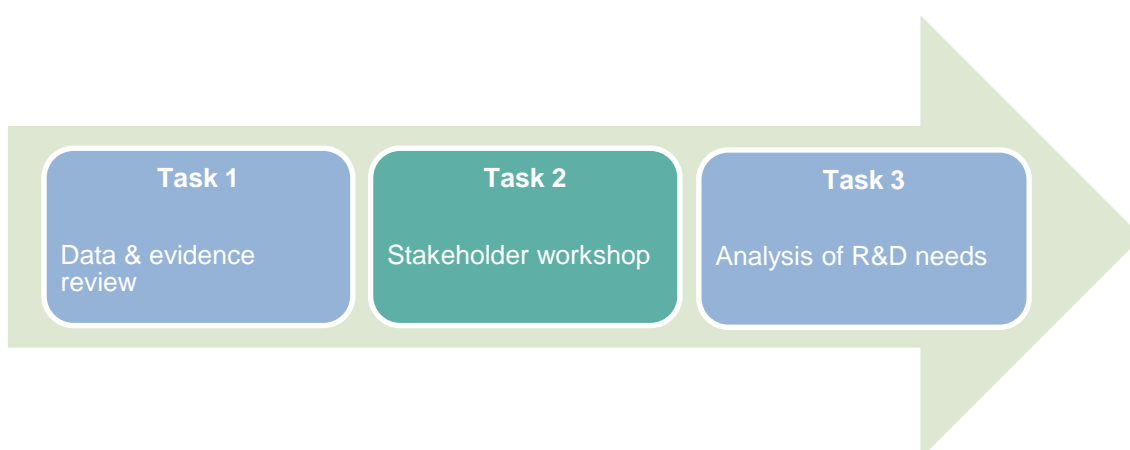


Figure 3.3 Task 2 – WWNP stakeholder workshop

The WWNP stakeholder workshop was held in September 2013 in Sheffield. A wide range of attendees (see Appendix F) were involved in group workshops to look at:

- **Evidence currently used** – for example, data, reports, toolkits and guidance
- **Research needs** – by discussing and exploring a number of initial research questions that had been developed by the project team (see section 3.3.1)
- **Research gaps** – current gaps that limit or prevent the achievement of WWNP
- **Project ideas** – which could potentially plug these research needs and gaps

The workshop helped improve understanding of the most important research gaps (see Appendices A to E). The workshop outputs were used to inform Stage 2 (refinement of research gaps, identification and prioritisation of research projects). Appendix F includes the full list of project ideas put forward at the workshop.

3.3 Task 3 – Analysis of R&D needs

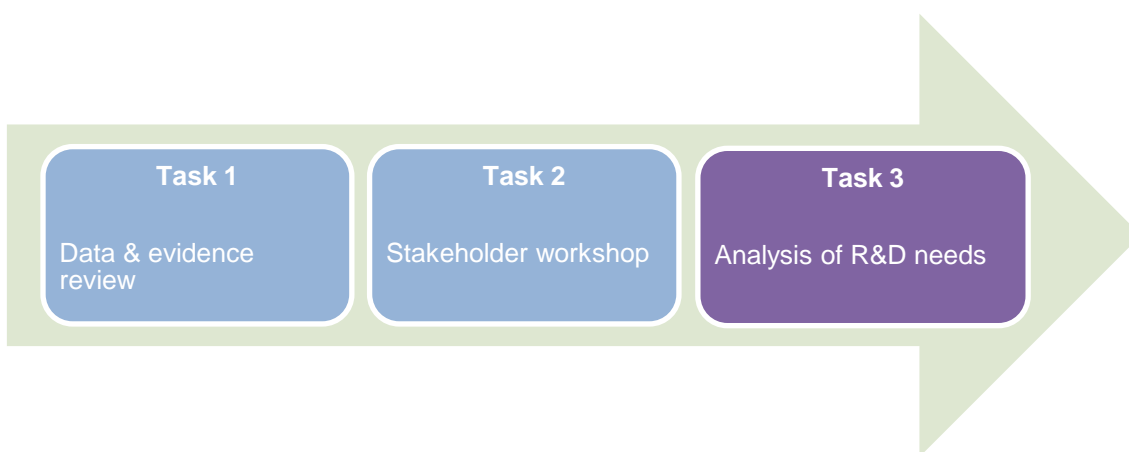


Figure 3.4 Task 3 – R&D needs

3.3.1 Identifying and summarising research needs

To identify WWNP research needs, a list of 13 research questions across the five topics (Table 3.1) was developed by reviewing:

- research priorities in the LWEC FCERM Strategy (Moores and Rees 2011)
- WWNP research needs developed at an internal Environment Agency workshop in October 2012
- WWNP research needs identified in a questionnaire completed by attendees prior to the WWNP workshop (September 2013)

These broad research questions were used in discussions at the WWNP workshop (see section 3.2) and subsequently matched to existing evidence in the DER to help identify research gaps (see section 3.3.2).

Table 3.1 WWNP research questions

Ecosystem services – including the ecosystem approach

- Q1) Are we able to effectively apply the ecosystem approach/ ecosystem services assessment to make WWNP possible?
- Q2) Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management techniques (for example, SuDS)?

Fluvial and coastal geomorphology

- Q1) Do we understand the value of sediments in natural flood and erosion protection in estuarine and coastal environments sufficiently to allow us to identify solutions?
- Q2) Can we identify catchments where river morphology and FCERM are most likely to be sensitive to sediment dynamics at a range of scales to enable proactive management of sediment related FCERM issues?
- Q3) Do we understand the implications of sediment supply and dynamics for FCERM over a variety of timescales to enable us to manage sediment related issues sustainably?

Green engineering

- Q1) Are there effective techniques to apply green engineering solutions in FCERM?

Habitat and species management (including fish and eel passage)

- Q1) How effective is FCERM habitat creation in meeting Habitats, Bird and Water Framework Directive requirements and the England biodiversity strategy?
- Q2) How effective are we at managing riparian, marginal and aquatic vegetation to reduce flood risk by using WWNP to achieve wider environmental and socioeconomic benefits?
- Q3) How well are we able to measure and predict the range of FCERM and other benefits that small to large scale habitat creation/ restoration provides?
- Q4) What methods are available to assess the habitat requirements of fish, in order to meet FCERM and Water Framework Directive objectives?
- Q5) What is our understanding of the effectiveness of engineered to more natural fish passage and screening techniques that might be used in achievement of WWNP, to meet the Eel Regulations and SAFFA (Salmon and Freshwater Fisheries Act) requirements?

Natural flood management

- Q1) What evidence is there to support the development and promotion of land use based flood mitigation at a range of spatial scales?
 - Q2) Are there effective techniques to apply natural flood management in FCERM?
-

3.3.2 Identifying research gaps

A perceived research need is not necessarily a research gap. Once the three tasks outlined above had been completed, each piece of evidence in the DER was cross-referenced against each of the research questions in Table 3.1. This helped identify any research needs **not** currently being answered by completed, ongoing or planned research – these were then defined as research gaps.

A graphical tool, referred to as ‘the R&D spectrum’, was developed and applied to help identify research gaps (Figure 3.5). This tool is based on the approach used to develop the LWEC FCERM strategy. This R&D spectrum helped to quickly assess whether current WWNP research meets the needs of its end users. It assumes the following:

- Research starts as an idea or theory (at the conceptual level) usually developed by a university or research institution (academic level).
- Research is then developed further by empirical testing and observation, and is subject to broader peer scrutiny.
- Finally the research is embedded into practical use through manuals, handbooks and guidance.

In theory, research should progress through these three important stages before it can be confidently adopted for practical use – following the line of the blue arrow in Figure 3.5. There may also be links between different types of research, for example, empirical evidence may be used to calibrate and validate predictive models.

If the position of the blue arrow current research in WWNP is plotted, it is possible to establish:

- what type of research needs to be progressed
- who needs to progress it
- how it needs to be applied to enable WWNP in practice

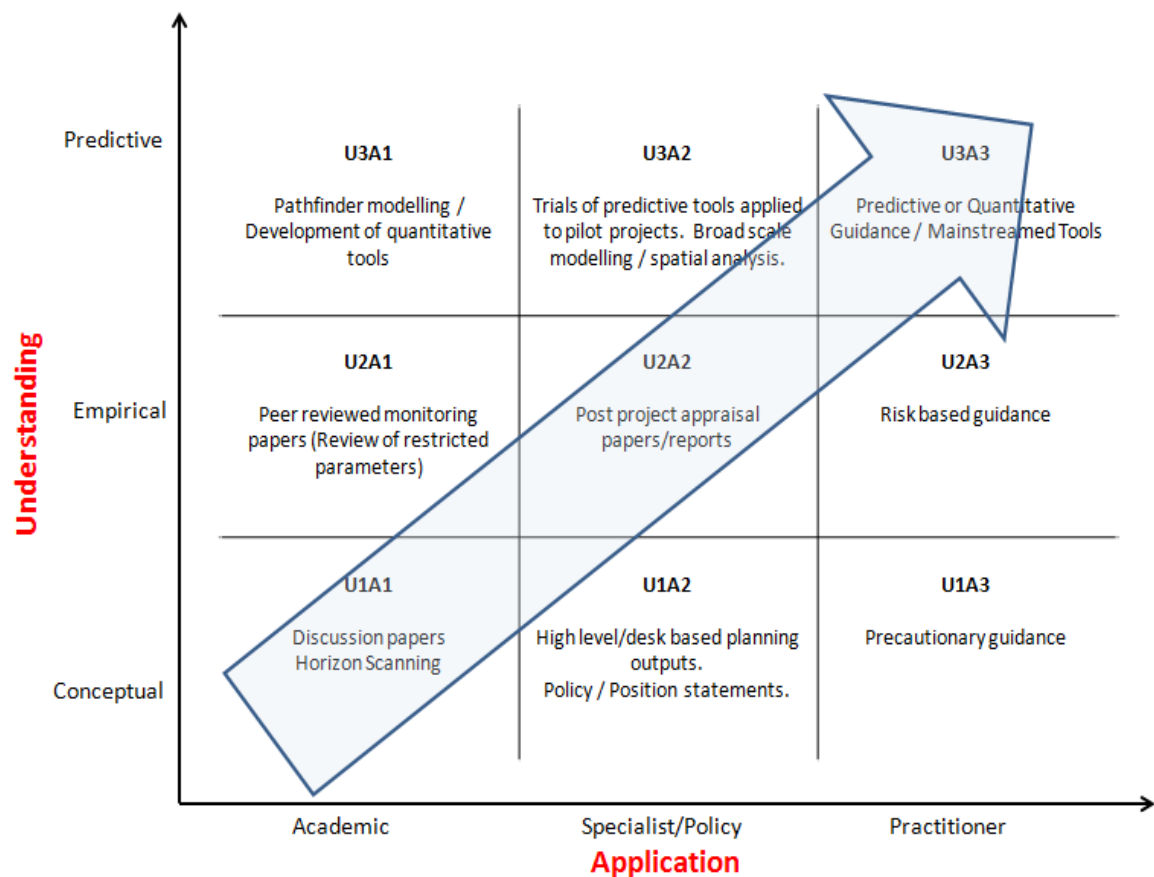


Figure 3.5 R&D spectrum and types of evidence

The following procedure was used to map existing evidence (collected in the DER) onto the R&D spectrum:

1. Each piece of evidence in the DER was **categorised** by:
 - **understanding** – whether research is conceptual, empirical or predictive
 - **application** – whether research is academic, policy/specialist or practitioner.
2. Each piece of evidence in the DER was **cross-referenced** to the research questions in Table 3.1. If considered relevant to the research question(s), the piece of evidence was given one of nine codes (for example, U3A2) based on its understanding and application categories (Figure 3.5).
3. Each piece of evidence was **colour-coded** to indicate how well it could help support the justification (or business case) for WWNP (red = poor, amber = partially, green = good, grey = not yet known),
4. **An R&D spectrum was populated for each of the research questions** (see Appendices A to E). Figure 3.6 shows a hypothetical example of this. The size of each pie chart represents the number of pieces of evidence relevant to the question, and the colours and location on the spectrum as per the steps above.

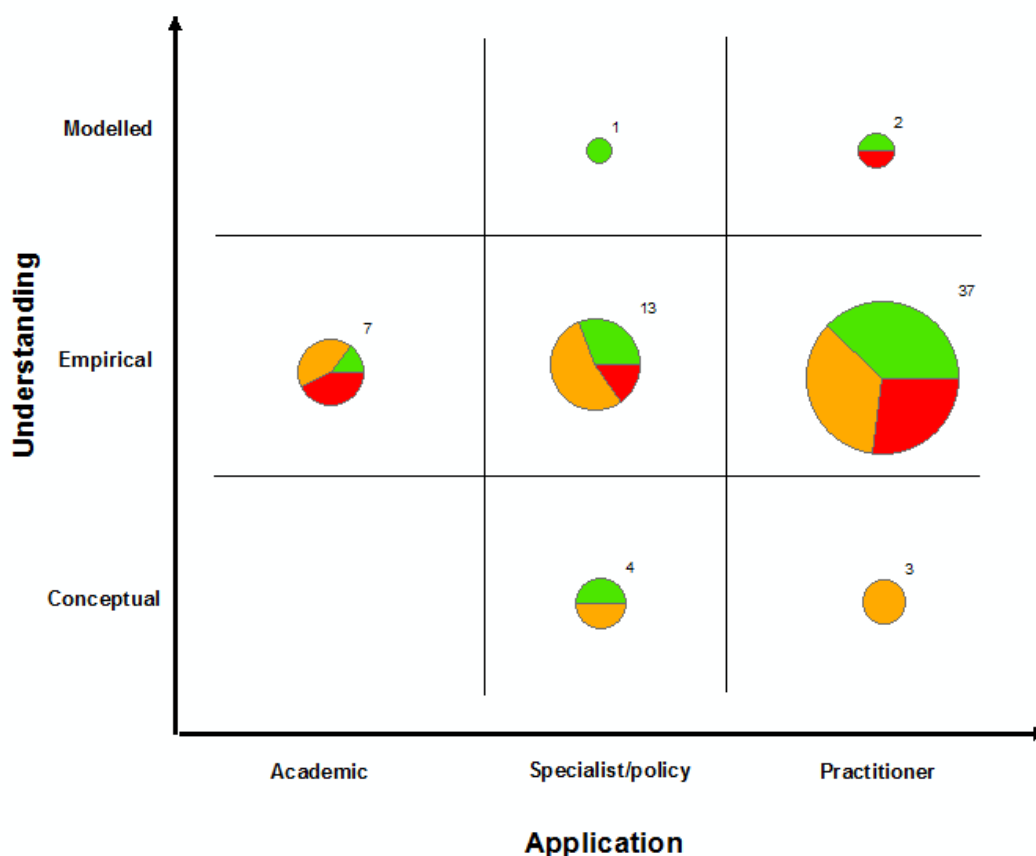


Figure 3.6 Example of a populated R&D spectrum

The analysis of the DER, R&D spectrums and stakeholder workshop outcomes identified 41 research gaps. Due to the nature of WWNP, many of these gaps overlapped between the five topics. Appendices A to E present detailed analysis of each of the five topic areas from this stage of the project.

The focus in the data and evidence review was on collecting evidence used in everyday practice including reports, journal articles, guidance and manuals. This included a wide mixture of peer and non-peer reviewed information. Most of these documents were identified by asking practitioners what they used. Such evidence largely populated the ‘specialist/policy’ and ‘practitioner’ columns in the R&D spectrum and reference to ‘academic’ evidence was less frequent. The ‘academic column’ was therefore supplemented by asking the topic leads and peer reviewers to identify relevant published journal papers and research reports that might not have picked up initially. Hence, the R&D spectrums are likely to under-represent the actual amount of academic literature of relevance to WWNP and FCERM. This limitation was considered when defining the research gaps and identifying potential projects later in the project.

4 Research gaps

4.1 Summarising WWNP research gaps

A total of 41 topic-specific research gaps were identified from the data and evidence review and the WWNP workshop. These were reduced to eight broader research gaps (Figure 4.1). For example, all research gaps that showed a need to review or monitor pilot projects or case studies across the five topic areas (ecosystem services, fluvial and coastal geomorphology, green engineering, habitat and species management and natural flood management) were grouped together. Appendix G shows how the eight WWNP research gaps were identified from the original 41 research gaps.



Figure 4.1 Summary of research gaps at end of Stage 1

The sections below describe the research gaps as stated at the end of Stage 1 of the project. They were used further during Stage 2 to help prioritise R&D projects (see Section 5).

4.2 Research gap 1 – understanding approaches to community and stakeholder engagement

This research gap explored the need to review different approaches to community and stakeholder engagement methods to put in place WWNP in FCERM, including:

- how to involve communities and stakeholders earlier in options identification and appraisal
- how to use the ecosystem approach in community and stakeholder engagement

- what methods such as visual aids, software, group exercises and learning tools are available to use when communicating and collecting information about WWNP
- how to encourage others to take on lead consultation roles
- what information could be co-produced with communities and stakeholders through information exchange to help make more informed decisions
- how to encourage those implementing and delivering WWNP with incentives (for example payment for ecosystem services, biodiversity or carbon off-setting, compensation)
- setting out a standard range of approaches to use depending on available resources or funding

This will help to:

- identify the potential to use WWNP earlier in FCERM options identification
- appraise multiple benefits of options against more legislative and policy drivers (not just flood risk)
- enable two-way communication which informs and educates everyone involved
- maximise the potential for innovative funding, delivery and maintenance of FCERM (for example, by payment for ecosystem services or partnership contributions)
- demonstrate the multiple benefits of WWNP to potential funders, policy and decision makers
- enable greater acceptance and use of WWNP at a local scale
- encourage communities to help with implementation and after care
- communicate clearly to communities and stakeholders how WWNP will help them and that they can help with it

4.3 Research gap 2 – understanding cultural and institutional barriers to WWNP in flood risk management authorities

This research gap is about identifying cultural or institutional barriers, within and between different agencies, which restrict the use of WWNP in flood risk management and possible ways to remedy this so that WWNP becomes more mainstream. There is a consensus that the barriers exist but the processes leading to those barriers, why they occur and how to break them down are not clear.

Practitioners felt that WWNP is rarely considered in FCERM options appraisal and that this is a barrier to delivering more sustainable solutions in FCERM. This may be because there is a lack of evidence of demonstrable benefits.

The WWNP stakeholder workshop identified the need to:

- establish if and why FCERM options appraisal tends to identify a limited set of options which frequently exclude WWNP

- identify why local stakeholders and communities are not engaged earlier in the options identification process
- explore how to break down barriers that prevent institutional co-operation
- establish why decisions about WWNP usually fail to consider non-market values and are primarily based on market-based economic values
- identify what holds back full consideration of WWNP techniques in FCERM
- demonstrate the multiple benefits of WWNP to decision makers

4.4 Research gap 3 – guidance and/or training in WWNP for practitioners

There is a need to provide clear and concise guidance to practitioners to enable them to undertake WWNP with confidence. This is not always a research gap but can be a signposting exercise to make practitioners aware of existing guidance. In other cases, practitioners know evidence exists but need guidance to help them implement it, or to turn conceptual understanding or empirical data into something more useable in practice.

Guidance is needed that:

- indicates where to find evidence of changes in ecosystem services associated with WWNP
- directs practitioners to proven tools and models to assess the impacts of natural flood management at a range of spatial scales
- specifies the scales at which evidence should be used, which may be differentiated by geography, ecology and hydrology
- provides advisory scenarios for ecosystem services to help manage uncertainty
- identifies when new data collection is likely to be needed
- keeps in touch with other developments, research and networks
- identifies what level of proof constitutes ‘reasonable certainty’ when making assumptions about the benefits of WWNP techniques in FCERM
- advises how to demonstrate the wider environmental benefits and cost-effectiveness of WWNP

4.5 Research gap 4 – learning lessons from pilot projects and case studies

The WWNP workshop attendees identified a need to revisit past pilot projects and case studies to understand what benefits had been achieved and the lessons learnt. They also felt such research should be regularly updated. Part of this need may be met by ongoing long-term monitoring projects, especially those producing over five years of data to capture more variability. Specific research requirements included:

- models or tools to show long-term morphological change in estuary and coastal environments – this gap is partly being studied through CoaEST and iCOAST research programmes
- evidence for the long-term effects of sediment dynamics and their effect on FCERM maintenance regimes
- learning what benefits WWNP can provide for FCERM in different types and sizes of catchments over different timeframes
- evidence of how using WWNP can help to meet multiple policy objectives
- improving understanding of natural ways of managing sediment and vegetation to benefit FCERM, for example, using riparian shading to reduce weed growth
- identifying the stakeholder and community engagement methods which have worked best, linking to research gap 1

4.6 Research gap 5 – new studies to improve the WWNP evidence base

Revisiting previous projects and case studies alone was not seen as sufficient to fill all research needs. There is a need for the following new scientific studies:

- scientific evidence to show how the types of ecosystem services affected vary between different WWNP measures
- additional evidence for ecosystem services where there is a lack of understanding on how they might be changed by different WWNP techniques, focusing on those services that contribute most to economic appraisal by influencing the cost-effectiveness of different options
- identification and quantification of the benefits of habitat creation – essential to support future WWNP guidance and business case development
- assessment of benefits to FCERM of sediment management along coasts and estuaries by, for example, beach nourishment, dune management or saltmarsh creation
- quantification of how land use affects ecosystem services, sediment management and FCERM
- better understanding of the long-term effect of different WWNP and traditional FCERM approaches on sediment supply and dynamics
- assessment of how FCERM activities might best benefit fish passage and habitats
- additional evidence for the benefits to FCERM of WWNP techniques such as use of woody debris, green engineering or shading
- develop an understanding of the impacts of WWNP on FCERM at the catchment scale

4.7 Research gap 6 – prioritising catchments for WWNP delivery

There is a need to map catchments nationally to identify those that would benefit most from WWNP measures. Working in priority catchments makes it more likely that evidence of the significant benefits of WWNP will be established, especially in terms of flood risk protection, diffuse pollution, sediment management and other ecosystem services. Prioritising catchments helps achieve value for money and to demonstrate to the actual benefits of WWNP to important decision makers. Research needs include:

- catchment profiling in terms of geomorphology and ecology to identify those most sensitive to changes in hydrology and flow, sediment processes, diffuse pollution and land-use change
- identifying where the greatest economic benefits could potentially be made so as to demonstrate the benefits of WWNP to decision makers

4.8 Research gap 7 – experimental integrated studies of WWNP in catchments

The workshop identified the need for test catchments to examine different land management and land uses, and various WWNP techniques to observe changes in natural processes, in particular water flows and sediment processes that could benefit FCERM.

Test catchments should:

- include a range of land management and uses
- include a range of WWNP techniques or measures
- assess the multiple benefits of measures
- observe changes in natural processes during different events
- assess whether, where and by how much WWNP reduces flood risk and if it can reduce FCERM capital costs and maintenance requirements
- provide learning opportunities
- build on existing pilot projects and case studies

4.9 Research gap 8 – developing more adaptive/resilient green engineering technologies

Research needs include:

- a review of existing green engineering techniques
- assessment of the risk and uncertainty of using green engineering in FCERM
- developing green engineering techniques that can adapt or be adapted to uncertainties (for example, climate change/variability) and compare these to grey/ hard engineered alternatives
- comparing the performance of 'grey' and 'green' WWNP measures

- considering how green engineering techniques work in combination and as mitigation for grey engineering
- advice for practitioners on the number and type of WWNP techniques that are equivalent to more traditional measures (in terms of contribution to FCERM)

4.10 Cross-cutting research needs

The following 'cross-cutting' research needs were identified by stakeholders at the workshop. These cut across the initial WWNP topic areas and multiple research gaps. They include developing a better understanding of:

- the range of environmental and socioeconomic benefits that natural coastal systems provide
- the link between hydromorphological processes and habitats and species to support an ecosystem approach to WWNP, particularly in heavily modified catchments
- the potential range of effects that climate change or variability can have on natural processes, thus enabling the development of more adaptive and resilient WWNP approaches

During Stage 2 these three cross-cutting research needs were assessed alongside the eight specific WWNP research gaps to ensure that relevant needs will be addressed by the WWNP research framework or by other ongoing research.

5 Developing WWNP projects

Stage 1 established existing evidence and tools, and the primary research gaps that restrict the uptake and effectiveness of working with natural processes for FCERM. This section describes Stage 2, which involved the production of a shortlist of high priority WWNP R&D projects from which a series of business cases were prepared for developing and seeking funding for future projects (see Section 6). This process was split into two stages:

- Stage 2A – Identifying projects
- Stage 2B – Prioritising and scoring projects

5.1 Stage 2A – Identifying projects

Figure 5.1 sets out the steps followed to identify potential WWNP projects.

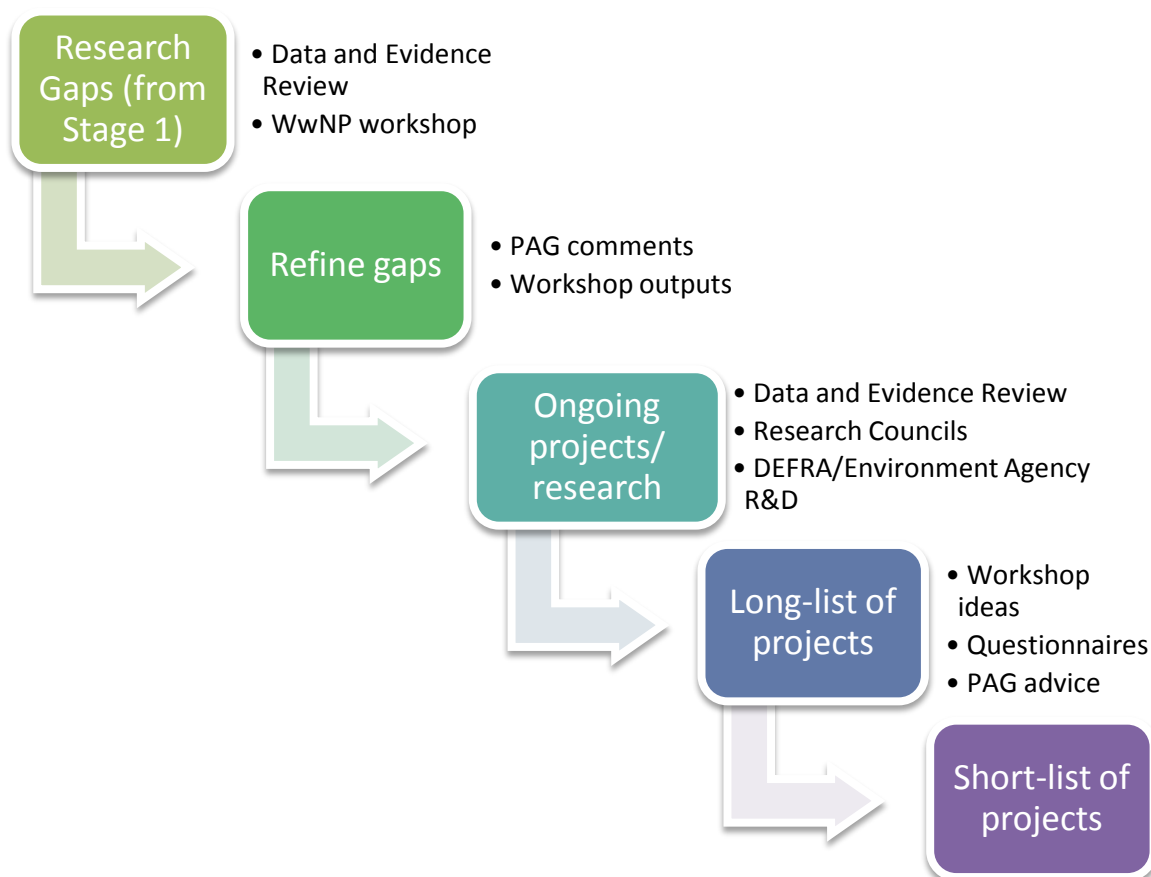


Figure 5.1 Stage 2A – identifying and short-listing projects

The eight initial research gaps listed in Section 4 were refined based on:

- PAG comments and feedback
- further matching with WWNP workshop outputs
- project team discussions including advice from external experts

Research gap 1 (stakeholder engagement), is important for implementing WWNP in the field. However, sufficient guidance and approaches already exist and so this is not a specific priority for this R&D framework.

Research gaps 5 and 7 were combined as they both relate to improving the evidence base from field trialling and monitoring of WWNP measures. It was concluded that these gaps could be addressed by similar types of R&D projects.

The research gaps were then cross-referenced to:

- research already completed and listed in the DER
- research proposed or underway or planned for the near future by research councils – NERC, ESRC and the Engineering and Physical Sciences Research Council (EPSRC)
- research underway or already proposed under other Defra/Environment Agency R&D themes
- other research and projects identified by the PAG

This process reduced the risk of duplicating existing or ongoing R&D (see Appendix H). A total of 23 initial project ideas were identified that fitted in with the remaining research gaps. These projects included:

- ideas that had arisen from the data and evidence review (see Table 3.1)
- project ideas identified at the WWNP workshop and in follow-up discussions
- additional suggestions from the project board, project team, academic and Environment Agency/Defra experts and the PAG

Working with PAG members using a questionnaire,³ the project ideas were developed to include:

- a description of the scope of the project
- links to existing or contributing research
- strategic research objectives or links to research council priorities
- potential funding streams
- which organisations might complete the type of research involved in the project
- timescales and level of resource use
- the priority of each project

The PAG helped decide how to refine, revise or combine projects. Some projects were not thought to be priorities or were not 'R&D', and these were not taken forward. The project shortlist included 17 projects at this point, which were prioritised and scored in Stage 2B. The list of potential projects is given in Appendix I.

³ The questionnaire was sent to PAG members, external reviewers and other selected consultees within the Environment Agency. A total of 43 responses were received.

5.2 Stage 2B – project scoring

In Stage 2B, illustrated in Figure 5.2, each of the 17 projects was matched to research priorities identified by LWEC and the WWNP research gaps, and then scored against five indicators. These indicators are based on those used in the LWEC FCERM research strategy and the CoRDDi research framework.

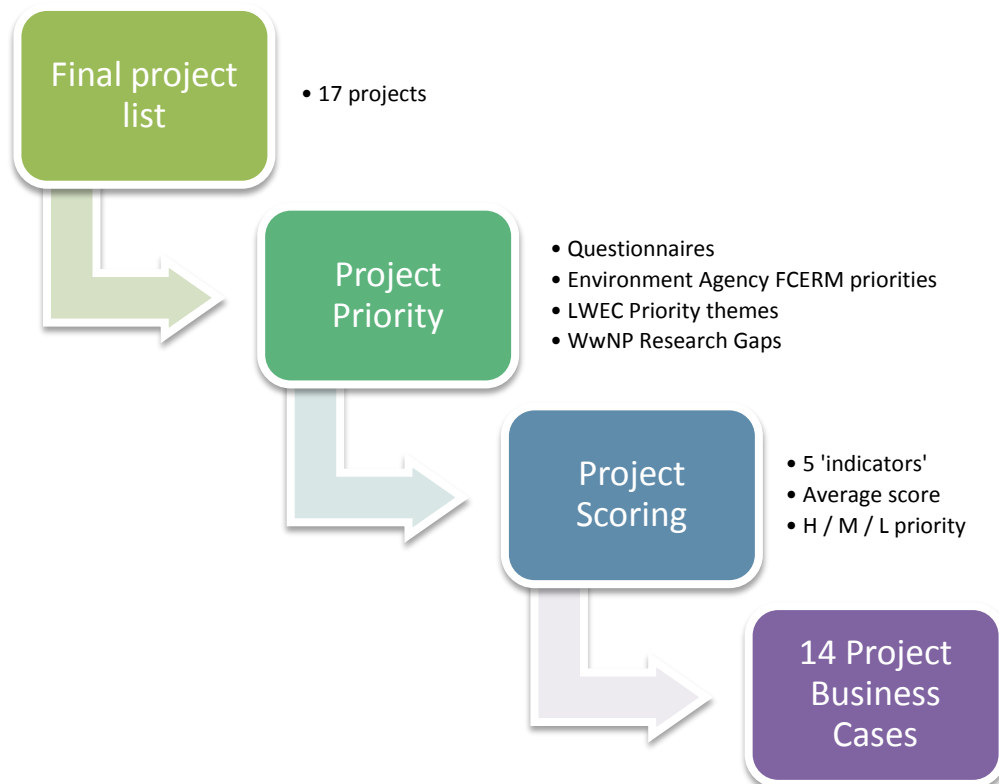


Figure 5.2 Stage 2B – Prioritising and scoring projects

Each project was scored on a scale of 1 to 4 for the indicators shown in Figure 5.3. A four-point score avoids the use of an average on a five-point scale, or creating an artificially wide range of scores by using a ten-point scale. It was agreed in discussion with the PAG that weightings would not be applied to scoring, but that the individual scoring components could be used to further distinguish between projects on individual factors.



Figure 5.3 Stage 2B – Project scoring indicators

The project scores were scored out of 20 and then summarised with an overall importance category of high (16 to 20), medium (11 to 15) or low (less than 11) to provide an indication of their priority. A sub-score indicates those that have links to research council objectives or may attract other external funding.

Short project business cases were written for 14 projects with high or medium overall priority scores, and these are included in Section 6. The list of all potential projects is given in Appendix I.

6 WWNP priority projects

6.1 WWNP framework

The WWNP framework includes four different project types as illustrated in Figure 6.1:

- applied research to improve **knowledge** and scientific understanding about WWNP
- developing and sharing **experience** of using WWNP in practice
- building a ‘toolbox’ of applications, **tools and guidance** to help decision making for WWNP
- changing perceptions that **people** have of WWNP and developing incentives to promote its wider use

All the WWNP R&D projects will need to include communication of their progress and results. They should also link with existing R&D framework projects such as CoRDDi to join up with coastal research activities (see Appendix J). This will ensure the project outputs can be used by a wide audience and provide feedback for other R&D to benefit from the new evidence. Good governance structures (see Section 7) will create opportunities to work with other established groups.

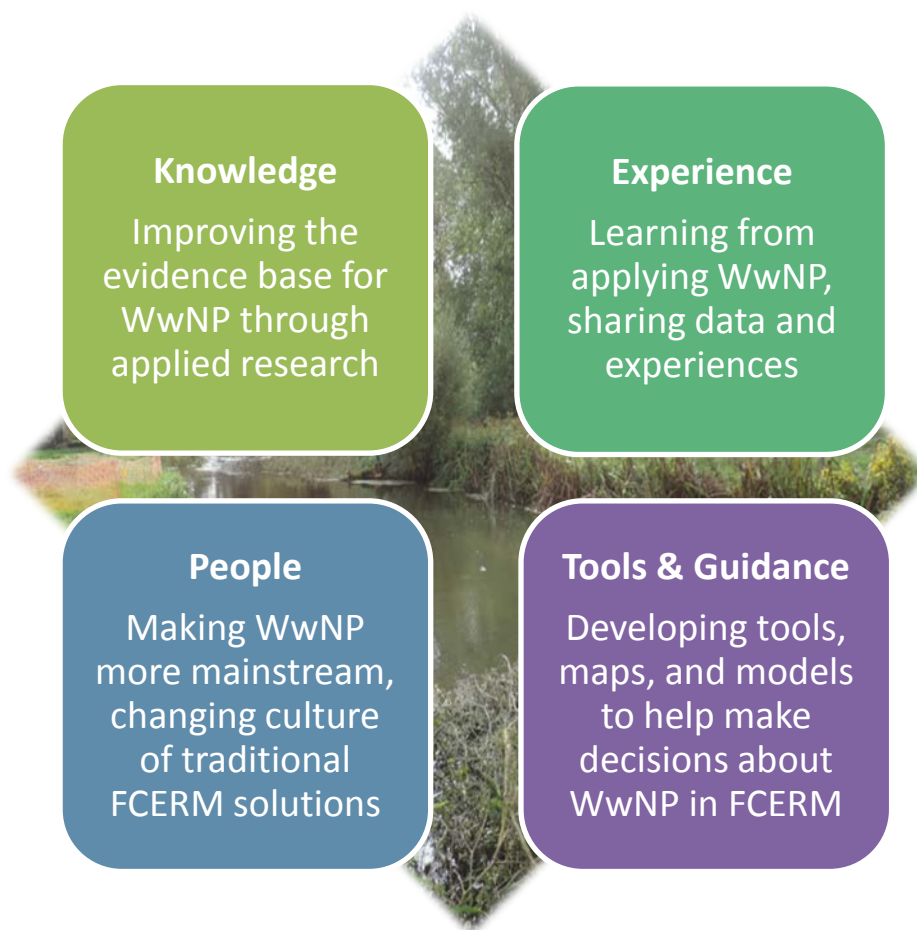






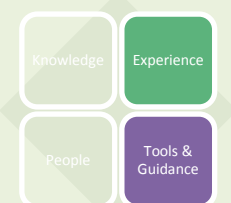
Figure 6.1 WWNP framework

6.2 WWNP projects

The proposed WWNP projects are listed in Table 6.1. This is followed by individual business case summaries which describe:

- the project objectives and how it fits into the WWNP framework
- the WWNP outcomes the project will deliver
- the project's priority (within the shortlist), potential leads, indicative costs and timescales – based on the project scoring, questionnaires and PAG/peer review comments

Table 6.1 WWNP projects ¹

Project title	Priority ²	Project type	LWEC priorities
WWNP catchment laboratories – scoping study	H		<ul style="list-style-type: none"> • Multiple
WWNP catchment laboratories (see sub-projects 1 to 5)	H		<ul style="list-style-type: none"> • Multiple
Catchment laboratories sub-project 1: sediment monitoring and tool development	H		<ul style="list-style-type: none"> • Coastal morphology • Fluvial geomorphology • Sediment management • Catchment land use management
Catchment laboratories sub-project 2: incentivising and communicating WWNP	H		<ul style="list-style-type: none"> • Ecosystem services approach to valuation • Encouraging uptake • Community & individual engagement
Catchment laboratories sub-project 3: hybrid WWNP approaches and 'greening the grey'	H		<ul style="list-style-type: none"> • Effects of climate change on FCERM assets • Natural FCERM measures and 'green design'

Project title	Priority ²	Project type	LWEC priorities
Catchment laboratories sub-project 4: land management trials	H		<ul style="list-style-type: none"> Catchment land use management Vegetation management Sediment management
Catchment laboratories sub-project 5: woody debris tools	H		<ul style="list-style-type: none"> Vegetation management Natural FCERM measures and 'green design'
Mapping priority catchments where WWNP measures provide flood risk benefits	H		<ul style="list-style-type: none"> Multiple
Modelling effects of WWNP measures on flood risk	M/H		<ul style="list-style-type: none"> Understanding of flooding sources and trends in light of environmental change
Developing a 'blue-green engineering rating' and design guide for FCERM	M/H		<ul style="list-style-type: none"> Natural FCERM measures and 'green design' Surface water modelling including SuDS
Attitudes, cultural and scientific barriers to WWNP	M		<ul style="list-style-type: none"> Community and individual engagement
Ecosystem approach for funding opportunities in WWNP	M		<ul style="list-style-type: none"> Ecosystem services approach to valuation Encouraging uptake Community & individual engagement

Project title	Priority ²	Project type	LWEC priorities
Developing operational guidance to deliver FCERM using WWNP	M		<ul style="list-style-type: none"> Natural FCERM measures and 'green design' Adaptation of existing assets to climate change
Joining up delivery of Water Framework Directive and Floods Directive	M		<ul style="list-style-type: none"> Encouraging uptake Biodiversity management
Costs and benefits of fish and eel screening measures at FCERM structures	M		<ul style="list-style-type: none"> Fish and FCERM Biodiversity management

Notes: ¹ See business cases for details of individual projects.
² H = high; M = medium

6.3 WWNP catchment laboratories

There is much enthusiasm for the idea, identified at the WWNP workshop, to trial, test and monitor the effects of WWNP measures (Figure 1.3) in a series of catchment laboratories. This is one of the highest priority projects because it is vital to demonstrate with numerical evidence and experience which WWNP measures work in different environments. The laboratories will also provide opportunities to:

- answer specific research questions
- demonstrate collaborative and partnership working
- explore issues of implementation and funding for WWNP techniques

The catchment laboratories project covers the four project types shown in Figure 6.1. These are envisaged to be programme-based projects that link the individual elements of R&D together. Maximum benefit will be gained by undertaking these projects within a fully collaborative research network that looks at a number of WWNP measures and R&D needs together. If this is not possible and as a fall-back, the projects have been outlined in a way that would enable them to be pursued as individual projects. The flood events of winter 2013 to 2014 (see section 1.5) have highlighted the potential importance of adding WWNP to the range of alternatives available for the management of river and coastal flooding and erosion.

The catchment laboratories project will:

- make use of various existing catchment pilot/test sites where possible to build on existing data and for 'control' purposes
- have a 'track record' of flood risk to people, property or other assets

- be collaborative and involve a range of stakeholders, implementers and funders
- explore the multiple benefits of WWNP measures
- include a range of different land uses and water body types (modified and unmodified, upland and lowland, rural and urban, river and coastal) in different catchment sizes
- run over a number of years, appreciating that evidence will improve with time and be dictated by the range of climatic and rainfall events experienced during the investigation timescales
- be suitable for a range of different WWNP measures to address flood risk and so link 'natural flood management' approaches with more 'engineered' approaches
- include long-term monitoring to develop evidence of performance and allow adaptive management

The project will examine how WWNP measures can reduce flood risk in different contexts and at different spatial scales, and how they can reduce FCERM capital and maintenance costs.

The realistic number of catchments needed will be determined during the scoping stage and confirmed by funding availability. This should be a minimum of three, but preferably five or more.

The project will provide evidence that is transferable to a wide range of catchments and contexts, and produce a series of decision and communication tools that can be applied and used by the Environment Agency, Internal Drainage Boards (IDBs), Natural Resources Wales, Lead Local Flood Authorities (LLFAs), rivers and wildlife trusts, non-governmental organisations and local groups. The research will aim to:

- improve community interest and input to FCERM
- identify practical funding mechanisms
- learn from different WWNP techniques and their effectiveness
- report back the findings to the wider communities involved
- produce new scientific evidence to support the benefits of working with natural processes

Five priority subject areas were identified for study (Figure 6.2) and these are discussed in separate business cases. To improve integrated understanding, there would be a greater benefit from mixing the topics within a range of suitable catchments, but each could form an individual project if restricted by funding opportunities. The subject areas are:

- sediment monitoring and tool development for flood risk management
- visualising and incentivising WWNP
- hybrid WWNP approaches – combining grey and green engineering, or 'greening the grey'
- land use management including floodplain woodland trials and upland grip-blocking – this may build on existing research including the Defra multi-objective pilots (see section 1.3)

- woody debris (effects on flood risk and habitat) tools, including vegetation management

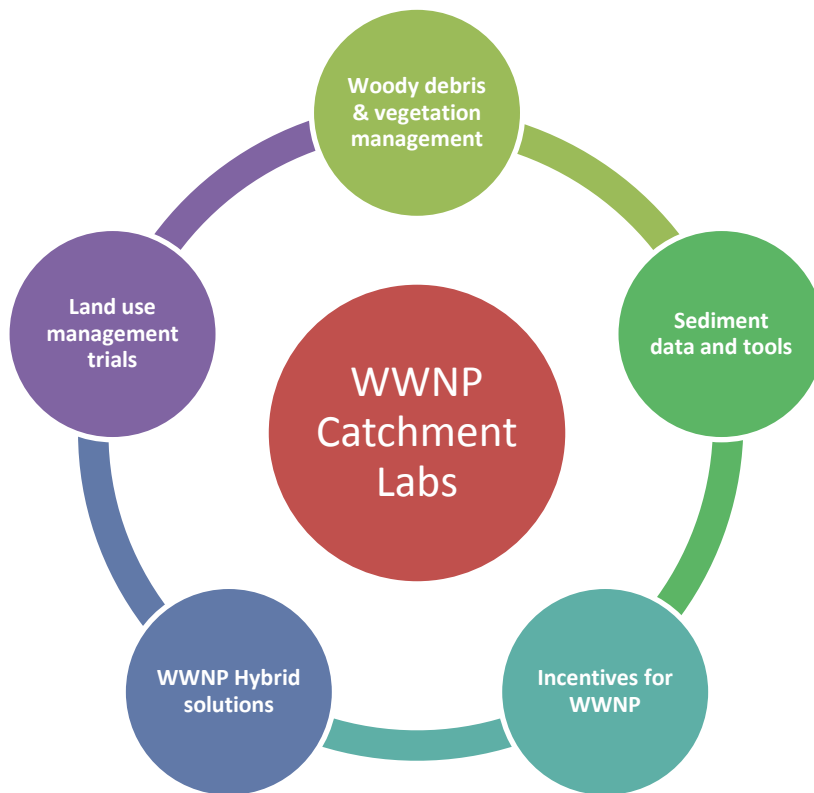



Figure 6.2 Catchment Laboratories sub-projects

An initial scoping stage will confirm the technical objectives for the catchment laboratories and identify suitable locations, partnerships, timescales and funding. This will be followed by establishing a number of catchment laboratories, which might be based in existing pilot catchments or include new sites. These will look at WWNP measures in combination and undertake the specific research projects.

The business case summaries for the catchment laboratories scoping study and sub-projects are presented in Tables 6.2 to 6.7.

Table 6.2 Project business case for WWNP catchment laboratories – scoping study

<p>WWNP catchment laboratories – scoping study</p>	
<p>This project will scope out the full experiments for the project in terms of the technical details. It will also identify how many laboratories are needed and potential locations.</p> <p>The project will need to look at how the catchment laboratories can build on data already collected rather than risk duplicating other scoping studies and databases. To do this, the scoping project will collect and collate information about existing UK catchment studies involving WWNP (see links below for existing studies). The project will bring together stakeholders involved in previous or ongoing catchment pilots to draw on their knowledge and encourage their involvement. Evidence of what has worked well or not so well will be summarised for all the existing catchment studies, focusing on natural flood management and other WWNP measures. It could also include scope for new, innovative and creative ideas that have not been tried out in the past.</p> <p>Possible catchments will be classified based on whether they already provide data on WWNP for flood risk, and if they could be tailored to do so. The catchments will need to cover the range of terrain, climate and land use combinations that are ‘typical’ of England and Wales. The project will select the catchments for the catchment laboratories and confirm the priorities to be studied within each. As far as possible existing study catchments will be used but, if needed, new ones will be identified.</p>	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Summarise factual information for all existing WWNP catchment pilot sites – those from the Flood Risk Management Research Consortium (FRMRC), Defra Demonstration Test Catchments, academic research catchments, Scottish NFM pilots and others, potentially including catchment-based approach WFD catchments, Natural Resource Management catchments in Wales and Ouse Burne blue-green city catchment. • Provide a summary (possibly map-based) of existing evidence in useable format for end users. • Identify gaps in the knowledge base, for example, multi-scale research and understanding, where new data and understanding are required. • Consider the willingness of stakeholders to host a catchment laboratory and the potential for flood risk authorities to link with them for long-term monitoring. • Identify the existing or new catchments to be used for specific catchment laboratory projects. • Develop detailed, peer-reviewed specifications for catchment laboratory tests/ experiments that will improve the future evidence base for WWNP. 	
<p>Links with existing or ongoing research projects</p> <ul style="list-style-type: none"> • Belford catchment studies by Newcastle University • CIRIA 2013 report Land use management effects on flood flows and sediments – 	

[guidance on prediction](#)

- CREW [natural flood management database](#)
- Defra [Multi-Objective Pilots \(PDF, 174 KB\)](#) and [Demonstration Test Catchments](#)
- Defra (Tender reference LM0308) [Developing more effective models for managing water from the local to national scale from a risk and pollution perspective \(PDF, 579 KB\)](#)
- European Union [Natural Water Retention Measures network and map database](#)
- [FRMRC outputs](#) – including studies on the Hodder and Pontbren catchments
- Potential Defra/Environment Agency Local Flood Risk project: ‘Demonstration urban and rural SUDS catchments’

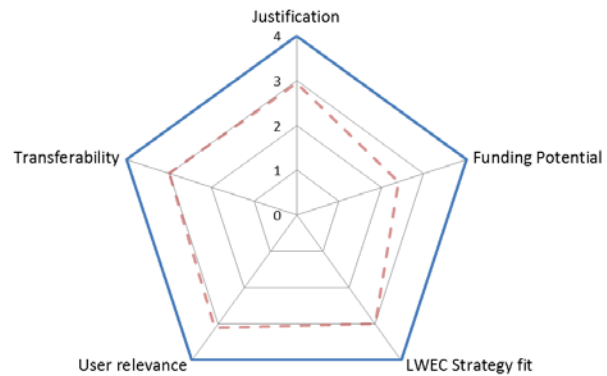
Project priority score: 20/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 4/4

Potential contributors/ funders:


- Defra/ Environment Agency
- EPSRC
- Forestry Commission
- National Trust
- Natural Resources Wales/ Welsh Government
- NERC



Indicative cost: £ (L) <100,000

Indicative project length: 1 year

Table 6.3 Project business case for WWNP catchment laboratories – sediment monitoring and tool development

<p>WWNP Catchment laboratories sub-project 1: Sediment monitoring and tool development for flood risk</p>	
<p>Sediment modelling and tool development were considered a priority by many attendees at the WWNP workshop in 2013. They identified a concern that previous research and the tools developed were not always fully applicable or useable. Practitioners need to be able to apply them in given timescales to help them quantify effects on flood risk, such as what techniques of sediment management will work best. In particular, and linked to other project objectives, there is a need to investigate:</p> <ul style="list-style-type: none"> • how land use management and other WWNP measures affect sediment supply • how this can be managed at source • how sources and sinks operate through the catchment • how perceived needs for sediment management (including dredging) can be reduced 	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Investigate the feasibility of setting up sediment, erosion and morphological change monitoring networks to fill existing data gaps (scales of data collection, technical feasibility, equipment requirements, benefits and costs, priorities for fine/ coarse sediment issues). This should consider situations for coarse and fine sediments, natural and modified water bodies. • Consider which aspects of contemporary sediment dynamics in the UK are unpredictable and problematic enough to warrant investment in monitoring, and identify a proportionate approach that covers fluvial, estuarine and marine situations. • Develop and test a practitioner toolbox to look at catchment sediment management, building on FRMRC and other existing models and tools. • Focus on 'bottom-up', observation-driven and hybrid models and methods that account for hydrology, sediment and vegetation. • Produce tools that are cost-effective, can be applied to real life decision making situations, are transferable and are in proportion to the scale of risks. • Identify broader links (for example, sediment pressures within WFD and diffuse pollution and water quality) to increase the potential for multiple benefits. 	
<p>Links with existing or ongoing research projects</p> <ul style="list-style-type: none"> • CIRIA 2013 report Land use management effects on flood flows and sediments – guidance on prediction • Defra Demonstration Test Catchments • Defra 'Upscaling soil erosion' project – being set up as of May 2014 	

- [Dynamics of Run-off and Erosion Modelling](#) (DRAEM)
- Environment Agency 2011 report [Sediment Matters: A Practical Guide to Sediment and Its Impacts in UK Rivers](#)
- Environment Agency 2011 report [Key Recommendations for Sediment Management – A Synthesis of River Sediments and Habitats \(Phase 2\) \(PDF, 4.7 MB\)](#)
- FRMRC report UR9 [Accounting for Sediments in Rivers \(PDF, 2.9 MB\)](#)
- Potential Defra/Environment Agency Local Flood Risk project: ‘Improving understanding of sediment balances in catchments and how these affect hydraulic capacity of drainage networks and watercourses’
- RRC [Manual of River Restoration Techniques](#)
- Various academic papers – see data and evidence register for more references

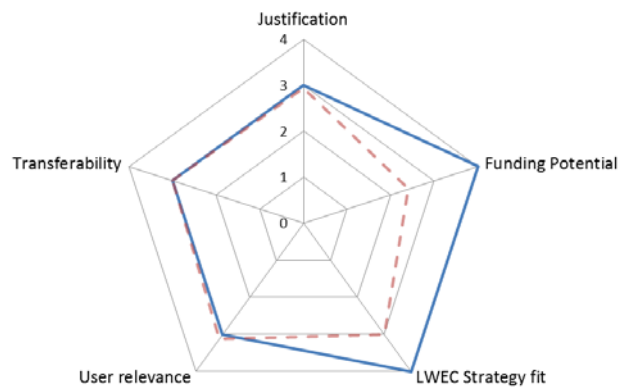
Project priority score: 17/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 4/4

Potential contributors/ funders:


- Defra/ Environment Agency
- EPSRC
- NERC
- National Trust
- Forestry Commission
- Natural Resources Wales/ Welsh Government



Indicative cost: £££ (H) >250,000

Indicative project length: minimum of 5 years

Table 6.4 Project business case: WWNP catchment laboratories – incentivising and communicating WWNP

<p>WWNP catchment laboratories sub-project 2: incentivising and communicating WWNP</p>	
<p>There is a need to help non-experts understand more about what WWNP involves and how it can be used to reduce flood risk and provide other benefits. This could help to encourage people to become involved and help bring about WWNP. The catchment laboratories project provides a good opportunity to do this. There are links to other WWNP projects on ecosystem services and the understanding of cultural barriers. Part of the project focuses on visualisation, communication, knowledge exchange and understanding. Building on this, another part considers whether WWNP can benefit ecosystem services through identifying and exploring the multiple benefits, and potentially generating values and incentives for payments to help WWNP on a local basis.</p>	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Create a range of novel visualisation tools (digitally or physically based) to help decision making and test these within the catchment laboratories. An original idea was proposed at the WWNP workshop (see Appendix F) for a proof-of concept to visually represent and test changes in ecosystem services. This could be built on for specific use in WWNP. • Consider how decision making for WWNP can be progressed through local discussion (bottom–up) approaches. • Identify the potential monetary values of WWNP and how values could be generated from bottom–up approaches linked to consideration of WWNP options. • Link this into the visualisation tool to help local stakeholders understand ‘what’s in it for me’ and ask what they can do to contribute to WWNP. 	
<p>Links with existing or ongoing research projects</p> <ul style="list-style-type: none"> • Belford catchment studies by Newcastle University • CREW NFM local authorities in Scotland project and NFM land manager research • Defra Demonstration Test Catchments • Environment Agency ecosystem service pilots projects – due to report in 2014 • Environmental Virtual Observatory (PDF, 824 KB) (NERC) • Potential Defra/Environment Agency Local Flood Risk projects: ‘Guidance on raising community awareness and educating communities in flood risk management’ and ‘Open data repository and visualisation tool: dissemination of visual information and data’ • SEPA NFM handbook – due to be published in summer 2014 • Welsh Government payment for ecosystem services project – due to report 2014 	

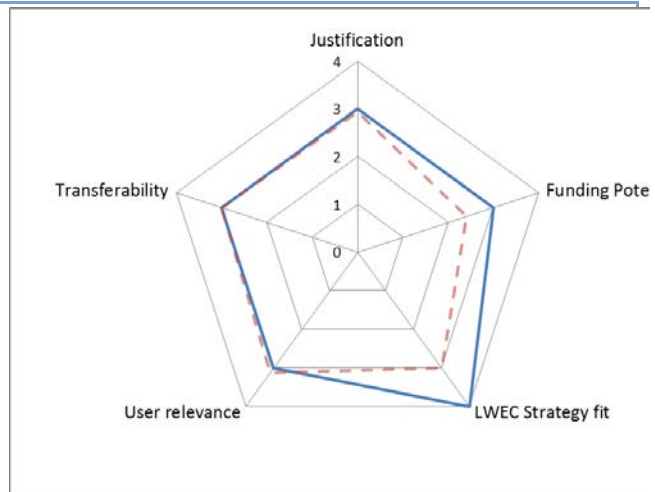
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 3/4

Potential contributors/ funders:

- Defra/ Environment Agency
- NERC
- National Trust
- Natural Resources Wales/ Welsh Government



Indicative cost:

££ (M) 100,000 to 250,000

Indicative project length: 2 years

Table 6.5 Project business case: WWNP catchment laboratories – hybrid WWNP approaches and 'greening the grey'

WWNP catchment laboratories sub-project 3: hybrid WWNP approaches and 'greening the grey'



The project will provide evidence for where WWNP approaches can be used alongside existing hard or 'grey' engineered assets as a reliable and cost-effective alternative to relying entirely on more traditional methods. The focus should be in areas where a particular standard of protection is required, but where there is an opportunity to adapt the solution to mimic or allow more WWNP – ideally in at least two urban or two heavily modified rural locations. It will look at developing approaches to green engineering and green–blue infrastructure that could increase/extend asset life while providing other benefits such as habitat and/or amenity improvements. It will provide evidence via existing data and evidence, new specific catchment laboratory examples, or alternatively integration within new Environment Agency capital FCERM schemes. It should include aspects of maintenance and opportunities to reduce future costs. The project should primarily draw upon FCERM benefits but also contain a strong thread referring to the Water Framework Directive.

Objectives and outcomes for WWNP

- Test examples of using WWNP approaches alongside existing grey engineering assets within catchment laboratories.
- Assess whether green engineering approaches (within the river channel and corridor) and the design of 'green–blue infrastructure' and planning approaches can increase or extend flood defence asset life while providing other benefits such as habitat and amenity improvements.
- Include opportunities to deliver WFD environmental improvements and assess their effect on scheme performance and maintenance, as well as developing a method to demonstrate how these contribute to meeting WFD targets.
- Develop cost estimates to implement hybrid approaches retrospectively in different contexts.
- Catalogue retrofit or new FCERM design options for fluvial, estuarine and coastal situations. This could also be used to contribute to, or update, the separate proposed WWNP blue–green engineering rating and design guide.

Links with existing or ongoing research projects

- CIRIA 2013 report [Quantitative assessment methods for the monitoring and inspection of flood defences: new techniques and recent developments](#)
- [Coastal Structures as Habitats](#)
- EU LIFE Sustainable Urban Waters Integrated Project – programme being set up in 2014
- Joint Programme 2013 report [Asset performance tools – data management \(PDF, 1.41 MB\)](#)
- Outputs of the ongoing three-year [Blue–Green Cities research consortium project](#)

- Potential Defra/Environment Agency Local Flood Risk projects: ‘Evidence assessment for SUDS – maintenance and renewal costs’ and ‘SUDS and run-off performance’ Current Environment Agency project on prioritising flood storage areas for biodiversity gains

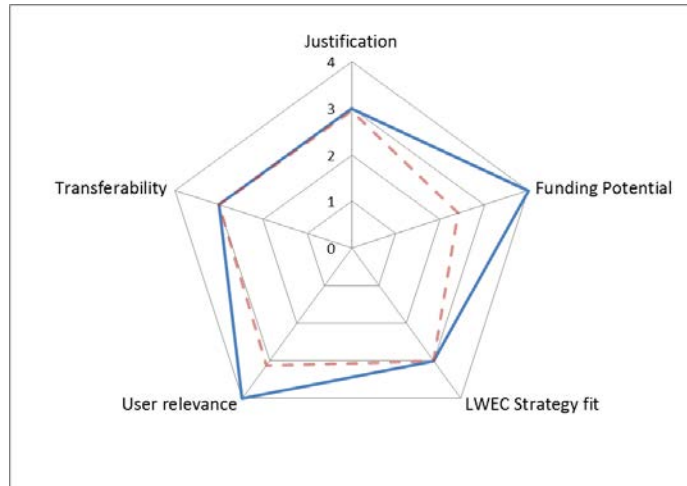
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 4/4

Potential contributors/ funders:

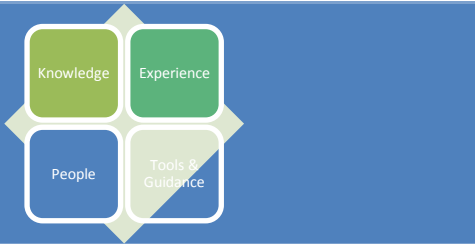
- Defra/ Environment Agency
- EPSRC
- NERC
- National Trust
- Forestry Commission
- Natural Resources Wales / Welsh Government



Indicative cost:
£££ (H) >250,000

Indicative project length: 3 to 5 years

Table 6.6 Project business case: WWNP catchment laboratories – land use management trials

<p>WWNP catchment laboratories sub-project 4: land use management trials</p>	
<p>Previous studies within the Defra multi-objective pilots have demonstrated some evidence for land management effects on flood risk, including woodland trials at Pickering, upland land management in the Upper Derwent, and farm scale management at Holnicote, and in other locations and catchments such as Belford, Pontbren and the Hodder.</p> <p>Providing opportunities to extend ongoing research and data gathered in these locations could compliment other parts of the WWNP framework. This would allow larger/multiple scale, longer term or alternative WWNP and NFM techniques to be considered together. While some focus has been given to techniques like upland grip-blocking, lowland land management options should also be considered. Floodplain woodland trials in particular have been identified as a high priority gap by the Forestry Commission. These will seek to address evidence gaps identified in the recent 2013 Forest Research ‘Woodlands for Water’ report and current woodland opportunity mapping projects.</p> <p>This work will also need to be linked with agri-environment schemes to consider how land management changes can be better integrated into farm business plans to encourage uptake.</p>	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Focus on WWNP measures that are most directly related to flood risk reduction but also provide opportunities for multiple benefits including water quality and ecological improvements. • Evaluate the effects of upland land management including grip-blocking and bog re-wetting on hydrology and sediments, flood alleviation and diffuse pollution control. • Evaluate the effect of woodland design and management factors on the efficacy of woodland measures for flood alleviation and diffuse pollution control. • Extend previous measurements/ monitoring and use to validate modelling to test the impact of woodland creation on flood management, including floodplain and riparian woodland. Ideally include at least one long-term floodplain woodland planting trial (20 ha or larger and potentially over a 25+ year timescale). • Link with agri-environment (Catchment Sensitive Farming and Stewardship schemes) to join up with broader farm management and business planning. 	
<p>Links with existing or ongoing research projects:</p> <ul style="list-style-type: none"> • CREW natural flood management database • Catchment Hydrology and Sustainable Management (CHASM) project at Newcastle University • Defra multi-objective pilots (PDF, 174 KB) at Pickering, Holnicote and Upper Derwent 	

- Defra [Demonstration Test Catchments](#) (Eden, Wensum, Avon)
- Forestry Commission/ Forest Research 2011 report [Woodland for Water](#)
- [FRMRC outputs](#)
- [Peatland Programme](#) (formerly known as Peatscapes) – North Pennines
- Potential Defra/Environment Agency Local Flood Risk project: ‘Land management and agricultural techniques – their impact on local flood risk’
- [Scottish land use strategy pilots](#)
- United Utilities [SCaMP project – Hodder catchment](#)

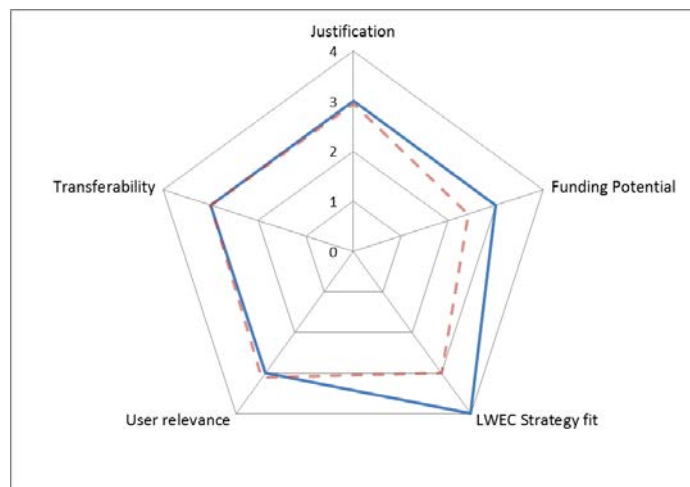
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 4/4

Potential contributors/ funders:


- Defra/ Environment Agency
- NERC
- Natural England
- National Trust
- Forestry Commission
- Natural Resources Wales/ Welsh Government



Indicative cost:
£££ (H) >250,000

Indicative project length: > 5 years

Table 6.7 WWNP Catchment Laboratories – Woody Debris effects and tools – Project business case

<p>WWNP catchment laboratories sub-project 5: woody debris effects and tools</p>	
<p>Attendees at the WWNP workshop in 2013 across many different disciplines raised a need to undertake wider trials across a range of conditions of various woody debris management techniques from natural to engineered so as to generate evidence and produce simple tools. This could be integrated into the catchment laboratory project to test how woody debris can be used with other measures and look at some specific needs for proofs/ demonstrations of the benefits and impacts. The project should begin with a review of the terminology (such as debris, placement, large versus coarse), risks and perceptions related to wood in rivers, as well as a detailed review of existing trial sites in the UK and internationally. There is a wealth of information and literature on the subject, but still a lack of consensus and of ‘demonstration’ to help use wood placement safely and to most benefit.</p>	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Assess the effectiveness of measures designed to trap large woody debris and the use of woody debris to hold back flow on different types of rivers in a series of field trials. • Consider how to use simple and proportionate data to look at modelling the effects of woody debris on water levels, blockage and flood risks, and what evidence is needed in different circumstances for decision making. • Link to existing woody debris trial sites and also ongoing Environment Agency development of conventional hydraulic models for assessment of blockage risks. • Prepare a risk based design guide to enable practitioners to look at the most appropriate methods for using woody debris within WWNP. 	
<p>Links with existing or ongoing research projects</p> <ul style="list-style-type: none"> • CREW natural flood management database • Logjams during floods • New Forest EU LIFE restoration project • Joint Programme research on blockage/debris modelling – planned for 2014 to 2015 • Pickering ‘Slowing the Flow’ multi-objective pilot project • RRC Manual of River Restoration Techniques • Staffordshire Wildlife Trust 2010 report Fish live in trees too (PDF, 4.3 MB) • Trees on the River Uck 	

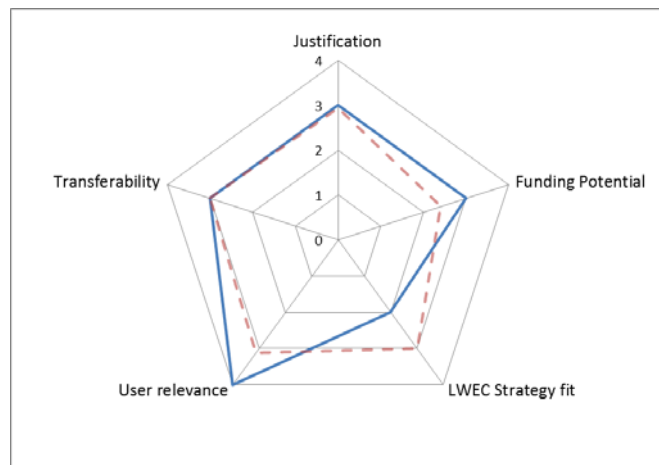
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 3/4

Potential contributors/ funders:

- Defra/ Environment Agency
- NERC/ ESPRC
- Natural England
- National Trust
- Forestry Commission
- Natural Resources Wales/ Welsh Government



Indicative cost:

££ (M) 100,000 to 250,000

Indicative project length: minimum of 3 years

6.4 Mapping priority catchments for WWNP

National mapping of catchments is needed to identify opportunities for WWNP. SEPA has already completed this exercise for Scotland – see the example in Figure 6.3. The Joint Programme is also currently developing woodland creation opportunity maps in partnership with the Forestry Commission, Forest Research and Natural Resources Wales. The business case summary for the project is presented in Table 6.8.

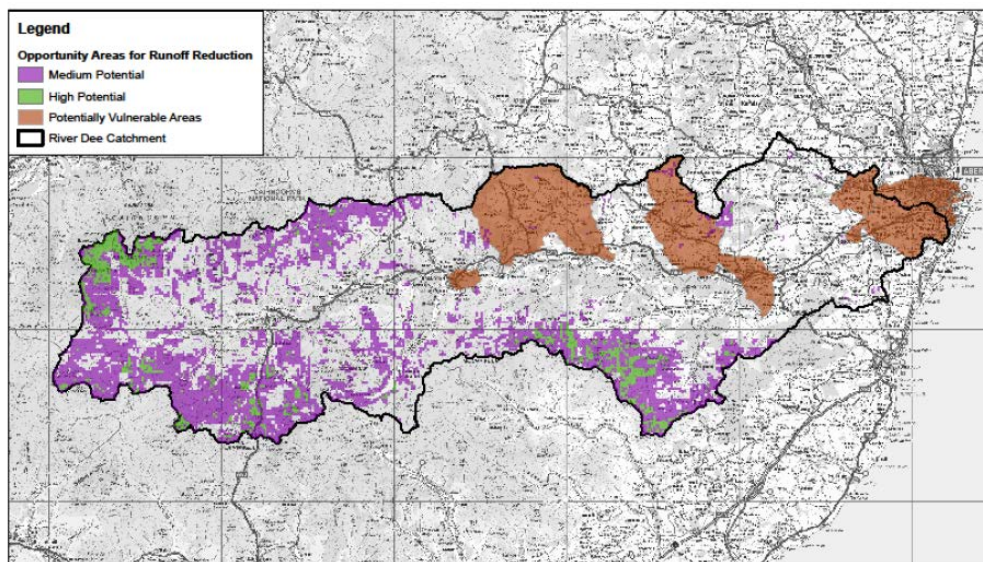



Figure 6.3 Example SEPA NFM opportunity mapping: River Dee catchment

Source: SEPA (2013, Figure 1)

Table 6.8 Project business case: mapping priority catchments where WWNP measures provide flood risk benefits

<p>Mapping priority catchments where WWNP measures provide flood risk benefits</p> 
<p>This project will undertake national mapping within England and Wales to identify river, estuary and coastal catchments where FCERM might benefit most from different types of WWNP measures to help optimise their use. It will also identify catchments where morphology is likely to be most sensitive to sediment dynamics to help target future sediment management.</p> <p>The project will review other national mapping projects and tools to decide if they are suitable for this purpose, or if new methods specific to WWNP are required. The recently completed SEPA NFM opportunity maps form a basis for the project. There should be liaison with SEPA (including end users) while scoping this project to look at what worked well previously or any improvements that could be made. A scoping stage will identify the practicality of the methods and confirm the list of types of WWNP measures that should be mapped, including identifying of consultation with potential end users to understand their requirements.</p> <p>Following this, the project will map the locations in catchments where WWNP could be delivered and identify a prioritised list of catchments to deliver WWNP effectively. This project could help to integrate implementation of Water Framework Directive and Floods Directive requirements.</p>
<p>Objectives and outcomes for WWNP</p> <p>Stage 1: Scoping stage</p> <ul style="list-style-type: none"> • Review relevant national mapping methods and data to decide if existing tools can be used or adopted with new data to assess FCERM benefits of WWNP measures. • Include estuary and coastal cells in the review of mapping methods. • Understand how different WWNP measures can be used to fulfil FCERM requirements at both catchment and more local scales, and list the measures to be included in mapping. <p>Stage 2: Prioritise catchments for assessing the benefits of WWNP measures</p> <ul style="list-style-type: none"> • Develop new or adapt existing tools and models to map locations in catchments based on sensitivity to FCERM activities. • Identify opportunities, constraints and priority locations. • Develop a prioritised list to identify catchments, estuaries and coastal cells that would benefit most from different types of WWNP measures applied at different scales. • Provide a ‘opportunity map’ based on geographical information systems (GIS) for use by stakeholders to implement multi-objective projects which reduce flood risk and improve the environment.

Links with existing or ongoing research projects

- Defra Science and Research project WQO128 [Evidence base of ecological impacts of farm-derived fine sediments](#)
- Defra Science and Research project PE1022 [Modelling water and sediment delivery to watercourses \(PSYCHIC and ASPIRE models\)](#)
- Forest Research [opportunity mapping](#)
- [Land Utilisation & Capability Indicator \(LUCI\)](#) (Polyscape)
- SEPA [natural flood management maps](#)
- [SNIFFER](#)

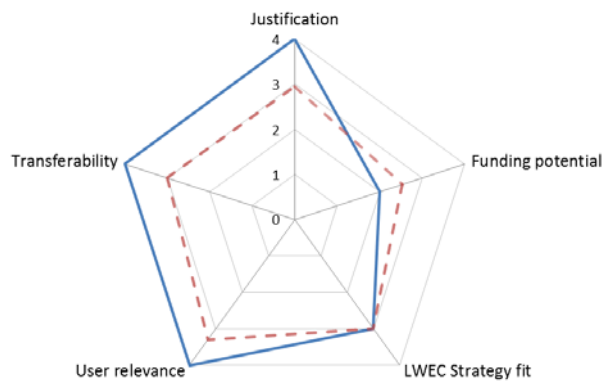
Project priority score: 17/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 1/4

Potential contributors/ funders:

- Defra/ Environment Agency
- LIFE Natural Capital Financing



Indicative cost:

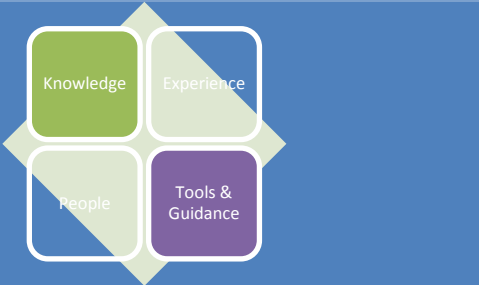
££ (M) 100,000 to 250,000

Indicative total project length: 2 years

6.5 Modelling effects of WWNP measures on flood risk

Recommendations from previous FRMRC studies gave a high priority to continuing the development of modelling approaches that demonstrate the effects of WWNP techniques. This need includes modelling land use and natural flood management options at a variety of spatial scales, particularly for larger catchment sizes. Modelling is necessary to inform decisions in the short and medium term based on the best information currently available. It can be improved in the future with more data and evidence gained through experience of WWNP in practice. The business case summary for the project is presented in Table 6.9.

Table 6.9 Project business case: modelling effects of WWNP measures on flood risk

<p>Modelling effects of WWNP measures on flood risk</p>	
<p>This project will develop a method to simulate and quantify the impact of implementing WWNP techniques, building on the recommendations from the 2013 CIRIA land use management report. From this, the additional contribution from WWNP can be assessed in relation to other FCERM options. While WWNP alone may not be sufficient to prevent flooding in high risk areas, it could be used alongside other traditional engineering approaches to help reduce flood risk. Simulating the effects of WWNP measures will help to provide evidence to justify their use. This needs to be increased in scale upwards from the field to small catchment scale effects for which there is already some evidence. Modelling will allow a degree of ‘what if?’ scenario testing such as investigating the resilience of WWNP measures to climate change.</p> <p>The modelling approach is needed to inform decisions in the short and medium term based on the best information currently available, while further evidence is gathered from catchment trials including the WWNP catchment laboratories project. This should make use of data gathered from existing catchments experiments from across the UK, and could therefore link to the outputs from the catchment laboratory scoping project. Modelling has a role to play in guiding the design of the catchment experiments by simulating the overall integrated effect of a potential portfolio of measures that could be installed on the ground. With the information and technology available at this stage, the model outputs will remain indicative with wide confidence intervals which need to be understood to show uncertainty and allow for this in decision making. The confidence levels can be improved using evidence from the catchment laboratories over time.</p>	
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Review existing modelling tools and studies before developing modelling techniques which can simulate the effect of different WWNP techniques in catchments. • Develop an approach that can be used cost-effectively by those designing flood management schemes for quantitative assessment of WWNP measures in direct comparison with traditional engineering options. This approach would be for use by consultants and FCERM staff. • Use of modelling techniques to assess a wide range of different land management and more online measures such as leaking dams, grip blocking and woody debris dams. Coastal measures should also be considered if not already modelled in more conventional approaches. • Provide visual and numerical evidence to demonstrate if there are flood risk benefits of WWNP for individual catchments and indicate levels of uncertainty to help understand this in decision making and discussions. 	
<p>Links with existing or ongoing research projects</p> <ul style="list-style-type: none"> • Belford catchment studies by Newcastle University • CIRIA 2013 report Land use management effects on flood flows and sediments – 	

[guidance on prediction](#)

- CREW [natural flood management database](#)
- [FRMRC outputs](#)

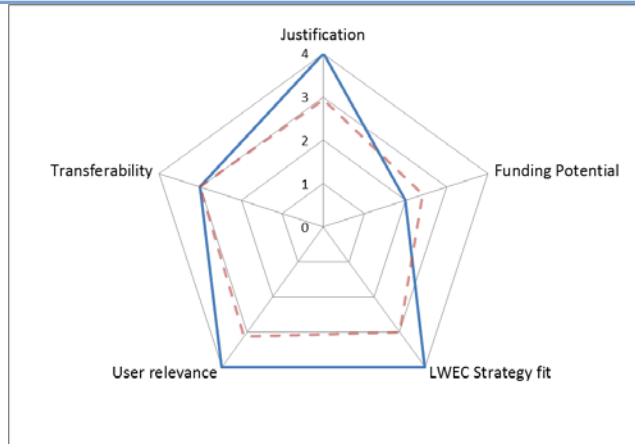
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 2/4

Potential contributors/ funders:

- Defra/ Environment Agency
- NERC
- ESPRC



Indicative cost:

££ (M) 100,000 to 250,000

Indicative project length: 3 years

6.6 Developing a 'blue-green engineering rating' and design guide for FCERM

A priority identified by the WWNP workshop and within FCERM operations teams is the development of a 'design guide' for green engineering using WWNP techniques to help demonstrate alternative approaches to traditional engineering.

'Blue-green' describes infrastructure that works with natural processes in the context of FCERM and is 'green' most of the time, but turns 'blue' when there's a flood. This terminology is gaining momentum and is already well established internationally.

Developing a blue-green engineering rating that could be linked into existing assessments such as BREEAM (Building Research Establishment Environmental Assessment Method) or CEEQUAL (sustainability assessment, rating and awards scheme for civil engineering) would also help to assess the contributions of green engineering to sustainable FCERM schemes more clearly.

The business case summary for the project is presented in Table 6.10.

Table 6.10 Project business case: developing a 'blue-green engineering rating' and design guide for FCERM

Developing a 'blue-green engineering rating' and design guide for FCERM



At present, there is a lack of high quality scientific evidence to promote and foster support for greener engineering (see Table 1.1) or hybrid measures (see Table 6.5) in FCERM. These data are needed to help implement more blue-green engineering solutions on the ground.

Stage 1 of the project will review relevant examples, case studies and guidance to provide evidence on the current application of blue–green engineering in FCERM. This will find out what information is available on standard of service, standard of protection and design life provided by green versus grey engineering techniques implemented over the last 5 to 10 years. This could be linked with the green/grey catchment laboratory project set out in Table 6.5. The project will include consultation to identify good and less good examples of blue–green engineering and to identify the potential for innovation. The more progressed work on SuDS will be applied to blue–green infrastructure and include practical aspects on maintenance, adoption, regulation (including protected species impacts) and effectiveness for FCERM activities.

Stage 2 of the project will develop a blue–green engineering rating for FCERM assets which could be aligned with existing standards such as BREEAM or CEEQUAL.

Objectives and outcomes for WWNP

Stage 1: Case studies and guidance

- Review relevant examples, case studies and existing guidance manuals to draw together evidence for the application of blue–green engineering in FCERM.
- Identify what the most important aspects of ‘performance’ are to help set ‘performance standards’ for blue–green engineering techniques.
- Include a review of costs, lifespan and the pros and cons of blue–green engineering techniques implemented over last 5 to 10 years, both nationally and internationally, utilising examples and case studies.
- Draw out the multiple benefits of blue–green engineering for FCERM such as WFD, carbon savings and biodiversity targets.
- Produce a blue–green engineering design guide (similar to a CIRIA guidance document) to draw together quantitative evidence that supports the application of blue–green engineering in FCERM. The principal target audience would be engineering designers.

Stage 2: Develop blue–green engineering standards/ rating

- Develop a blue–green engineering rating scheme for FCERM assets that could be integrated into BREEAM or CEEQUAL or used as a standalone assessment.

Links with existing or ongoing research projects

- CIRIA [SuDS Manual](#) – and other current SuDS projects
- Environment Agency flood storage area study
- Environment Agency [Fluvial design guide](#)
- [Healthy Catchments](#) – managing water for flood risk and the Water Framework Directive
- Outputs of the ongoing three-year [Blue–Green Cities research consortium project](#)
- Potential Defra/Environment Agency Local Flood Risk projects: ‘Evidence assessment for SUDS – maintenance and renewal costs’ and ‘SUDS and run-off performance’
- [Rivers by design: rethinking development and river restoration \(PDF, 5.9 MB\)](#)
- River Restoration Centre [Manual of river restoration techniques](#)

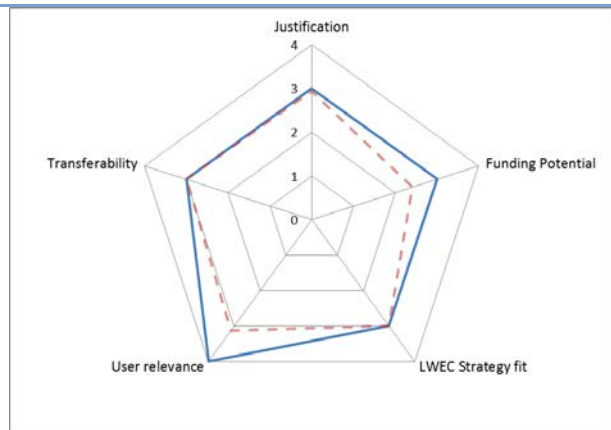
Project priority score: 16/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 3/4

Potential contributors/ funders:

- Defra/ Environment Agency
- BREEAM/ CEEQUAL
- CIRIA



Indicative cost:

££ (M) 100,000 to 250,000

Indicative project length: 2 to 3 years

6.7 Attitudes, cultural and scientific barriers to WWNP

During the WWNP workshop participants identified a perception that natural forms of flood protection are often thought to be less effective or less reliable than harder conventional solutions (see Figure 1.6), forming a cultural barrier to widespread adoption of WWNP measures. This may be linked to the fact that many FCERM staff come from an engineering or land drainage background which may place less confidence in softer WWNP or green engineering solutions.

Wide adoption of a wider range of approaches to FCERM, including WWNP, is likely to involve a degree of cultural change (partially based on a lack of evidence). There is a need to identify cultural or institutional barriers and associated perceptions, such as lack of evidence or demonstration of the benefits of alternatives, and look at how to address these. The business case summary for the project is presented in Table 6.11.

Table 6.11 Project business case: attitudes, cultural and scientific barriers to WWNP

Attitudes, cultural and scientific barriers to WWNP



Traditionally FCERM has focused on delivering single function, engineering solutions to reduce flood risk in the area to be protected by a specific project or scheme. The arrival of new environmental legislation has changed the way FCERM is carried out to ensure schemes provide wider benefits for people and the environment as well as protecting people and property with no detriment to people or property in other areas of the catchment, estuary or coastal cell. Adopting this wider range of approaches to FCERM including WWNP involves a cultural change for many practitioners, as well as acceptance by landowners and the wider public.

This project will examine the attitudes and perceptions held by FCERM stakeholders about WWNP through a market research project. The main aim will be to identify cultural or institutional barriers and associated perceptions that restrict the use of WWNP in FCERM, and identify methods to remedy them.

The project will be informed by recent press (positive and negative) in response to the 2013 to 2014 river and coastal floods, and other previous flood events. It will use stakeholder workshops, interviews and questionnaires to identify the evidence needed to increase uptake of WWNP. The outputs of this project should be used together with the Defra 'Synergies' report to inform institutional change and themes that can be considered further in the development of WWNP catchment laboratories.

Objectives and outcomes for WWNP

- Undertake market research and interviews to establish knowledge of WWNP.
- Identify the range of perceived barriers to support for WWNP approaches.
- Compare commonly held beliefs against current scientific understanding of flood risk and multiple benefits provided by WWNP.
- Assess how beliefs, preferences and perceived risks affect institutional and stakeholder decision making.
- Review and identify what information and incentives are required to positively influence decision making.
- Identify cases studies (using stakeholder experiences) that illustrate and compare the potential pros and cons of WWNP and grey engineering approaches.
- Identify what needs to change and how to enable WWNP to be embedded within FCERM as a credible tool for reducing flood risk.

Links with existing or ongoing research projects

- [Blue-Green Cities](#) work on public perception
- CREW [NFM land manager research](#)
- Defra [Demonstration Test Catchments](#)
- Defra Science and Research project WC0812 [Segmentation study on landowner attitudes to woodland creation](#)
- Defra Science and Research project FD2617 [Economic appraisal of adaption options in flood risk management](#)
- ['Mainstreaming' natural approaches to flood risk management](#)
- Scottish Government 2013 report [Strong and resilient sources and supply chains for water and renewable energy \(PDF, 750 KB\)](#)

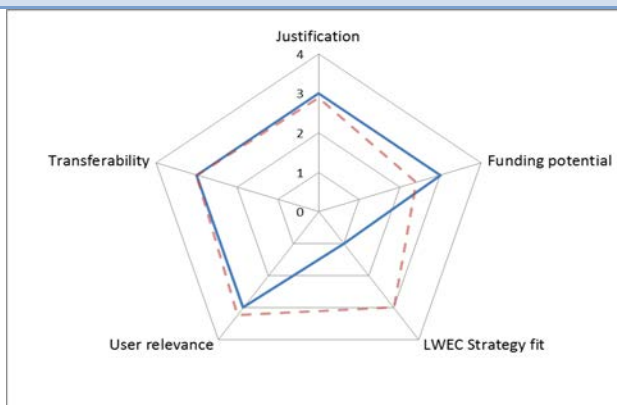
Project priority score: 13/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 3/4

Potential contributors/ funders:

- Defra/ Environment Agency
- ESRC




Indicative cost: £ (L) <100,000

Indicative project length: 1 to 2 years

6.8 Ecosystem approach for funding opportunities in WWNP

Another priority identified during some recent Environment Agency ecosystem services pilot studies was the need for more research into Payments for Ecosystem Services (PES). Even where there is a good appreciation that a scheme may deliver multiple benefits, turning those into financial incentives for the promoting organisation is often a stumbling block. The business case summary for the project is presented in Table 6.12.

Table 6.12 Project business case: ecosystem approach for funding opportunities in WWNP

<div style="display: flex; justify-content: space-between; align-items: center;"> <div style="flex: 1;"> <p>Using the ecosystem approach for co-funding opportunities in WWNP</p> </div> <div style="flex: 1; text-align: center;">  </div> </div>
<p>It is accepted that there is sufficient guidance on how to undertake ecosystem services assessment to help appraise FCERM options. Recent pilots have shown where ecosystem services can inspire options development and stakeholder engagement. In particular, options that focus on delivering multiple benefits, rather than single flood risk reduction, are needed. This is a great opportunity to promote WWNP measures. What is lacking is guidance and examples of how to address uncertainties in the assessment and how to encourage co-funders (through PES or other).</p>
<p>This project should help to revise the approach to developing multi-benefit options to be convincing to both internal Environment Agency and external stakeholders. The project should refine how ecosystem services are explained and communicated, and how stakeholders can be engaged to make, test and agree (scientific and socioeconomic) assumptions. It will be important to link the economic and social benefits that WWNP measures could generate for each stakeholder (for example, local authority/ population, tourism industry, agriculture, forestry) or what ecosystem services these stakeholders can provide that can be counted as part of a WWNP option.</p>
<p>The project should follow completion of Defra’s current broader work on PES (different structures, incentives and penalties for buyers/ sellers and so on) and explore what information is needed within FCERM to be able to participate in PES schemes. It could be linked to the catchment laboratory sub-project on incentivising WWNP.</p>
<p>Objectives and outcomes for WWNP</p> <ul style="list-style-type: none"> • Explore how stakeholder engagement can be used to seek agreement on assumptions – in the face of uncertainty about ecosystem services provision. • Obtain more convincing evidence on the benefits of WWNP for each type of stakeholder to convert potential PES buyers and sellers to actual PES buyers and sellers. • Explore different co-funding arrangements (for example, reference to PES, partnership rather than funding arrangements). • Set up better communication and help different experts to talk to each other. • Create new quantitative and monetary evidence through case studies.
<p>Links with existing or ongoing research projects</p>

- Defra [Payments for ecosystem services \(PES\): best practice guide](#)
- Defra-funded [Catchment Change Network](#)
- Environment Agency ecosystem services pilots – report due in 2014
- Natural Resource Management Catchments (Natural Resources Wales) – future programme
- Potential Defra/Environment Agency Local Flood Risk project: ‘FRM – how can the wider benefits be valued?’
- Potential Defra/Environment Agency CoRDDi projects: ‘Ecosystem service benefits to flood and coastal erosion risk management’ and ‘Valuing ecosystem services
- [Scottish land use strategy pilots](#) .

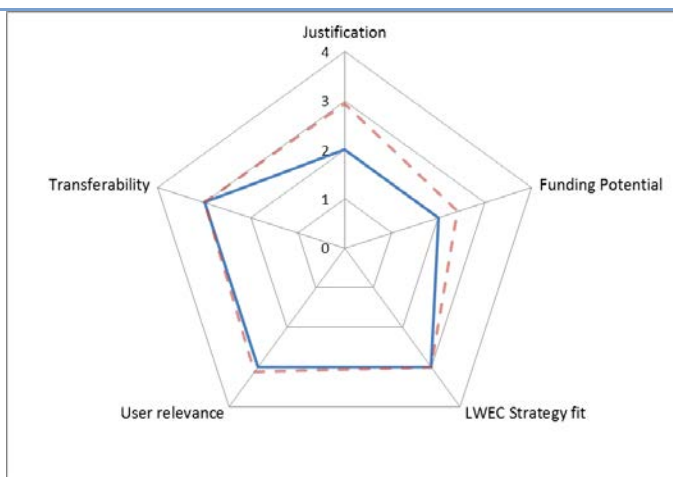
Project priority score: 13/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 2/4

Potential contributors/ funders:

- Defra/ Environment Agency
- ESRC
- NERC (Valuing Nature)



Indicative cost: £ (<100,000)

Indicative project length: 1 year

6.9 Developing operational guidance to deliver FCERM using WWNP

Stakeholders at the WWNP workshop felt that guidance should be a high priority. On consideration the project team decided that more evidence is needed before producing detailed tools and guidance. What is needed is more effective ‘signposting’ to existing information to help people implement WWNP measures before the tools and guidance that may be developed through other projects becomes available. The business case summary for the project is presented in Table 6.13.

Table 6.13 Project business case: developing operational guidance to deliver FCERM using WWNP

Developing operational guidance to deliver FCERM using WWNP

Clear and concise guidance is needed for practitioners to help them deliver FCERM capital programmes and projects using WWNP. The current Environment Agency guidance, ‘Working With Natural Processes to Manage Flood and Coastal Erosion Risk

– A Guidance Document', published in 2010 is a 'living draft' that should be updated with more recent research and evidence. The multi-agency WWNP working group concluded in 2012 that greater use of WWNP would help develop multi-benefit projects and achieve more for FCERM.

This project will provide FCERM practitioners, clients and decision makers with the guidance and supporting tools to bring about more WWNP solutions. Guidance will enable consideration and use of WWNP in the development and implementation of FCERM programmes and projects. It will also provide a clear link for practitioners to understand how WWNP methods, tools and examples link with FCERM planning, appraisal processes (potentially developing the ecosystem approach outlined in Table 6.12) and implementation.

The guidance will be supported by 'how to' resources (possibly web-based) and updated at the end of the WWNP Framework period to capture other WWNP outputs.

Objectives and outcomes for WWNP

- Build on current WWNP guidance – see links to existing and ongoing research.
- Provide a step-by-step analysis of how successful WWNP projects have been based on current FCERM appraisal guidance, identifying how the use of tools, risk management, stakeholder engagement and partnership working has supported project outcomes.
- Recommend how WWNP approaches and techniques can be better incorporated into FCERM planning, appraisal and implementation.
- Define the risks and uncertainties of WWNP and recommend how to manage these.
- Demonstrate how WWNP costs & benefits can be better included in FCERM schemes.

Links with existing or ongoing research projects

- Additional guidance and research in the WWNP Data and Evidence Register
- European Commission proposed [Guidance on natural water retention measures](#)
- [Healthy Catchments](#) – managing water for flood risk and the Water Framework Directive
- River Restoration Centre [Manual of river restoration techniques](#)
- SEPA NFM handbook – due to be published in summer 2014

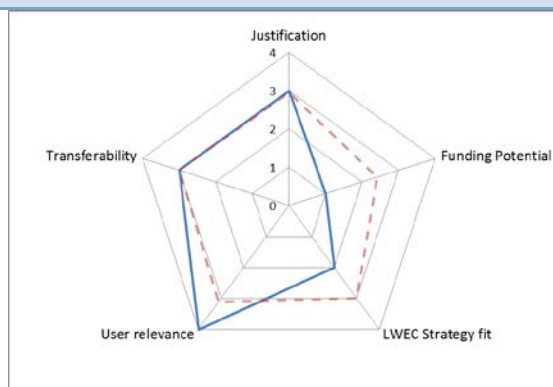
Project priority score: 13/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 1/4

Potential contributors/ funders:

- Defra/ Environment Agency




Indicative cost: £ (L) <100,000

Indicative project length: 1 year (+ 6 months for update after 4 to 5 years)

6.10 Joining up delivery of Water Framework and Floods Directive requirements

There is also a need to develop clearer understanding of the linked up delivery of the requirements of the Water Framework Directive and Floods Directive. This will look at plan-level implementation through the development of tools to help meet WFD targets through flood risk management activities on the ground. Using WWNP techniques as part of FCERM schemes will provide an opportunity to achieve this and to reduce flood risk sustainably. The business case summary for the project is presented in Table 6.14.

Table 6.14 Project business case: joining up delivery of Water Framework Directive and Floods Directive requirements

Joining up delivery of Water Framework Directive and Floods Directive requirements	
<p>The Floods Directive is a sister directive of the Water Framework Directive. It has the same unit of reporting and the same six-year planning timescales. The Floods Directive requires co-ordinated delivery of the directives taking account of WFD objectives in flood risk management plans (FRMPs). Draft river basin management plans (RBMPs) (second round for WFD) and the first round of FRMPs were consulted on in June 2014.</p> <p>There are differences in how the requirements of the Water Framework and Floods Directives will be achieved as the former is entering its second round and the latter is in its first. Under the Floods Directive, the Environment Agency and Natural Resources Wales will produce FRMPs for flooding from en-mained rivers (where they have statutory responsibility for flood risk management), the sea and reservoirs, and LLFAs will prepare FRMPs for identified flood risk areas for flooding from surface water, ordinary watercourses and groundwater.</p> <p>More clarity is needed on integrated delivery of the Water Framework and Floods Directives to comply with the legislation and maximise potential synergies. This applies at plan level and implementation within catchments and flood risk areas. The project will show how to join management across the systems to indicate how, for example, areas identified for additional storage and land use management can reduce flood risk in areas designated for maintaining existing standards of protection in catchment flood management plans (CFMPs).</p> <p>The project will produce guidance on implementing local delivery of the Water Framework and Floods Directives through the next cycle of RBMPs and FRMPs, highlighting the opportunities for WWNP to meet their objectives. The project will map the processes, identify practical examples and highlight the benefits of improved outcomes, cost and time savings. It should seek the views of the Environment Agency, Natural Resources Wales, Welsh Government, Defra, LLFAs, IDBs, Rivers Agency (Ireland), water companies and other important stakeholders. It should also consider wider aspirations for multiple benefits and biodiversity gains to support delivery of Habitats Directive and Biodiversity 2020 targets.</p>	
Objectives and outcomes for WWNP	

- Improve integrated and cost-effective achievement of Water Framework and Floods Directives outcomes.
- Map out the integrated delivery process identifying where, when and how this can

be achieved, including practical examples and benefits of integration at national, river basin and catchment level.

- Identify further integration within future RBMP and FRMP planning cycles.
- Produce guidance for practitioners to use in developing RBMPs and FRMPs, and then in implementing these plans using WWNP where appropriate.

Links with existing or ongoing research projects

- CREW project: [Assessing potential soil and water quality options for SRDP](#)
- Defra/Environment Agency/Welsh Government/Natural Resources Wales 2013 report: [Summary report of consultation on: the approach to flood risk management plans in England and Wales \(PDF, 1.27 MB\)](#)
- Defra '[Synergies](#)' Report 2013 (PDF, 1.93 MB)
- Defra/Environment Agency/Welsh Government/Natural Resources Wales 2013 report: [Flood risk management plans – an overview for risk management authorities \(PDF, 186 KB\)](#)
- European Commission proposed [Guidance on natural water retention measures](#)
- Scottish Government guidance – due for publication summer 2014

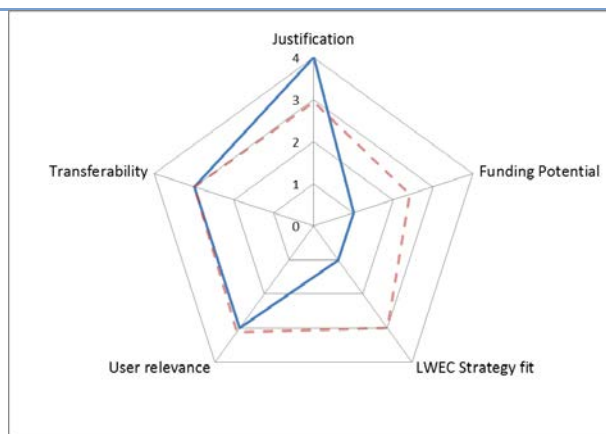
Project priority score: 12/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 1/4

Potential contributors/ funders:

- Defra/ Environment Agency



Indicative cost: £ (L) <100,000

Indicative project length: 1 year

6.11 Costs and benefits of fish and eel screening measures at FCERM structures

Legislation requires that existing FCERM structures and new structures that may be part of WWNP, such as flood storage areas, must include measures to protect eels. Earlier legislation already requires the protection of other fish.

Fish and eel screens have the potential to increase flood risk locally if they are not well maintained or designed. Guidance is required to improve understanding of the risks and cost-effectiveness of different types of eel and fish screening methods, and their effects on FCERM assets and maintenance.

Table 6.15 Project business case: costs and benefits of fish and eel screening measures at FCERM structures

Costs and benefits of fish and eel screening measures at FCERM structures



The Eels (England and Wales) Regulations 2009 require existing and new intakes, outfalls and pumping stations to install measures for the protection of eels. Existing intakes should be compliant by the beginning of 2015 or have gained an exemption to allow further investigation and design. Additional legislation (for example, SAFFA 1975) requires the protection of other fish. Consideration is also required for potential upcoming fisheries protection legislation and ensuring that measures are future proofed.

Physical screens can require the use of a fine mesh. If these are not kept clear, their operation may be jeopardised resulting in potential flood risks as well as health and safety risks for operatives. Selecting the most appropriate screening involves these considerations in addition to providing the required protection for eels and fish. The Defra cost–benefit analysis model for the eel regulations can also be applied to different technologies and solutions, for example, to sites to provide an indication of their relative grading of appropriateness.

The project will carry out a literature review of existing scientific and grey literature within the UK and overseas (Europe provides similar case studies to the UK, and the US and Australia have a wealth of studies and research organisations dedicated to this topic). This will consider available technologies, their effectiveness (including cost-effectiveness), and crucially, their operational experience. The focus will be on the problems encountered and how they have been overcome, effectiveness, health and safety, and cost benefits. The assessment and output will look specifically at:

- effects of physical screens on flood risk and other operational elements such as health and safety, carbon costs and cost versus. benefit
- cost-effectiveness of behavioural screens in practical operation, and on short- and long-term capital and operational expenditure

If required, the outputs of the review will be used to provide guidance for designers and operators of FCERM assets to provide a clear pathway for selecting, designing and operating eel and fish protection solutions. The guidance will consider flood risk, health and safety, practical operation and maintenance, upfront and ongoing costs, effects on carbon savings, as well as appropriate and effective protection of fish and eel.

Objectives and outcomes for WWNP

- Provide guidance on selecting the most cost effective beneficial eel and fish protection technologies in relation to best available information on effectiveness and operation for a variety of types of sites and structures.
- Guide decisions on the best solutions for specific structures. Focus on least cost but highest benefit solutions that comply with legislation.
- Consider how other solutions such as fish passes or structure removal can be used to reduce or eliminate need for screening.
- Ultimately provide appropriately effective eel and fish protection whilst minimising risks potentially resulting from increased flood risk.

Links with existing or ongoing research projects:

- [Eel regulations screening guidance](#)
- Fish screening assessments for hydropower schemes (Hydropower Evidence Projects, Environment Agency) –ongoing research for which results are not yet available
- Water and power company research – results not often publically available

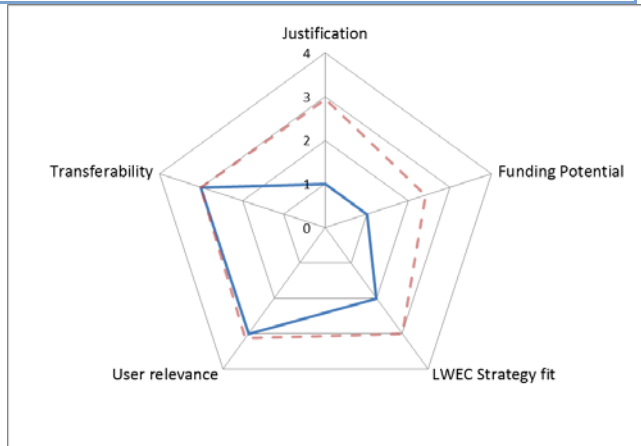
Project priority score: 11/20

(graph blue line = project score, red dashed line = average of all projects)

Funding sub-score: 1

Potential contributors/ funders:

- Defra/ Environment Agency
- UK Water Industry Research (UKWIR)
- private developers



Indicative cost: £ (L) <100,000

Indicative project length: 1 year

7 Summary and next steps

7.1 Summary and WWNP projects

The research priorities and potential projects for the new WWNP research framework have been identified. Although there is some evidence for WWNP effects on flood risk, action is needed to increase the evidence base using both practical implementation and modelling to help change perceptions and enable WWNP measures to be more widely applied. There is also a need to use available information to its maximum effect and to learn more about uncertainties so that people can understand the advantages and disadvantages of WWNP when making decisions about FCERM.

Figure 7.1 summarises the overall process gone through from the initial data and evidence review, to identifying the research needs and gaps, and finally the stage where priority projects that will help to utilise WWNP more frequently and more effectively in FCERM have been developed. Table 7.1 summarises the projects in the order of their priority scoring and identifies potential links between them such as where data from some projects will help inform others.

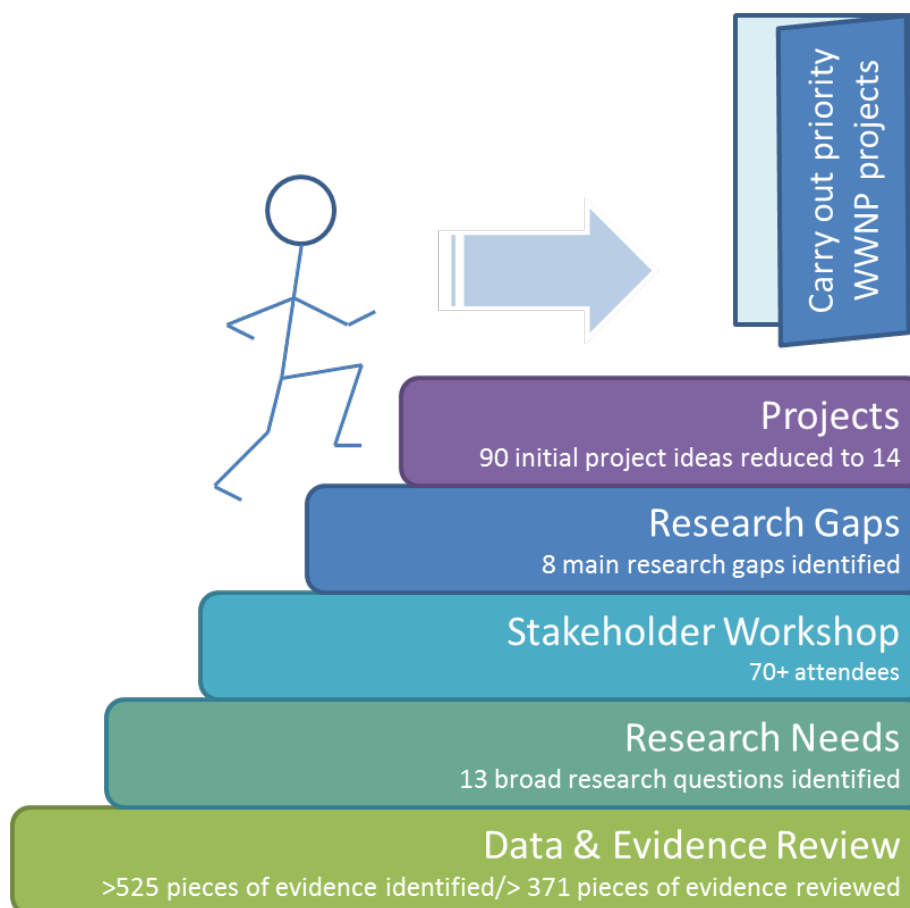


Figure 7.1 WWNP framework stages

Table 7.1 WWNP projects and interconnections

Title	Priority (scores 5 to 20)	Links to other WWNP projects
WWNP catchment laboratories – scoping stage	20	<ul style="list-style-type: none"> • Must happen first to agree scope, collaborative arrangements and locations • Could inform scope of numerous other WWNP projects
National mapping of priority catchments for WWNP	17	<ul style="list-style-type: none"> • May inform locations of catchment laboratories within suitable priority catchments, depending on timescales
Catchment laboratories sub-project 1 – sediment monitoring and tool development	17	<ul style="list-style-type: none"> • Would happen after catchment laboratories scoping • Will provide evidence and data for ‘Modelling effects of WWNP’ and ‘Operational guidance to deliver WWNP’ projects
Catchment laboratories sub-project 3 – hybrid WWNP approaches	17	<ul style="list-style-type: none"> • Would happen after catchment laboratories scoping • Will provide evidence and data for ‘Blue–green engineering rating and design guide’ and ‘Joining up Water Framework and Floods Directives’ projects
Catchment laboratories sub-project 2 – incentivising and communicating WWNP	16	<ul style="list-style-type: none"> • Would happen after catchment laboratories scoping • Could inform ‘Attitudes, cultural and scientific barriers’ project • Will provide evidence for ‘Ecosystem approach for funding in WWNP’ and ‘Operational guidance to deliver WWNP’ projects
Catchment laboratories sub-project 4 – catchment land use trials	16	<ul style="list-style-type: none"> • Would happen after catchment laboratories scoping • Will provide evidence and data for ‘Modelling effects of WWNP’ and ‘Operational guidance to deliver WWNP’ projects
Catchment laboratories sub-project 5 – woody debris tools	16	<ul style="list-style-type: none"> • Would happen after catchment laboratories scoping • Will provide evidence and data for ‘Modelling effects of WWNP’ and ‘Operational guidance to deliver WWNP’ projects
Modelling effects of WWNP measures on flood risk	16	<ul style="list-style-type: none"> • Catchment laboratory scoping could identify existing empirical data to start this project • Data generated from catchment laboratories could be used to improve modelling and verification over time
Developing a ‘blue–green engineering rating’ and design guide for FCERM	16	<ul style="list-style-type: none"> • Links to catchment laboratory projects in particular ‘Hybrid WWNP’ as this could help create performance standards and tests for blue–green engineering solutions
Attitudes, cultural and scientific barriers to WWNP	13	<ul style="list-style-type: none"> • May be useful to undertake this twice at outset of the framework to help to scope what evidence is needed and again following completion of catchment laboratories projects to look at changes in perception

Title	Priority (scores 5 to 20)	Links to other WWNP projects
Ecosystem approach for funding opportunities in WWNP	13	<ul style="list-style-type: none"> • Could tie into findings of the 'Incentives for WWNP' project
Developing operational guidance to deliver FCERM using WWNP	13	<ul style="list-style-type: none"> • Could be produced in short term to 'fill current gap/need' and then updated with experience from the catchment laboratories project • No specific links with other WWNP projects, but outputs from catchment laboratories and 'Blue-green engineering rating and design guide' projects will help inform future local catchment delivery of the Water Framework and Floods Directives
Joining up delivery of Water Framework and Floods Directives	12	
Costs and benefits of fish and eel screening measures on FCERM structures	11	<ul style="list-style-type: none"> • No specific links with other WWNP projects

7.2 Next steps

This report and launch of the WWNP framework are only the first steps in ensuring the wider use of WWNP in FCERM and other fields. Figure 7.2 shows an overview of the next steps for WWNP. The immediate steps required are:

- communications and publicity to inform interested parties, end users and potential funders
- identification and agreement of funding sources for the projects, potentially involving a 'brain trust' panel to bring together potential researchers

Together, these two steps are vital to implement the WWNP R&D programme and achieve the project objectives.

Following this there would need to be a call for proposals through either the Environment Agency/Defra Joint Programme or the other funding routes.

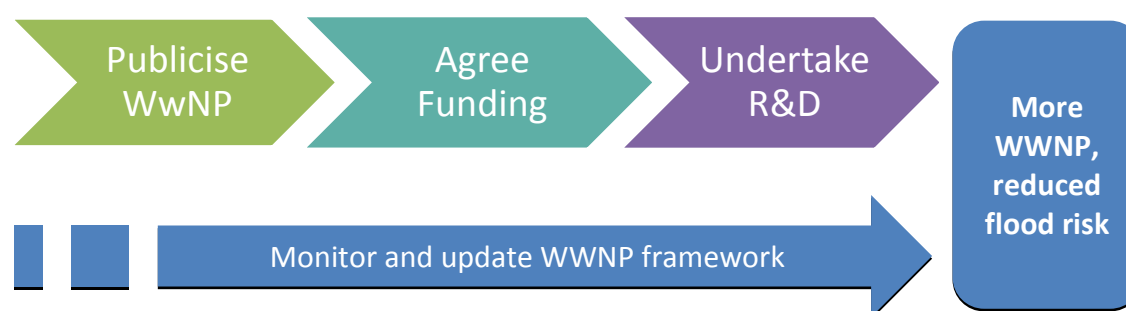


Figure 7.2 Overview of next steps for WWNP

It is suggested that the data and evidence register should be kept up-to-date to add new evidence to help refine project ideas and avoid duplication, as well as being a valuable source of information and knowledge exchange for stakeholders. When setting up the next stages of the framework, a priority should be to consider how this can become a live document and the best format for it to be used and kept up-to-date.

7.3 Publicising WWNP

Details of the WWNP framework projects will be communicated widely within the research community, inside and outside academia, the FCERM community, funding bodies and important decision makers. The aim will be to:

- allow others to use the research findings from this project, including the data and evidence review
- attract funding bodies to support and contribute to the suggested projects
- inform people involved in related research so they are aware of the WWNP projects and can be involved in scoping or carrying them out
- explain how the WWNP framework fits into the wider research arena for FCERM and related activities
- inform practitioners that work is planned that will help them use WWNP

The following events and opportunities will be used to help raise awareness of the WWNP framework:

- RRC annual conference – spring 2014
- Natural Flood Management event – planned for summer 2014 by CIWEM in association with their Rivers and Coastal Group
- other conferences – in particular those run by CIWEM and the Institution of Chemical Engineers (ICE)
- publication on the Defra/Environment Agency Joint Programme website and updates in the bi-annual 'Research News' newsletter
- use of less formal media including the FlowNet forum and Linked In

EPSRC recently funded a network, FCRM-NET, to bring researchers and practitioners together, building on one of the main recommendations of the LWEC FCERM research strategy. An annual event is planned, focusing on R&D problems and opportunities. This may present opportunities to refresh the WWNP priorities on an annual basis and to discuss potential funding and project delivery opportunities.

7.4 Agree funding

Funding is needed to progress the WWNP framework. This will be particularly important for projects that involve long-term collaborative working, or mix academic, practitioner and local inputs. For each project, potential funders are identified in the business cases summarised in Section 6. Other potential contributors include:

- Environment Agency/Defra Joint Programme through Theme Advisory Groups
- research councils including NERC, EPSRC and ESRC through formal calls or Knowledge Exchange Partnerships
- Natural Resources Wales and/or Welsh Government
- biodiversity funds such as the 'State of Nature' Fund in Wales
- Natural England and Forestry Commission (for example, Science and Innovation Strategy)

- Scottish Government
- Rivers Agency (Ireland) and Department for Agriculture and Rural Development (Northern Ireland)
- UKWIR
- EU funded programmes and projects, such as LIFE, where there are links to WWNP objectives

Others may also be able to contribute smaller amounts of funding or involvement through time or data or other resources. They include:

- National Trust
- Royal Society for Protection of Birds (RSPB)
- National Farmers Union
- water companies
- land owners/estate owners with land management interests

7.5 Review and governance: Joint Programme and WWNP

It is anticipated that the WWNP framework will operate within the structure of the Joint Programme for research and development into FCERM. It is likely that there will be a number of future participants and a communications plan is being developed to establish and clarify these potential roles in more detail. There will need to be a balance between leadership and the freedom of researchers to think and act creatively within the remit of the research, particularly for the catchment laboratories project. The constitution and governance of the programme are crucial to its success and need careful consideration. The expected governance roles are set out below.

- **Joint Programme Theme Advisory Groups (TAGs).** Each of the three current themes of the Joint Programme has a Theme Manager who has day-to-day responsibility for the theme programme and a Theme Champion who provides overall direction to the theme. These two roles are supported by a Theme Advisory Group (TAG) which provides input and review for its specific programme. Some WWNP projects are likely to be included in the Joint Programme thematic structure. These representatives could act as links between the WWNP framework and the Joint Programme.
- **LWEC partners.** A wide group of organisations and individuals are supporting the development of the LWEC strategy. They could fulfil an important role in the governance and implementation of the WWNP framework by providing a wider community of researchers and practitioners. LWEC partners could provide impetus to the WWNP framework to integrate its aims and projects within the broader strategy.
- **WWNP Project Advisory Group.** At the outset of WWNP, a PAG was formed to define the framework objectives, help identify R&D gaps, and provide technical advice. PAG members could continue to provide input to the WWNP framework as projects are commissioned. The PAG would be responsible for ensuring that an annual review process refreshes and updates the framework, generating and prioritising new R&D as lessons are learnt from projects as they are progressed and completed.

7.6 Legacy and monitoring

To ensure success, the outcomes of the projects should be monitored against both their specific technical objectives and the wider WWNP framework aims to help keep the priorities up-to-date. The PAG could undertake this role if it met annually.

Monitoring does not need to be complex and should include:

- assessing project outputs against their objectives as set out broadly in Section 6
- checking priorities across the whole framework
- identifying possible funding sources for future projects
- assessing how the WWNP framework is filling the identified research gaps as set out in Section 4
- considering other evolving needs and project ideas to maximise the impact of the WWNP framework and allow adaptive management

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List of abbreviations

CIWEM	Chartered Institute of Water and Environmental Management
CREW	Centre of Expertise for Waters
CoRDDi	Coastal Research Development and Dissemination
DER	data and evidence register
Defra	Department for the Environment Food and Rural Affairs
ESRC	Economic and Social Research Council
EPSRC	Engineering and Physical Sciences Research Council
FCERM	flood and coastal erosion risk management
FCRM	flood and coastal risk management
FRMP	flood risk management plan
FRMRC	Flood Risk Management Research Consortium
LLFA	Lead Local Flood Authority
LWEC	Living With Environmental Change
NERC	Natural Environment Research Council
NFM	natural flood management
PAG	Project Advisory Group
PES	Payments for Ecosystem Services
R&D	research & development
RBMP	river basin management plan
RRC	River Restoration Centre
SuDS	sustainable drainage system (urban or rural)
WFD	Water Framework Directive
WWNP	working with natural processes

Appendix A1 – Data and evidence for Ecosystem Services

The tables below summarise the evidence base collected during the Data and Evidence Review for each of the individual topic areas, along with views on the existing evidence-base from the stakeholder workshop.

Topic: Ecosystem Services (including Ecosystems Approach)

What does this topic cover?

Existing and on-going research and evidence in WWNP and FCERM relevant to:

- Ecosystems approach
- Ecosystem services assessment and valuation
- Stakeholder participation and decision making.

What is included in the Data & Evidence Review? (Part 1)

Each piece of evidence has been documented including basic information such as title, author, year published, organisation etc:

160 pieces of evidence have been received from various sources including the Environment Agency, Defra, The Hutton Institute and Ecosystems Knowledge Network. 127 were deemed relevant to both FCERM and WWNP. Of these, 102 are completed documents/reports/papers published between 1990 and 2013. 25 are in draft or yet to be published of which 13 are research studies commissioned or yet to be completed e.g. BESS/UK NEA Follow-on.

What types of evidence are included in the Data & Evidence Review? (Part 2)

The evidence has been categorised to interpret its spread and coverage in the following ways:

Number of pieces of evidence delivered through the Joint Defra/EA Flood & Coastal Erosion Risk Management R&D programme: 2 of 127

Number of pieces of evidence by R&D Category (of 127):

- Basic (concepts & philosophies) – 15
- Applied (methods & approaches) – 49
- Dissemination & training (software, guide, training) – 1
- Development & pilots (tools, case studies) – 26
- Implementation (better decision) – 4
- Not yet known⁴ – 32

Number of pieces of evidence by output type (of 127):

- Report – 49
- Data – 1
- Tool – 7 (although there are many more tools detailed within summary reports)
- Guidance – 16
- Paper – 18
- Other/not known – 36

⁴ It was not possible to fully read every document in the Data and Evidence Review therefore, where it was not possible to glean information from the document abstract or executive summary this was categorised as 'not known'.

Topic: Ecosystem Services (including Ecosystems Approach)

Number of pieces of evidence by geographical coverage (of 127):

- Site specific – 11
- Local – 15
- Regional – 2
- National – 54
- Global – 11
- Not known – 34

Number of pieces of evidence by principal data type (of 127):

- Primary quantitative (incl. monetary data) – 35
- Primary qualitative – 7
- Secondary quantitative (incl. monetary data) – 21
- Secondary qualitative – 3
- Not applicable/not known – 61

Number of pieces of evidence by target audience (of 127):

- Academic – 30
- Policy/specialist – 33
- Practitioner – 55
- Not known – 9

Number of pieces of evidence by type of understanding⁵ (of 127):

- Conceptual (or theoretical) – 31
- Empirical (based on actual observation) – 60
- Modelled (predicted behaviour based on observation elsewhere) – 26
- Not known – 10

Popular or additional evidence for this topic from stakeholder workshop

At the workshop held in September 2013, attendees were asked to list the existing information (reports/tools/guidance etc) that they use primarily to deliver WWNP in FCERM under this topic. Key documents used by stakeholders under this topic can be summarised as the following:

- Various economic valuation studies (revealed and stated)
- UK National Ecosystem Assessment (UK NEA)
- The Green Book (HMT Treasury)
- Multi-Criteria Analysis: A Manual (DCLG)
- FCERM: Economic Valuation of Environmental Effects Handbook (eftec)
- The Ecosystems Approach (CBD)
- The Economics of Ecosystems and Biodiversity for Water and Wetlands (TEEB)
- SUDS Manual (CIRIA)
- SUDS Guidance (WWT/RSPB)
- Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) (Environment Agency)
- Multi-Coloured Manual and pending update (FHRC)
- How to do an Ecosystem Services Assessment' Manual (not published) (Defra)

⁵ See main report for definition/glossary

Appendix A2 – Research gaps for Ecosystem Services

The following tables summarise how relevant the existing evidence base is in answering each overarching question (see report section 4), or supporting a business need for delivery of WWNP through FCERM (and therefore potential need for further research and development).

ESS Q1: Ecosystem services (including ecosystems approach)

Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

Summary of question

This question is relevant to the FCERM options appraisal process (not data as per Question 2). It is about what methods should be used to understand how FCERM WWNP measures affect ecosystem services in different ways. It is about how to empower communities and stakeholders to explore this using different methods and visual tools earlier on in the options appraisal process; whilst ensuring that this takes place at appropriate ecological and geographical scales. In total there are twelve principles of the Ecosystems Approach that need to be considered⁶. This approach can help FCERM schemes incorporate WWNP whilst achieving more sustainable outcomes, incentivise land use change, access innovative funding sources, generate community ownership and identify new delivery and funding mechanisms through for example, Payment for Ecosystem Services.

Initial findings from the Environment Agency's Ecosystem Services FCERM Pilot Projects suggests that there is still a challenge with the options appraisal process. It appears that only a few options are initially selected for appraisal and not enough are initially considered. Specifically, initial option identification appears to be largely limited to flood cell boundaries, flood risk reduction benefits and individual EA department responsibilities (or EA as a whole). This often results in an inadequate consideration of possible options (particularly WWNP measures) and appreciation of multiple benefits of working with natural processes. Also, the pilot projects suggest that there is a need to raise awareness and to provide information about ecosystem services to communities and stakeholders prior to the options identification and appraisal process. This will help address gaps in their knowledge and inform perceptions about different environmental goods e.g. 'saltmarsh looks ugly' (Ozdemiroglu, E., 9th September 2013, pers. comm.).

The attendees at the WWNP Stakeholder Workshop identified that it is important that communities and stakeholders are engaged earlier in FCERM appraisal to identify a wider range of possible options, including WWNP options in particular. They also agreed that appraisal must consider the plurality of stakeholder values and also less tangible spiritual/aesthetic values. It was noted that the NEA follow-on research is

⁶ Secretariat of the Convention on Biological Diversity (2004) 'The Ecosystem Approach, (CBD Guidelines)' Montreal: Secretariat of the Convention on Biological Diversity
<http://www.cbd.int/doc/publications/ea-text-en.pdf>

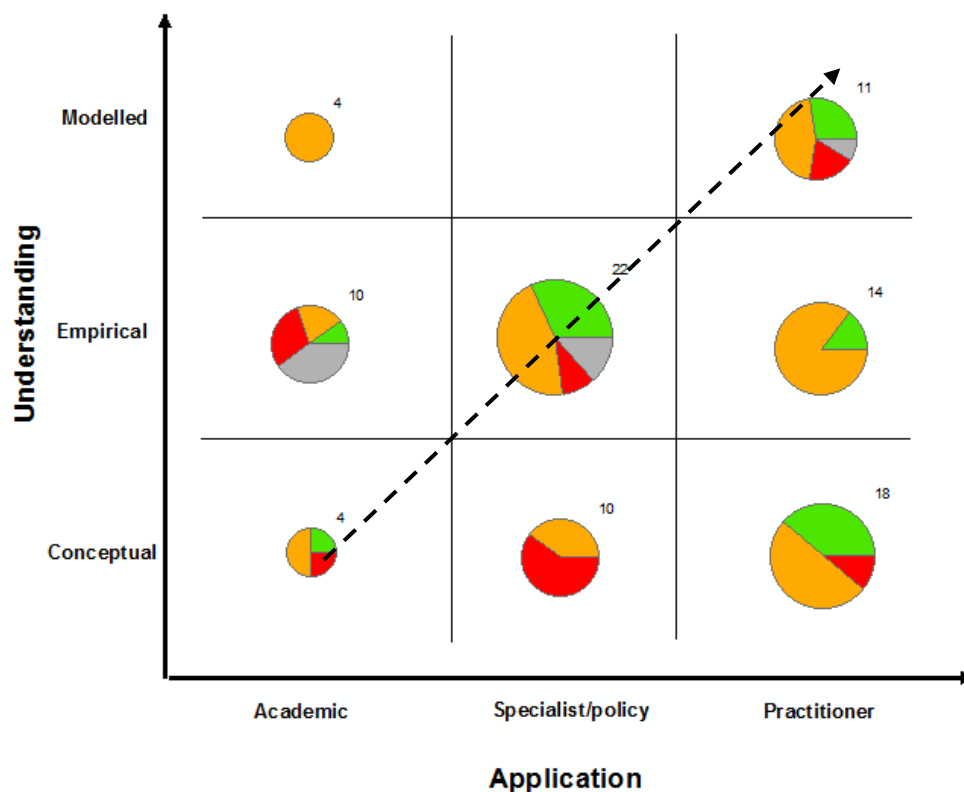
Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

looking at this to some extent. They also felt that often ecosystem services associated with WWNP would be better assessed at catchment scale⁷ rather than site-based (supported by the LWEC stakeholder workshop). Stakeholders also stated that we need appropriate methods and evidence to demonstrate the benefits of WWNP in FRM to policy makers and legislators, as well as communities and stakeholders, in order to change local planning decisions and building regulations, and so to make implementation of WWNP easier.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this research question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of relevance to the question and how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not completed).



The graph shows that most evidence is available at the practitioner and specialist/policy level and includes evidence such as toolkits, policy research, advisory and predictive guidance (e.g. The Magenta Book: Guidance for Evaluation, Water Body Level Cost Benefit Analysis, Payments for Ecosystem Services Guidance, InVEST). However, less evidence appears to be completed at empirical/conceptual or academic

⁷ A new concept emerging here is the 'Benefit Footprint' - this is the spatial distribution of benefits accruing from a particular natural asset and the ecosystem services that it provides (see work of Richard Fenner, as part of the EPSRC Blue-Green Cities research consortium).

Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

level. Not all the evidence is directly relevant to applying the ecosystems approach/ecosystem services assessment in WWNP and FRM; in most instances it is only partially relevant. Papers such as Rouquette et al.⁸, Fish et al.⁹ and projects such as EcoServ and InVEST demonstrate a range of different stakeholder/community engagement methods pertinent to WWNP and FCERM. Not every piece of evidence could be covered by this literature review (including the reference lists for key documents). However, the DER includes a number of pieces of research that are currently underway (shown by grey e.g. LWEC funded 'The Ecological Impacts of Flooding – Developing a Methodology') which will also strengthen the evidence base once completed.

Only a small proportion of the evidence seems to be directly relevant (depicted by the colour green) to WWNP in FCERM. For example, most of the evidence refers to ecosystem services assessment but less about how to incorporate this into a wider ecosystems approach. Some documents, albeit a few (e.g. Everard 2009 Ecosystem Services Case Studies) provide a review of stakeholder/community engagement methods to adopt in FRCEM that support the ecosystems approach. Also, many examples of applying the ecosystems approach in FRM may not have been written up or published. Finally, earlier studies that may be relevant may not have used the term 'ecosystems approach'.

In summary, although the data in the graph suggests that most evidence has been completed at practitioner level, the literature review and practitioner knowledge suggests that the sources of evidence are currently still few and far between and do not adequately address this question. It either a) focuses on one small area of the ecosystems approach/ecosystem services assessment (such as Payment for Ecosystem Services or the value of habitat creation) or b) only partially covers ecosystem services/ecosystems approach and WWNP (such as The Multi-Coloured Manual).

Lastly, while empirical studies (i.e. pilot/case studies) that have only recently been completed or are currently underway will help to address this question (e.g. Environment Agency's Ecosystem Services FRM Pilot Projects), practitioners at the WWNP Stakeholder Workshop suggested that more post project monitoring and evaluation or appraisal are required to strengthen learning and establish the effectiveness of each of the different approaches, particularly in the context of WWNP in FCERM.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP Stakeholder Workshop in September 2013.

This research question has been produced from four sources:

⁸ Rouquette J.R., Posthumus H., Morris J., Hess T.M., Dawson Q.L. & Gowing D.J.G. (2011) 'Synergies and trade-offs in the management of lowland rural floodplains: an ecosystem services approach' Hydrological Sciences Journal 56(8) p.1566-1581

⁹ Fish, R., Burgess, J., Chilvers, J. Footitt, A., Haines-Young, R. Russel, D., Winter, D.M. (2011) 'Participatory and deliberative techniques to embed an ecosystems approach into decision making: An introductory guide' (Defra Project code: NR0124)

Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

- An internal Environment Agency workshop held in October 2012 (specifically in relation to tools to incorporate ecosystem services into decision making and scheme design, empowering communities and stakeholders to identify and appraise FCERM options, case studies to demonstrate the multiple benefits of WWNP in FRM, payments for ecosystem services and catchment visualisation tools that express the multiple benefits of different options).
- The LWEC FCERM Strategy. This identified needs specific to how best to incorporate the ecosystems approach into economic appraisal and environmental mitigation and enhancements of FRM; and how to demonstrate WWNP benefits in order to incentivise flood source control measures in urban areas (e.g. SUDS). LWEC stakeholder workshop outputs specifically identified the need to understand the multiple benefits of catchment ecosystem services, the need for options to be appraised by a larger multi-disciplinary community at catchment scale and identifying best practice in terms of community engagement and training
- Peer reviewer, Ece Ozdemiroglu's (eftec) informal feedback based on emerging lessons from the Environment Agency's Ecosystem Services FRM Pilot Projects (see above)
- The WWNP Stakeholder Workshop held on 24th September 2013 identified that there is a need to:
 - develop clear communication strategies/disseminate training to facilitate WWNP in FRM;
 - empower communities and stakeholders to identify and appraise options earlier in the decision making process. Balancing this empowerment with the need for top-down decisions based on funding, resource and policy drivers;
 - test the ecosystems approach/ecosystem services assessment in terms of facilitating WWNP in FRM in some experimental catchments or sub-catchments i.e. at appropriate ecological scales (rather than to flood/coastal cell or administrative boundaries) and look at multiple benefits (not just those of flood risk reduction);
 - monitor and appraise projects to inform learning and understanding of what the most appropriate and cost-effective methods are of working with communities/ stakeholders and how this benefitted decision makers;
 - facilitate payment for ecosystem services to the providers (e.g. land owner), how this links with the ecosystems approach to community engagement and how this can benefit delivery of WWNP in FRM;
 - integrate the plethora of practitioner guidance into a one-stop shop for practitioners e.g. into one manual, or via one web portal.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

Most of the evidence in the DER refers to ecosystem *services assessment* and less about how to incorporate this into a wider ecosystems *approach* to FCERM. The evidence is partial and either focuses on one small area of the ecosystems approach/ecosystem services assessment (e.g. Payment for Ecosystem Services guidance), or only partially covers ecosystem services/ecosystems approach and WWNP (e.g. FCERM: Economic Valuation of Environmental Effects Handbook and the Multi-Coloured Manual). Few evaluations/post project appraisals are available to strengthen our understanding of how the ecosystem approach to FCERM can be made to work in practice. However, pilot projects exploring different ways to incorporate ecosystems approach/ecosystem services assessment into FCERM are underway.

The WWNP Stakeholder Workshop identified the necessity to work with local communities and stakeholders earlier in the appraisal process, to identify options (in particular WWNP options) and explore how ecosystem services change between each option (although this should be balanced with values held by national and global populations e.g. carbon values). It was felt that this would help capture the ways that particular ecosystem services are understood and valued differs between individuals, communities, cultures and that these values cannot be standardised because they depend on the geographical and social/community contexts within which they are being valued. It was also felt that recognising the context-specific values of ecosystem benefits would help address institutional barriers that currently limit the extent to which WWNP measures are considered in FCERM options appraisal. Removing these barriers would facilitate new collaborations between stakeholders and help identify innovative ways for FCERM funding and delivery (supported by findings of the LWEC stakeholder workshop). In this respect the advantages of sharing the cost of FCERM-led actions and projects that deliver multiple benefits (for example, fisheries, social, community and ecological) with the funders of conservation, recreation and environmental actions and the communities that enjoy those benefits must be appreciated. Specifically, while the cost of an option that delivers multiple benefits may be higher than a single-function flood defence option, the cost to the FCERM funder may be lower because the overall cost of a multi-benefit solution can be shared between multiple funders.

The DER identifies that different approaches have been used to engage communities and stakeholders in option design and appraisal (each adopting the ecosystems approach to a different extent). However, the WWNP Stakeholder Workshop found that these approaches are not widely known or understood, and it is unclear in what situations they should be used. Indeed, there other innovative approaches are bound to be developed, with a risk that selecting the best option may become more rather than less complicated.

A key part of rolling out the ecosystems approach in FCERM (based on twelve principles of the ecosystems approach) is about empowering communities and stakeholders and engaging them earlier in the process in order to identify the range of possible FCERM options (in particular WWNP options) that should be appraised. There is a risk that stakeholder participation in option identification and appraisal will be limited by the availability of funding to support this activity. Hence, it is vital that cost-effective methods are developed to support stakeholder participation in practice e.g. using GIS or standard scoring. This raises fundamental questions related to the range of approaches and methods for engaging stakeholders that we already know about and how effective they are in practice. More specifically, we need to know a lot more about the circumstances under which existing approaches are suitable and at what

Topic: Ecosystem services (including ecosystems approach)

Question 1: Are we able to effectively apply the ecosystems approach/ecosystem services assessment to facilitate WWNP in FCERM?

geographical scale they are appropriate? What we need to next is work out what will still need to do before we will be in a position to facilitate the roll out of the ecosystems approach in FCERM nationally.

Feedback from the Environment Agency's Ecosystem Services FRM Pilot Projects suggests that it is important for any review of different methods and approaches to consider how information about ecosystem services should be provided to communities and stakeholders prior to engaging them in the options identification and appraisal process (including what terminology to use in describing and defining ecosystem services and the multiple benefits of adopting an ecosystems approach in provision of FCERM!). We also need to identify how stakeholder engagement can be made much more inclusive – which means using methods that can incorporate the plurality of stakeholder values and less tangible spiritual/cultural values into the appraisal process, rather than relying on values that can be monetised only. Only through doing this will we achieve a fuller and more comprehensive understanding of the multiple benefits (not just to FCERM but 'the benefits footprint more generally) of WWNP measures.

[Please note it is beyond the scope of this project to comment on the quality of individual pieces of research].

Research gaps identified for this question:

- ESS Q1a) An understanding of the different methods and approaches used to engage communities and stakeholders earlier in the options identification and appraisal process (as well as rolling out the ecosystems approach in practice)
- ESS Q1b) A review of institutional cultural barriers to changing the way decisions are made at policy/funding level and the way options are initially identified. The need to demonstrate the multiple benefits of WWNP in FCERM to policy/legislative makers – that is identifying the 'benefits footprint: which defines, what the benefits are, who are the beneficiaries, how they benefit and how the benefits are distributed - geographically and temporally. Is our inability to define the 'benefits footprint' what is holding back accurate identification and appraisal of the case for wider use of WWNP measures in FCERM options appraisal?
- ESS Q1c) To what extent is a lack of post project learning and monitoring of pilots projects and case studies that have been completed limiting our understanding of which stakeholder engagement methods work best?

ESS Q2: Ecosystem services (including ecosystems approach)

Topic: Ecosystem services (including ecosystems approach)

Research Question 2: Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management measures e.g. SUDS, wider catchment measures?

Summary of research question

This question is about the evidence used to inform the options appraisal process. It refers to the assessment of change in ecosystem services (qualitatively and quantitatively) and associated changes in values due to FCERM measures interacting (positively or negatively) with ecosystem services. Initial findings from the Environment Agency's Ecosystem Services FRM Pilot Projects suggest that particular needs centre on greater understanding of carbon sequestration, visitor values for new recreational opportunities and ecosystem services provided by agricultural land as associated with different FCERM measures (Ozdemiroglu, E., 9th September 2013, pers. comm.).

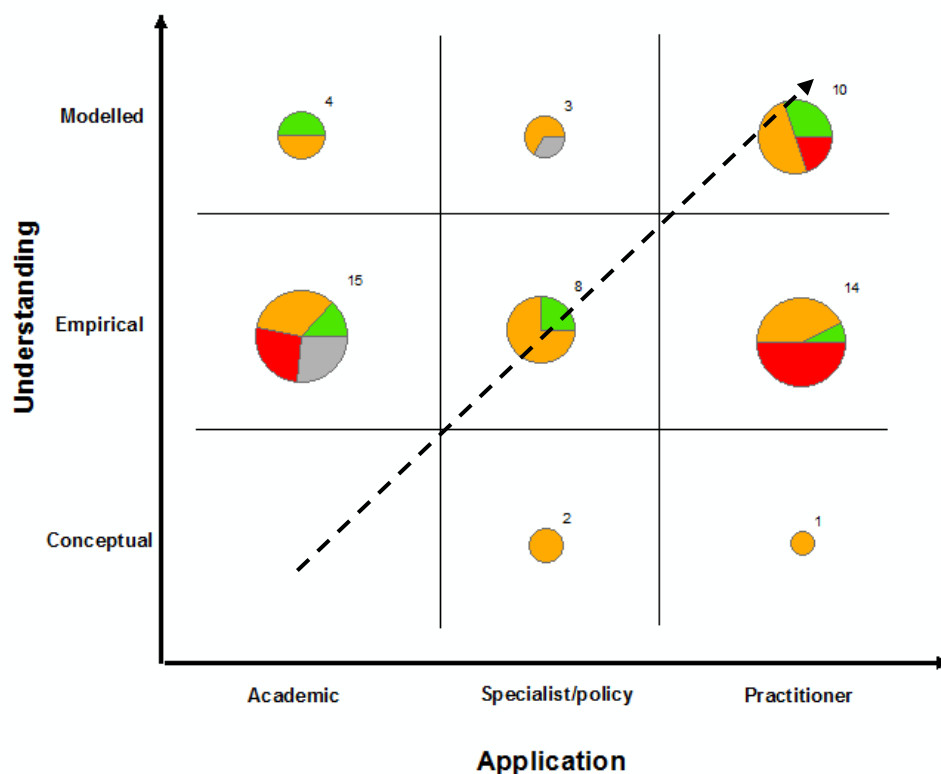
The WWNP Stakeholder Workshop identified a need to be able to describe, quantify and (where possible) monetise changes in ecosystem services associated with WWNP in FCERM. Workshop participants agreed that this is not done effectively at the moment due to a lack of evidence that is transferable from one area to another, but also due to a reluctance by decision makers to undertake ecosystem services assessments (despite Government guidance in place that is intended to facilitate this). Therefore, it is not necessarily due to a lack of evidence alone but is also due to an institutional inertia that makes it difficult to move towards making decisions differently and which tends to maintain the *status quo*. Participants also believed that geographical scale is an appropriate consideration and that, often, ecosystem services are better assessed at the catchment scale rather than on a site-by-site basis (a view endorsed at the LWEC stakeholder workshop).

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this research question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in the Science Report). The colours represent the strength of evidence, in terms of relevance to the question and how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not completed).

Topic: Ecosystem services (including ecosystems approach)

Research Question 2: Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management measures e.g. SUDS, wider catchment measures?



The graph shows that most evidence has been completed/is being completed through empirical observation (e.g. case studies, monitoring, primary data gathering); mainly by various universities/research institutes, but also by practitioners and specialists to an extent (e.g. consultants, Environment Agency). Current research projects of importance include those currently taking place as part of the NERC ecosystem services programme. Some evidence has also been modelled and provided to practitioners by means of guidance and handbooks (e.g. FCERM: Economic Valuation of Environmental Effects Handbook) intended to be applied in other contexts.

The graph suggests a lack of evidence in the conceptual/academic area. This includes papers and theories that discuss and identify what ecosystems services are, that they exist, that humans attach values to them and how these values constitute economic values. It was not possible to fully review all ecosystem services evidence (or lack of) in academic/scientific literature. Academics/practitioners in the field (from WWNP Stakeholder Workshop and Peer Reviewers) believe that, conceptually, there is good coverage of ecosystems approach/ecosystem services valuation. However, they recognise that gaps exist, principally in scientific empirical observation.

The graph suggests a need for further empirical evidence at specialist/policy level on how ecosystems services change due to implementation of different FCERM/WWNP measures (and how values associated with these services also change). This is supported by the fact that there are few pieces of evidence in this cell and fewer still are classed as 'green'. Likewise, this need translates to a lack of guidance at practitioner level (such as handbooks, manuals and standard data sets) to enable practitioners to deliver WWNP in practice and so 'get the job done'.

Topic: Ecosystem services (including ecosystems approach)

Research Question 2: Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management measures e.g. SUDS, wider catchment measures?

Only a small proportion of the evidence appears to be relevant (depicted by the colour green) to addressing the research question and specifically supporting wider uptake of WWNP as a mainstream option in FCERM.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP Stakeholder Workshop in September 2013.

This research question has been based on information from four sources:

- An internal Environment Agency workshop held in October 2012 (specifically identified a research need in relation to the value of saltmarsh in England).
- The LWEC FCERM Strategy specifically identified a research need in relation to whole-life carbon accounting in particular for SUDS. The LWEC stakeholder workshop identified a number of related needs. This included the need to understand the value of floodplains and, in particular, how to quantify the ecosystem services of floodplains. The LWEC stakeholder workshop also concluded that current research is under-used in practice and suggested that more training and knowledge transfer/dissemination to practitioners is required. The LWEC stakeholder workshop also found that greater emphasis should be placed on understanding the scale and spatial variation of ecosystem services, valuing a wider range of multiple benefits of different FCERM options, plus delivering multiple land and water objectives that extend beyond those associated with FCERM alone.
- Peer reviewer, Ece Ozdemiroglu's (eftec) informal feedback based on the emerging lessons from the Environment Agency's Ecosystem Services FRM Pilot Projects (see above).
- The WWNP Stakeholder Workshop held on 24th September 2013 specifically identified a research need to more effectively understand changes in flows of ecosystem services and how to quantify and value change. It identified a number of priority needs linked to this research question:
 - Assessment and valuation of all ecosystem services (particularly non-financial) is needed (though not necessarily through monetarising their value). It is unclear at present how non-linear relationships, tipping points/thresholds and cumulative impacts in assessment should be appropriately taken in to consideration in such evaluations;
 - Evaluating and learning more from completed pilot projects e.g. via monitoring of SCAMP 1 & 2, Lake Vyrnwy, Upstream Thinking;
 - Focus on the combined net value to society that maximises the combined benefits to different policy drivers e.g. WFD, FRM and biodiversity;
 - Empowering communities and stakeholders to identify and appraise a fuller range of options (including WWNP) earlier in the decision making process;

Topic: Ecosystem services (including ecosystems approach)

Research Question 2: Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management measures e.g. SUDS, wider catchment measures?

- Testing ecosystem services assessment using the ecosystems approach, focusing on WWNP in FRM, in some experimental catchments. Monitoring and evaluation is required to inform post project learning e.g. how do we best deliver the desired WFD and FRM outcomes?

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage but not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and outputs from the WWNP Stakeholder Workshop. This has been peer-reviewed.

Inspecting the DER more closely, and drawing on the knowledge of practitioners, suggests that much more evidence is available for some ecosystem services than others. There does not seem to be an even spread across all the ecosystem services potentially enhanced by WWNP and blue/green infrastructure. For example, it is generally accepted that there is currently sufficient evidence (change in flow and monetary values) associated with habitat creation and resultant carbon sequestration (WWNP Stakeholder Workshop) and also water quality (Ozdemiroglu, E., 7th October 2013, pers. comm.). However, evidence for other ecosystem services in relation to WWNP is patchy and dependent on the given context of a particular FCERM scheme. For some ecosystem services, there is sufficient monetary data to estimate values, but little in terms of understanding change in the flow associated with different FCERM schemes. For other ecosystem services, the situation is reversed – it is understood how ecosystem services are likely to change but little understanding of how values are likely to change. Lastly, for other ecosystem services, both types of data may be available (flow and value) but the parameters of each may be unmatchable in a given FCERM context.

For example, a recent ecosystem services assessment sought to estimate how cultural values associated with heritage assets protected against flooding by a proposed scheme, may change due to the scheme. [This is relevant to assessing the multiple benefits of WWNP FCERM measures which could range from water quality improvements, carbon storage and crop protection, to cultural and recreational values]. The lack of relevant UK evidence indicated that a bespoke, household survey was required to quantify and monetise the change (because the data necessary to do this routinely did not exist). Evidence of surface water attenuation associated with green infrastructure/habitat creation in the proposals was also limited (although monetisation would have been easier in this instance). Finally, a lack of evidence made it difficult to quantify the change in carbon sequestration associated with WWNP/FCERM measures other than habitat creation, such as the carbon sequestration associated with green space improvements (e.g. marginal habitat creation) and SuDS.

Knowledge of where to obtain evidence/monetary data appears to be limited among practitioners. Toolkits are available to assess the benefits of some WWNP measures (e.g. green infrastructure), but these tend to vary in quality and reliability. A lot of monetary data is available to estimate the values of benefits related to different ecosystem services (for example via the online Environmental Valuation Resource Inventory). Often, data from other sectors can be used (e.g. evidence collected from households for PR14) or datasets exist that practitioners rarely know about (e.g.

Topic: Ecosystem services (including ecosystems approach)

Research Question 2: Are we able to accurately identify and assess the change in ecosystem services (qualitatively and quantitatively) and associated values that occur due to natural flood management measures e.g. SUDS, wider catchment measures?

Environment Agency's recently published NWEBS survey data). Not all of this information is necessarily relevant to WWNP in FCERM – it very much depends on the local context. Guidance is available in terms of how to use the data in other contexts once accessed (see Environment Agency 'Benefits Transfer Guidance' for example). The problem is that many practitioners simply do not know that such data exists, where it resides, or how to access it. As a result, a lot of existing knowledge is under-used (a point supported by findings of LWEC stakeholder workshop).

[Please note it is beyond the scope of this project to comment on the quality of individual pieces of research].

Research gaps identified for this question:

- ESS Q2a) A need for further empirical evidence at specialist/policy level of how ecosystems services change due to different FCERM/WWNP measures (and how human values associated with these are likely to change – recognising this is often context specific). This is not required for those ecosystem services for which sufficient evidence/toolkits are available. A review is required to identify which ecosystem services have insufficient evidence, are potentially significant and require priority attention. For example, there appears to be a particular need to examine carbon sequestration associated with different WWNP measures other than habitat creation, visitor values for new recreational opportunities associated with WWNP measures, and identification of ecosystem services provided by agricultural land (other than crop yields).
- ESS Q2b) Knowledge of where to obtain evidence and monetary data varies among practitioners. hence, improved transfer/dissemination of knowledge and/or training is required for practitioners. Guidance for practitioners is needed to clearly spell out a) best available evidence to inform assumptions about change in different ecosystem service flows due to different types of FCERM/WWNP measures and, b) the best available data for the associated changes in values. It seems to be important to state the geographical scales (e.g. catchments, RBMPs, coastal cells) at which it is appropriate to apply this evidence, and the scales for which it is not. This will allow identification of situations where primary survey data collection is likely to be required due to a lack of empirical data that can be transferred from elsewhere. Guidance is required on how to undertake full, systematic assessments of all the ecosystem services affected by an FCERM measure.
- ESS Q2c) A review of institutional cultural barriers to changing the way decisions are made. Ways to demonstrate benefits of WWNP in FCERM to high-level decision makers in Local Authorities, the Environment Agency and Defra. What is holding back the identification and appraisal of WWNP measures in FCERM options?
- ESS Q2d) Experimental application of ecosystems approach/ecosystem services assessment in catchments to identify most appropriate methods to deliver multiple policy/legislative and wider benefits i.e. FCERM, WFD, water quality, biodiversity targets.

Appendix B1 – Data and evidence for Fluvial and Coastal Geomorphology

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

What does this topic cover?

Existing and on-going research and evidence in WWNP and FCERM relevant to:

- Applied geomorphology (fluvial, coastal and estuarine)
- Sediment management
- Restoring natural processes

What is included in the Data & Evidence Review? (Part 1)

Each piece of evidence has been documented including basic information such as title, author, year published, organisation etc:

The focus of the DER was on the collection of applied geomorphological evidence rather than on pure academic research, unless it was directly relevant to the research need. 77 pieces of evidence have been received from various sources, including the Environment Agency and Defra. 57 were deemed relevant to both FCERM and WWNP. Of these, 55 are completed documents/reports/papers published between 1990 and 2013. One is in draft or yet to be published and another document is a newly commissioned research study and yet to be completed titled, 'A Scoping Study for Coastal Asset Management', by the Environment Agency.

What types of evidence are included in the Data & Evidence Review? (Part 2)

The evidence has been categorised to interpret its spread and coverage in the following ways:

Number of pieces of evidence delivered through the Joint Defra/EA Flood & Coastal Erosion Risk Management R&D programme: 37 of 57

Number of pieces of evidence by R&D Category (of 57):

- Basic (concepts & philosophies) - 5
- Applied (methods & approaches) - 14
- Dissemination & training (software, guide, training) - 4
- Development & pilots (tools, case studies) - 29
- Implementation (better decision) – 5

Number of pieces of evidence by output type (of 57):

- Report – 20
- Data – 3
- Tool – 8
- Guidance – 20
- Paper – 3
- Other/not known – 3

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Number of pieces of evidence by geographical coverage (of 57):

- Site specific – 4
- Local – 1
- Regional – 1
- National – 49
- Global – 2

Number of pieces of evidence by principal data type (of 57):

- Primary quantitative – 18
- Primary qualitative – 10
- Secondary quantitative – 9
- Secondary qualitative – 15
- Not applicable/not known – 5

Number of pieces of evidence by target audience (of 57):

- Academic – 8
- Policy/specialist – 13
- Practitioner – 36

Number of pieces of evidence by type of understanding (of 57):

- Conceptual (or theoretical) – 16
- Empirical (based on actual observation) – 29
- Modelled (predicted behaviour based on observation elsewhere) – 12

Popular or additional evidence for this topic from stakeholder workshop

At the workshop held in September 2013, attendees were asked to list the existing information (reports/tools/guidance etc) that they use primarily to deliver WWNP in FCERM under this topic (list of attendees given in Appendix C). Key documents and tools used by stakeholders under this theme can be summarised as the following:

- The 'ST:REAM' tool.
- Research models eg. Xbeach
- Natural Flood Management (NFM) pilot projects
- Sediment system analysis
- Met office data. MORECS
- River Restoration Manual
- Estuary Edges guidance documents
- CIRIA, SUDS Manuals
- River Habitat Survey (RHS) techniques
- WFD compliance guidance documents

Appendix B2 – Gap analysis for Fluvial and Coastal Geomorphology

FCG Q1: Fluvial and coastal geomorphology

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Research Question 1: Do we understand the value of sediments in natural flood and erosion protection in estuarine and coastal environments, to allow us to identify solutions

Summary of research question

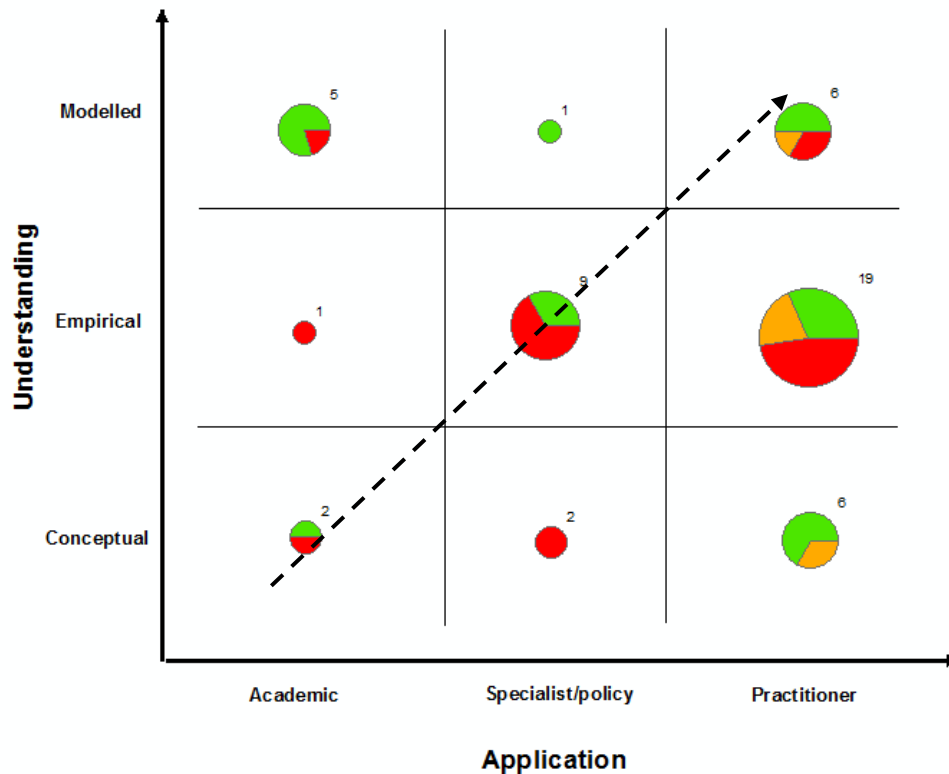
This is about understanding how sediment deposition and sediment management can impact flood risk within estuarine and coastal environments, both in terms of the positive contributions and risks. The Defra/EA Framework for Coastal Research, Development and Dissemination (CoRDDi) recently reviewed evidence that is directly relevant to this question (estuarine and coastal environment) and therefore it was not necessary to repeat this coverage in any significant depth here.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this research question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The size of the pie charts represent the strength of evidence in terms of relevance to the question and the colour indicates how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not completed).

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Research Question 1: Do we understand the value of sediments in natural flood and erosion protection in estuarine and coastal environments, to allow us to identify solutions



The graph shows that most evidence gathered has been completed/is being completed through empirical observation (e.g. case studies, monitoring, primary data gathering), which is mostly used by practitioners in the form of risk-based guidance. However, only a small percentage of this evidence is believed to be relevant in helping answer this research question regarding the value of sediments in the estuarine and coastal environments. A smaller percentage of the evidence base comes from modelled data. This evidence is generally relevant to the question, and is supportive of the business case for WWNP in FCERM. Examples from academia include previous research and models created by the EMPHASYS Consortium, and Shingle Beach Transport Models and predictive tools such as the EstSim model. The recently established 4-year NERC Coastal Sediment Systems Research Programme has the objective of improving our capability to predict long-term and regional scale change in estuaries and along coasts. It is envisaged that the CoaEST and iCOAST projects will directly contribute to an increase in modelled/predictive evidence for this area by the end of the programme.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP Stakeholder Workshop in September 2013.

Needs and gaps for this research question have been produced from three sources:

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Research Question 1: Do we understand the value of sediments in natural flood and erosion protection in estuarine and coastal environments, to allow us to identify solutions

- An internal Environment Agency workshop held in Oct 2012. This identified that FCERM can and must make better decisions on coastal management, based on knowledge of near shore bathymetry, sediment supply and transfer and for modelling software to better model the potential impacts of proposed WWNP-FCERM activities on geomorphology, bathymetry and sediment management.
- The LWEC FCERM Strategy identified a research need in relation to understanding of the environmental and socio-economic benefits of natural coastal systems, to allow us to identify solutions that work with coastal processes and landforms. Coastal morphology was identified as a specific topic under the 'Understanding Risk' Theme (UR9). Research is required to establish how coastal morphology is impacted by sequences of closely-spaced and/or coincident events involving gales, persistent, severe wave climates, storm surges, and fluctuations in sediment supply, particularly from eroding cliffs and near/off-shore sources. Research is required on all coastal types, including estuaries, over a wide range of temporal and spatial scales; this is fundamental for effective shoreline management, risk analysis and habitat creation. Better understanding of the processes, landforms and the benefits associated with natural coastal systems, particularly in light of environmental and socioeconomic change, is important.
- The WWNP Stakeholder Workshop held on 24th September 2013 specifically identified a number of priority needs linked to this research question:
 - Clearer definition of 'what nature does for us' (also known as ecosystem services), including natural flood protection. Better understand the dynamic nature/natural resilience of the protection provided by sediment-based coastal systems (storm response or dynamic change to climate change, RSLR and recoverability)
 - Sediment modelling - ability to quantify acceptable levels of erosion/siltation for FCERM including more predictive tools linking impacts on sediment systems to changes in flood risk. Medium and long term prediction of the morphological evolution of coastal/estuarine systems.
 - Understand and articulate the value of sediments to all aspects of ecosystem services and FCERM to the public, funders and coastal engineers. Greater stakeholder engagement in habitat creation and post scheme management/after care. A broader range of intertidal habitat creation demonstration sites, moving beyond bird reserves!

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage but not necessarily research gaps. To identify research gaps, coverage has been compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and outputs from the WWNP Stakeholder Workshop. This has been peer-reviewed.

The graph suggests that the research question is well represented by modelled evidence; however the number of pieces of evidence is relatively small. This fits with the need identified above for more sediment modelling to better quantify acceptable

Topic: Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Research Question 1: Do we understand the value of sediments in natural flood and erosion protection in estuarine and coastal environments, to allow us to identify solutions

levels of siltation for FCERM, including more predictive tools linking changes in sediment systems to responses in coastal and estuarine systems and flood risks.

The conceptual evidence base is also not well represented on the graph particularly at the policy and academic level. However, this may be because conceptual evidence has not been exhaustively reviewed. This is often the case because the spatial scales used in academic study do not translate well into more applied, working scales.

There is however, an identified need to better understand and justify sediment management to fulfil FCERM requirements, including understanding the dynamic nature/natural resilience of protection provided by sediment-based WWNP actions (such as beach recharge and creation of intertidal foreshores and habitats) and to articulate this value to stakeholders. Also there is a need to provide a greater understanding of the value of sediment (within the coastal and estuarine environment) to all aspects of ecosystem services and FCERM.

[Please note it is beyond the scope of this project to comment on the quality of individual pieces of research].

Research gaps identified for this question:

FCG Q1a) Long-term models/tools of estuarine and coastal environments using existing empirical data for practitioners to use to better predict change over time (this is being covered to some degree by the NERC funded projects CoaEST and iCoast).

FCG Q1b) More evidence/investigation of benefits of sediment management to FCERM (e.g. beach nourishment, sand dune management) along coasts and estuaries.

FCG Q1c) Education and dissemination to the public, policy makers and practitioners of the benefits of sediment management along our coasts and estuaries to fulfil FCERM requirements (i.e. intertidal foreshore and habitat creation).

FCG Q2: Fluvial and coastal geomorphology

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

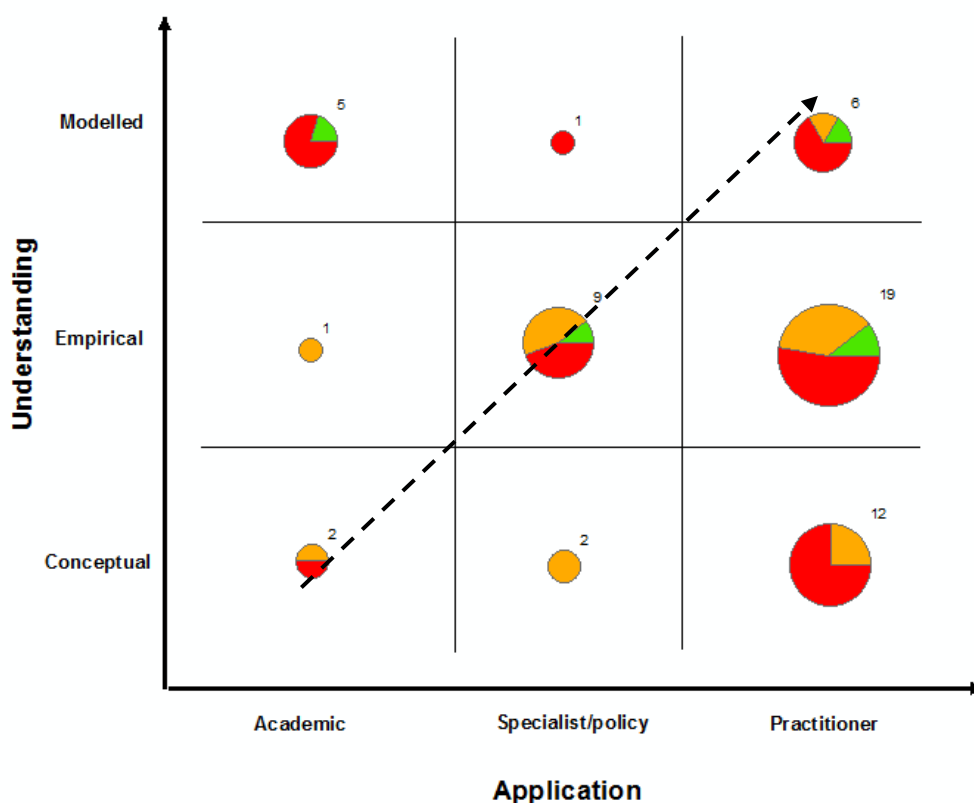
Question 2: Can we identify catchments where river morphology and FRM are most likely to be sensitive to sediment dynamics at a range of scales, to enable proactive management of sediment related FRM issues?

Summary of question

This is about understanding risk, identifying how to focus efforts and resources to better manage sediment within a catchment and to identify specific catchments or 'hotspots' where FCERM activities are likely to be sensitive to sediment dynamics.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this research question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The size of the pie charts represents the strength of evidence in terms of relevance to the question and the colour indicates how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not completed).



The graph shows that most evidence gathered has been or is being completed through empirical observation (e.g. case studies, monitoring, primary data gathering), which is mostly used by practitioners in the form of risk-based guidance. However, only a small percentage of this evidence is believed to be relevant in helping answer the research question. A smaller percentage of the evidence base comes from modelled data and this evidence is generally relevant to the question. Conceptual evidence collated does

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Question 2: Can we identify catchments where river morphology and FRM are most likely to be sensitive to sediment dynamics at a range of scales, to enable proactive management of sediment related FRM issues?

not appear to provide any strong support for the research question.

The graph suggests that there has been a lot of recent empirical evidence in sediments and habitats work, such as 'Sediment Matters', but it is either not widely known about or does not provide strong enough evidence base e.g. transferability from one site to another. Therefore, only a small proportion of the evidence appears to be relevant (depicted by the colour green) in addressing the research question as well as supporting WWNP in a FCERM business case.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP Stakeholder Workshop in September 2013.

This research question has been produced from three sources:

- An internal Environment Agency workshop held in Oct 2012 specifically identified a need to understand the catchment-scale benefits of land management, including rural sustainable drainage systems (and whether they can they reduce the needs for dredging by limiting sediment inputs to rivers).
- The LWEC FCERM Strategy identified a research need in the 'Understanding Risk' theme (Fluvial Geomorphology, UR10): Understanding how sediment mobility impacts flood risk management in terms of changing river regime is important in flood and erosion risk management. There is a need to profile catchments with characteristics that make them especially vulnerable and sensitive to sediment dynamics and impacts that could either induce, or could be induced by, vertical and lateral channel mobility.
- The WWNP Stakeholder Workshop held on 24th September 2013 specifically identified a number of priority needs linked to this research question:
 - Understanding the scale of land management required to contribute to flood risk and improved understanding (and justification for) sediment management to fulfil FRM requirements, including:
 - Role of sediment and morphology in influencing FRM and implication of changes;
 - Greater appreciation of the links between rivers and floodplains from a sediment perspective.
 - Morphological-ecological risk and sensitivity mapping at catchment and national scales.
 - Better large scale/extensive conceptual models that help target actions, including a more structured conceptual framework of linking (meaningful) sediment systems behaviour to flood risk management (conceptual framework).
 - Understanding catchment processes and needs alongside local restoration.

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Question 2: Can we identify catchments where river morphology and FRM are most likely to be sensitive to sediment dynamics at a range of scales, to enable proactive management of sediment related FRM issues?

Medium to long-term empirical case studies for cause and effect scenarios e.g. how would restoring a river and floodplain affect sediment management.

- The way to collect evidence that minimises reliance on expert judgement in the decision making process.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage has been compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph above only contains a small amount of evidence relevant to the research question (shown in green). This indicates that there is at present a gap in our general understanding of the research question in relation to identifying catchments and reaches where river morphology and FRM are particularly sensitive to changes in sediment dynamics triggered by changes in climate, land use and the introduction or removal of FRM infrastructure (grey or green). Currently, empirical and modelled data provides the most suitable evidence in relation to the research question but this is very limited in extent. The most relevant evidence is that provided by the Flood Risk Management Research Consortium (FRMRC) research programme, which includes information for practitioners on the impacts of rural land use management, including 'Land use management effects on flood flows and sediments - guidance on prediction' along with higher level information produced by the EA on 'Sediment Matters: A Practical Guide to Sediment and Its Impacts in UK Rivers'. There is a need for better evidence of catchment-scale benefits of land management including sediment controls through rural sustainable drainage systems, and if it could be used to demonstrate the utility and limitations of different sediment management actions, including dredging.

Conceptual evidence is also poorly represented on the graph. A need for better conceptual models was identified during the WWNP stakeholder workshop, to help target where to focus FCERM sediment management activities within the catchment and its drainage network. There was also a need for better morphological-ecological risk and sensitivity mapping at catchment and national scales, to further aid planning and decision making for FCERM at the local and regional levels.

[Please note it is beyond the scope of this project to comment on the quality of individual pieces of research].

Research gaps identified for this question:

FCG Q2a) Evidence on the catchment-scale benefits of land management. Identifying the key locations within the catchment and understanding the scale of land management changes required to contribute to flood risk management at the catchment scale. This understanding justifies sediment management as an integral element of FRM.

FCG Q2b) More case studies on the use of rural sustainable drainage systems, and their contribution to managing sediment (and sediment-related flood risks) sustainably and, hence, reducing the need for dredging. Of particular significance is gathering evidence to improve our understanding and

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Question 2: Can we identify catchments where river morphology and FRM are most likely to be sensitive to sediment dynamics at a range of scales, to enable proactive management of sediment related FRM issues?

appreciation of the importance of connectivity between rivers and their floodplains with respect to sediment management for FRM.

FCG Q2c) Geomorphological profiling and classification of catchments achieved through national and catchment scale sensitivity mapping (morphological-ecological) to help identify catchments particularly sensitive to sediment related FRM issues. Focussing on 'vulnerable' catchments where big gains could be achieved and on characteristics that make them especially vulnerable and sensitive to sediment dynamics and disturbance thereof.

FCG Q3: Fluvial and coastal geomorphology

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

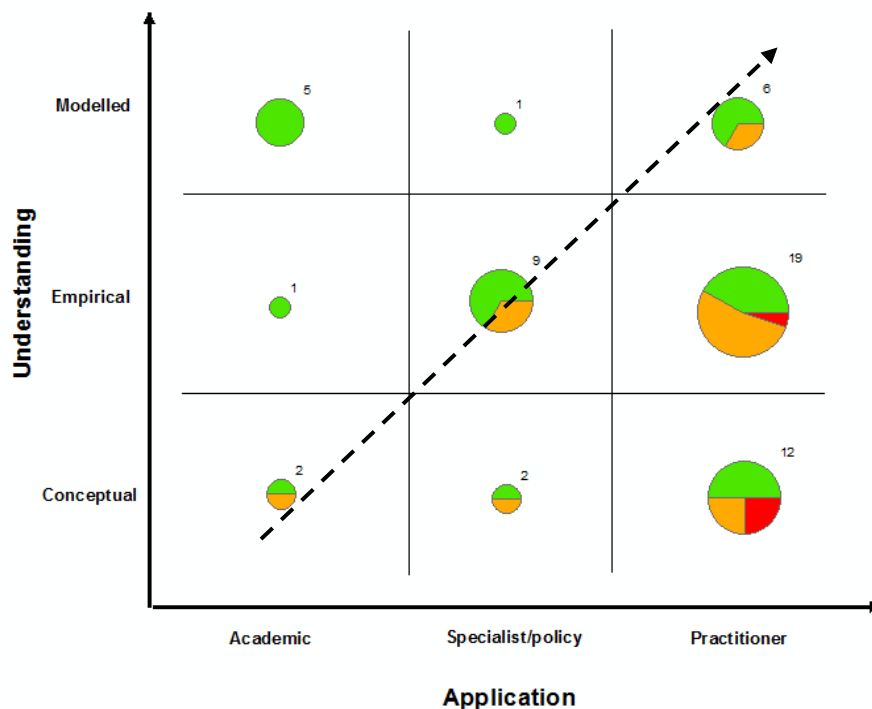
Question 3: Do we understand the implications of sediment supply and dynamics for FCERM over a variety of timescales, to enable us to manage sediment-related issues sustainably?

Summary of question

This is about understanding the implications of sediment supply and dynamics for FCERM to help decision makers, communities and stakeholders understand how best to manage sediment-related FRM issues sustainably. What information is required to assess catchment sediment supply and sediment dynamics in the fluvial system over a variety of timescales?

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this research question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The size of the pie chart represents the strength of evidence in terms of relevance to the question and the colour represents how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not completed).



The graph shows that there is a reasonable spread of evidence across the whole chart, and importantly there is a large amount of green in most areas suggesting available evidence is useful in addressing the research question. The most evidence available is at the practitioner level, consisting largely of guidance documents, reports, quantitative tools such as those developed through the FRMRC.

Understanding of need for this question:

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Question 3: Do we understand the implications of sediment supply and dynamics for FCERM over a variety of timescales, to enable us to manage sediment-related issues sustainably?

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP Stakeholder Workshop in September 2013.

This research question has been produced from three sources:

- An internal Environment Agency workshop held in Oct 2012 identified a need for guidance on sustainable sediment management techniques, helping to justify FRM maintenance programmes i.e. desilting/dredging.
- The LWEC FCERM Strategy identified a need ('Managing Probability' Theme, MP12) to better understand long-term change in sediment supply and dynamics.
- The WWNP Stakeholder Workshop held on 24th September 2013 identified the need to:
 - Improve the evidence base of long-term studies and data (coarse and fine from a range of locations, fluvial and coastal) to help define 'dynamism' versus 'natural' variability. This includes the ability to characterise morphological responses at a variety of time-scales from short term (intra-storm) to long term (multi-decadal).
 - Better monitoring and evaluation to determine the role of sediment and morphology in influencing FCERM actions and the implications of future changes in sediments and morphology for sustainable FCERM.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

This research question is addressed well by relevant evidence (shown in green in the graph). This however is variable and light in relation to academic research and specialist/policy evidence. This does suggest that we already know a fair amount about how to manage sediments, but we don't understand how this relates to flood risk and its sustainable management very well. This observation also came out of the WWNP stakeholder workshop, which identified that although, 'a lot of data has been collected - the problem is that it is not always fit for purpose i.e. trying to extrapolate trends for which data was not collected in the first place'. This research question therefore requires more appropriate data sources (with the correct spatial and temporal extents) from which to be able to address the need to better understand long-term changes in sediment supply and dynamics and the morphological responses to sediment imbalances in the fluvial system. Therefore, while the evidence collated is useful, the need is not well represented by the available evidence and this represents a widely recognised gap in our knowledge.

[Please note it is beyond the scope of this project to comment on the quality of individual pieces of research].

Fluvial and coastal geomorphology (including sediment management and restoring natural processes)

Question 3: Do we understand the implications of sediment supply and dynamics for FCERM over a variety of timescales, to enable us to manage sediment-related issues sustainably?

Research gaps identified for this question:

FCG Q3a) Improve the evidence base (case studies/post project monitoring and appraisal) to better understand long-term changes in sediment supply and dynamics so that we can identify better ways to manage sediment (in particular more evidence to support or amend existing FRM maintenance programmes; particularly through dredging/desilting).

Appendix C1 – Data and evidence for Green Engineering

Topic: Green engineering (including mitigation measure and sustainable alternatives to hard-engineering)

What does this topic cover?

Existing and on-going research and evidence in WWNP and FCERM relevant to:

- Fluvial and coastal green engineering solutions (including rural and urban applications)
- FCERM mitigation measures
- Sustainable alternatives to hard-engineering

What is included in the Data & Evidence Review? (Part 1)

Each piece of evidence has been documented including basic information such as title, author, year published, organisation etc:

79 pieces of research received from various sources including the Environment Agency, Defra, The Hutton Institute, Association of Drainage Authorities and the River Restoration Centre. 67 were deemed relevant to both FCERM and WWNP. Of these, 58 are completed documents/reports/papers published between 1993 and 2013. 3 are in draft or yet to be published. This also includes 6 pieces of commissioned or yet to be completed pieces of research e.g. SUDs Manual update/RRC Manual Update and the WFD Mitigation Measures Manual Update.

What types of evidence are included in the Data & Evidence Review? (Part 2)

The evidence has been categorised to interpret its spread and coverage in the following ways:

Research delivered through Joint Defra/EA Flood & Coastal Erosion Risk Management R&D programme: 25 of 67

Number of pieces of research by R&D Category (of 67):

- Basic (concepts & philosophies) – 10
- Applied (methods & approaches) – 19
- Dissemination & training (software, guide, training) – 10
- Development & pilots (tools, case studies) – 26
- Implementation (better decision) – 2
- Not known – 0

Number of pieces of research by output type (of 67):

- Report – 26
- Data – 0
- Tool – 0
- Guidance – 31
- Paper – 7
- Other/not known – 3

Number of pieces of research by geographical coverage (of 67):

- Site specific – 0
- Local – 5

Topic: Green engineering (including mitigation measure and sustainable alternatives to hard-engineering)

- Regional – 8
- National – 50
- Global – 4
- Not known – 0

Number of pieces of research by principal data type (of 67):

- Primary quantitative – 14
- Primary qualitative – 12
- Secondary quantitative – 8
- Secondary qualitative – 30
- Not applicable/not known – 3

Number of pieces of research by target audience (of 67):

- Academic – 7
- Policy/specialist – 18
- Practitioner – 42
- Not known – 0

Number of pieces of research by type of understanding (of 67):

- Conceptual (or theoretical) – 7
- Empirical (based on actual observation) – 57
- Modelled (predicted behaviour based on observation elsewhere) – 3
- Not known – 0

Popular or additional evidence for this topic from stakeholder workshop

At the workshop held in September 2013, attendees were asked to list the existing information (reports/tools/guidance etc) that they primarily to deliver WWNP in FCERM under this topic. Key documents used by stakeholders under this topic (list of attendees given in Appendix C) can be summarised as the following:

- Broad scale models of catchment sediment dynamics (e.g. SIAM, ST:REAM, Isis-Sediment)
- ADA/NE Biodiversity and Maintenance Guide
- Rural FRM using multifunctional green infrastructure. i.e. Beckingham Marshes, Lincolnshire
- Urban river habitat survey tool
- Mitigation Measures Manual
- Green roof toolkit
- SUDs Manual

Appendix C2 – Gap analysis for Green Engineering

GE Q1: Green engineering

Topic: Green engineering (including mitigation measure and sustainable alternatives to hard-engineering)

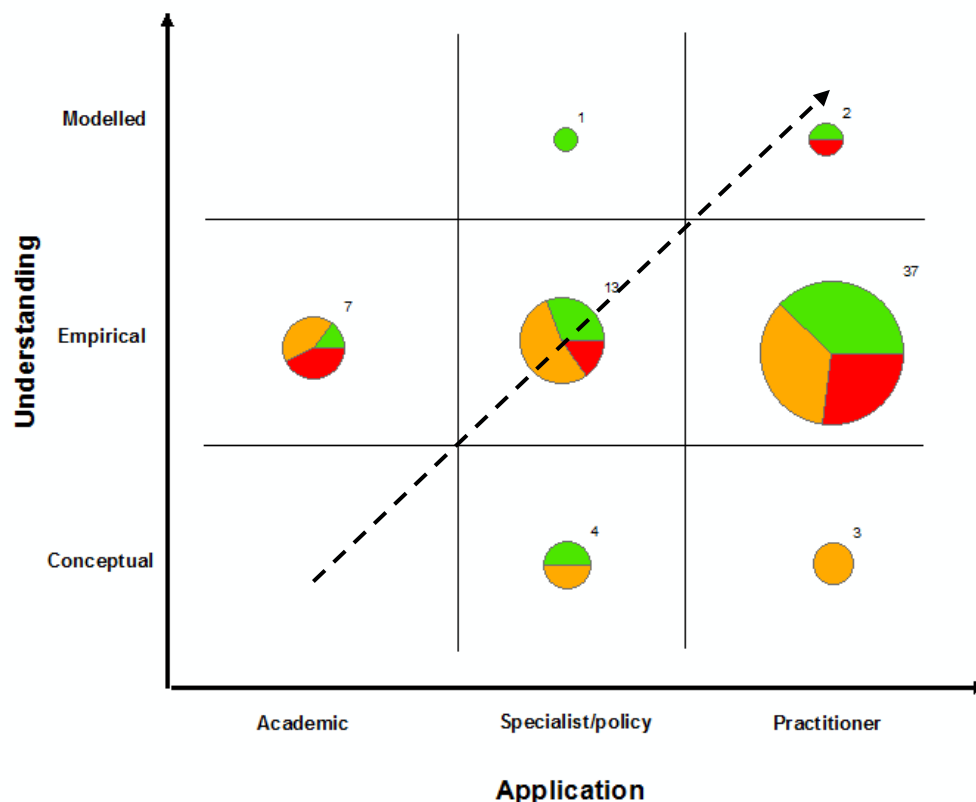
Question 1: Are there effective techniques to apply Green Engineering solutions in FCERM?

Summary of question

This is relevant to options appraisal (comparing traditional approaches with more sustainable ‘soft’ solutions, robustness within the FCERM context) and in implementation and delivery (developing and implementing sustainable alternatives to hard-engineering and post scheme mitigation measures in cases where there have in the past been unsympathetic solutions).

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this question by ‘understanding’ and ‘application’. This categorises the evidence into nine types (see Section 3.4 in report). The size of the pie chart represents the strength of evidence in terms of data/research relevance to the question, and the colour indicates how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).



Topic: Green engineering (including mitigation measure and sustainable alternatives to hard-engineering)

Question 1: Are there effective techniques to apply Green Engineering solutions in FCERM?

The graph shows that most research has been completed for practitioners (guidance documents and reports). The size of the pie charts clearly show that the number of research pieces tails off for application by specialists or in formulating policy, with the fewest pieces of research available from academics (such as papers). This observation was also inferred from the outputs of the WWNP stakeholder workshop.

Also, empirical research, particularly for practitioners, appears to be strongest (depicted by the colour) in addressing the question (Are there effective techniques to apply Green Engineering solutions in FCERM?). This is weakest at the conceptual end especially from academia. There was limited modelled information identified, however what there was, is relevant in addressing the question.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

This overarching question was derived from LWEC MP16 stating the need for more empirical studies and guidance for practitioners on the application of green design techniques. The EA R&D workshop identified the following specific needs which have also been taken into consideration within the development of the overarching question:

- Cost, lifespan, pros and cons of green engineering techniques.
- Techniques manual for green engineering (putting nature back into FCERM schemes) in both urban and rural environments.
- Giving local communities the capacity to deliver green engineering FCERM solutions.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage has been compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph suggests there is limited scientific research on green engineering from the academic arena. This is supported by the view from the WWNP stakeholder workshop which suggests there is a lack of scientific quantitative evidence on the use of green engineering techniques in FCERM. Looking at the Data & Evidence Register more closely, this identifies that there is a lot of research based on empirical data, which is especially abundant for practitioners, in the form of risk-based guidance. This suggests that there is limited need for more empirical studies and guidance for practitioners which was the need identified in LWEC. The gap analysis does, however, suggest that there is a need for sound quantitative evidence to support the wider use of green engineering in FCERM. This need was also identified within the WWNP Stakeholder Workshop, which highlighted the need for 'Quantitative evidence for bioprotection to reduce asset deterioration (more from pilot evidence to operationally robust evidence) and more funds to 'build evidence base on areas which are less well developed e.g. Structurally engineered designs; novel 'urban habitats' as well as 'Research looking at

Topic: Green engineering (including mitigation measure and sustainable alternatives to hard-engineering)

Question 1: Are there effective techniques to apply Green Engineering solutions in FCERM?

how urban ecosystems and infrastructure do/can provide FCERM and wider benefits’.

It was also highlighted at the WWNP Workshop that there is a need for a more ‘Adaptive’ approach to green engineering and acceptance that ‘the future is not just uncertain it is unknowable - hence engineering solutions must be adaptable and resilient – in order to go on providing good performance however the future unfolds’.

The WWNP Workshop also highlighted the need for ‘Legislation to facilitate FCERM and biodiversity, as current Habitat Regulations restrict bio-benefits’ and a need to ‘Align policies because existing HLS/ELS restrictions on farmers could conflict with sustainable FCERM’. This is consistent with the gap identified within the ‘conceptual’ area of the graph above.

The DER also indicates that the information collected is mostly derived from the UK, however it was indicated at the WWNP Stakeholder Workshop that ‘On the continent they seem to have passed a tipping point where a wider range of options can be discussed’. It may be necessary to explore the wider/global evidence base to provide further evidence supporting broadened implementation of green engineering in FCERM.

Research gaps identified for this question:

- GE Q1 a) More research to provide a sounder quantitative evidence base to support the application of green engineering in FCERM. This would be used to reduce uncertainty, manage risk, and answer challenges.
- GE Q1 b) Developing more adaptive/resilient green engineering to accommodate uncertainty and reduce future risks sustainably (i.e. the future is not just uncertain it is unknowable).
- GE Q1 c) Legislation to facilitate Green Engineering within FCERM and to ensure the consistency and alignment of existing policies.
- GE Q1 d) Ensure techniques and evidence from overseas are made available for application in the UK through enhanced knowledge transfer and uptake.

Appendix D1 – Data and evidence for Habitats and Species

Topic: Habitats and Species

What does this topic cover?

Existing and on-going research and evidence in WWNP and FCERM relevant to:

- Managing vegetation
- Meeting biodiversity targets
- Allowing fish and eel passage.

What is included in the Data & Evidence Review? (Part 1)

Each piece of evidence has been documented including basic information such as title, author, year published, organisation etc:

98 pieces of research received from various sources including the Environment Agency, Defra, and The Hutton Institute. 81 were deemed relevant to both FCERM and WWNP.

What types of evidence are included in the Data & Evidence Review? (Part 2)

The evidence has been categorised to interpret its spread and coverage in the following ways:

Number of pieces of evidence delivered through Joint Defra/EA Flood & Coastal Erosion Risk Management R&D programme: 15 of 81

Number of pieces of evidence by R&D Category (of 81):

- Basic (concepts & philosophies) - 16
- Applied (methods & approaches) - 26
- Dissemination & training (software, guide, training) - 11
- Development & pilots (tools, case studies) - 27
- Implementation (better decision) – 1

Number of pieces of research by output type (of 81):

- Report – 34
- Data – 1
- Tool – 6
- Guidance – 19
- Paper – 15
- Other/not known – 6

Number of pieces of research by geographical coverage (of 81):

- Site specific – 9
- Local – 4
- Regional – 11
- National – 46
- Global – 10
- Not known - 1

Number of pieces of research by principal data type (of 81):

- Primary quantitative – 24

Topic: Habitats and Species

- Primary qualitative – 5
- Secondary quantitative – 22
- Secondary qualitative – 29
- Not applicable/not known – 1

Number of pieces of research by target audience (of 81):

- Academic – 15
- Policy/specialist – 25
- Practitioner – 41

Number of pieces of research by type of understanding (of 81):

- Conceptual (or theoretical) – 15
- Empirical (based on actual observation) – 59
- Modelled (predicted behaviour based on observation elsewhere) – 7

Popular or additional evidence for this topic from stakeholder workshop

At the workshop held in September 2013, attendees were asked to list the existing information (reports/tools/guidance etc) that they use primarily to deliver WWNP in FCERM under this topic. Key documents used by stakeholders under this topic (list of attendees given in Appendix C) can be summarised as the following:

For vegetation management this included:

- Tools such as the Conveyance Estimate System (CES) to estimate vegetation roughness and inform vegetation management.
- Vegetation management guidance documents such as: those for riparian woods (developed by the Forestry Commission); management of invasive species (by the Centre of Aquatic Plant Management); the WFD Mitigation Measures Manual; Internal Drainage Board vegetation management guidance; Environment Agency Maintenance Standards; Passive design guidance; the new EA Channel Management Handbook, and; the soon to be published guide on flooding and agriculture for farmers.
- Reports such as the Woodland for Water review which includes recommendations for future research; reports on pilot and demonstration projects where vegetation management (and NFM) has been implemented such as the Pickering and Belford catchment pilot projects and the flood embankment vegetation management trials.
- Ongoing research and development projects by the Environment Agency on Aquatic Vegetation Management, further forest and water guidelines being produced by the Forestry Commission and the outcomes of dredging trials.

For meeting biodiversity targets, this included:

- Reports, case studies and data generated for pilot and demonstration projects where habitat creation (and NFM) has been implemented such as the Pickering and Belford catchment pilot projects, Bassenthwaite Ecosystem Approach project, Rivers Skerne and Cole Restoration Projects and other RRC case studies, outputs from the United Utilities SCaMP project, habitat creation projects on the Humber Estuary, and the Mersey Life Project (linking WFD to river restoration targets).
- Guidance documents such as the most recent FCERM Appraisal Guidance and The Drainage Channel Biodiversity Manual.

Topic: Habitats and Species

- Tools such as Cost-benefit appraisal tools; CFMP runoff modelling tool (for habitat creation and NFM); modelling and tools used in the development of EA estuary strategies to predict habitat losses and gains; the Environment Agency Synergies Mapping model being developed for WFD and Biodiversity delivery.
- Academic studies such as UEA's work on the quality of saltmarsh created through managed realignment and Robert Nichol's (Southampton University) work on using off-shore reefs for FCERM.

For meeting fish and eel passage requirements this included:

- A number of tools (concerning, for example, habitat assessments and requirements of different fish species, and swimming capabilities of fish), such as Habscore, PHabsim, SIDO-UK, River Habitat Surveys, and SWIMIT.
- Guidance documents such as screening and abstraction best practice guidance, assorted river restoration manuals, and various research and development projects through the 1990s-2000s, concerning the habitat requirements of different fish species.

Appendix D2 – Gap analysis for Habitats and Species

HS Q1: Habitats and species

Topic: Habitats and species

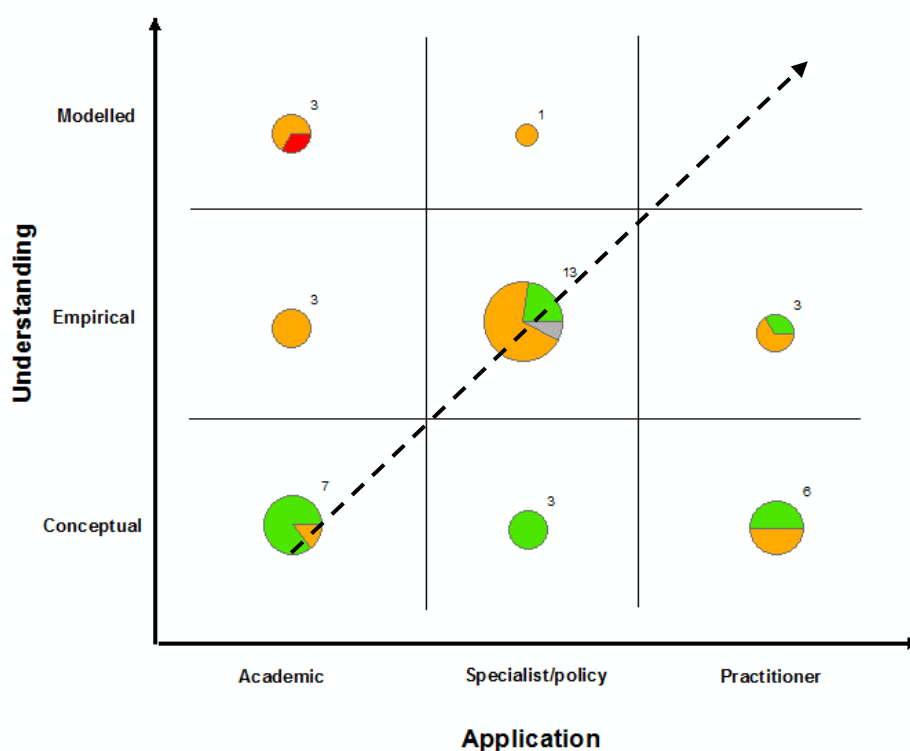
Question 1: How effective is FCERM habitat creation in delivering Habitats & Bird Directives, WFD Requirements and the England Biodiversity Strategy?

Summary of question

This question concerns how our present understanding contributes to achieving future biodiversity and habitat creation targets (both quantity and quality) through actions prompted by, or related to, FCERM. This includes the outcomes of: catchment and regional habitat creation projects and programmes; post project monitoring and appraisals; case studies and habitat creation guides, and; manuals and tools. Evidence is required for fluvial, estuarine and coastal habitat creation and restoration, both for sites that form discrete units, areas of wetland habitat and linear riparian corridors, across a variety of spatial scales.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The chart below maps the existing evidence available to help answer this question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of data/research relevance to the question, and how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).



Topic: Habitats and species

Question 1: How effective is FCERM habitat creation in delivering Habitats & Bird Directives, WFD Requirements and the England Biodiversity Strategy?

The R&D Spectrum graph indicates that the majority of research into habitat creation has been completed through review of empirical research (namely collections of case studies), or from the outputs of site specific monitoring and observations of habitat creation projects or actions. The chart also indicates that the creation of habitat is founded upon an established, academically peer reviewed, conceptual understanding of habitat creation principles that is documented in a number of advisory practitioner guides.

The strength of conceptual research and the availability of a number of established advisory guidance documents in meeting the need for habitat creation in FCERM was reflected in the observations made by attendees in the WWNP stakeholder workshop, with a general consensus that there is sufficient evidence at this level to understand the general requirements and techniques for habitat creation at the reach/site specific/local scale.

Despite there being wide coverage of empirical evidence from local and site specific case studies of habitat creation, less evidence is available on use and occupancy of habitats created. Generally, then, the strength of the coverage provided by case studies (either individually or collectively) is limited by the general short term “snapshot” nature of monitoring and review of project outcomes, and the variability in how biodiversity and FCERM outcomes were analysed, compared or linked. The observations of WWNP stakeholder workshop attendees also highlighted a perceived lack of long term monitoring of sites and, as a consequence, the remaining residual uncertainty over the success of habitat creation projects against quality targets and conservation objectives. Essentially, in linking habitat creation to benefits associated with increased biodiversity and improved provision of ecosystem services, there is still reliance on the concept that if wide range of good quality habitats are created, this will lead to increases in species richness and diversity – the so called ‘field of dreams’ hypothesis: *build it and they will come*, which has been seriously questioned in the academic literature.

Review of the available evidence base indicates that quantitative, modelled research is not well represented or documented either in the range of models available to aid habitat creation and in its level of maturity. This was reflected in outputs of the WWNP stakeholder workshop, where it was noted that current modelling tools are hydrological/hydraulic models that have been adapted for a use other than their intended, primary purpose (i.e. modelling flood flows and inundation extents), meaning that they may be sub-optimal in terms of providing the information needed for habitat design and creation.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

The LWEC FRM Strategy states the need to learn lessons from national and international experience to meet legal obligations to avoid habitat loss due to FCERM or (where that is unavoidable), mitigate habitat loss through identification of suitable sites/areas and understanding of pathways habitat creation. The WWNP stakeholder workshop and FCERM staff stated needs that underpin this question also include:

Topic: Habitats and species

Question 1: How effective is FCERM habitat creation in delivering Habitats & Bird Directives, WFD Requirements and the England Biodiversity Strategy?

- The need to maximise habitat creation and biodiversity improvement as part of the development of FCERM plans and projects.
- The need to create more habitat on existing FCERM assets (notably flood storage areas such as washlands and reconnected floodplains).
- The need to demonstrate with a high level of confidence the degree to which FCERM habitat creation can offset the adverse impacts of climate change.
- The need to demonstrate that habitat creation projects make best use sites and areas with the greatest ecological potential, in order to provide the quantity and quality of habitat required to meet biodiversity targets at the least cost.
- The need to understand the linkages between natural processes and ecosystem functions at a variety of scales to maximise benefits:cost ratios for habitat restoration and creation performed as part of FCERM projects and actions.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph indicates that, whilst there is an abundance of empirical evidence with a varying level of validity information regarding the performance of habitat creation, there is little risk-based guidance to support the development of habitat creation through FCERM asset management and development. This finding was supported at the WWNP stakeholder workshop, where it was noted that this gap contributes to the tendency 'silo-thinking' in the development of options for FCERM projects and actions. The result of silo-thinking is inadequate integration of land management, engineering, social and environmental functions in FCERM capital works and operations, both within the Environment Agency in delivering FCERM and by the suppliers it uses to design, construct and maintain FCERM infrastructure.

What is required is development of the evidence base necessary to better inform decision makers at all levels concerning how to avoid habitat damage or loss, how to take maximum advantage of opportunities for habitat creation, and how to recognise, deliver and evaluate the full range of FCERM (and other) benefits habitat conservation and creation can provide. Guidance is needed on the level and nature of evidence required to allow the development and acceptance of more robust business cases for FCERM with fully (or at least better) integrated habitat creation, at a range of scales during project planning, implementation, monitoring and adaptive management.

In this context, stakeholder views reinforce the finding evident in the Data and Evidence Register, that the link between systematic, long-term, post-project monitoring and appraisal, and the development of more "business" focused, risk based guidance on identification and development of habitat creation in FCERM plans and projects needs to be clarified.

The quality and duration of post project monitoring and appraisal vary widely between projects, and a number of studies highlighted remaining uncertainties associated with longer-term evolution of habitat creation sites (e.g. the diversity of saltmarsh flora) in the context of hitting obligatory targets for biodiversity. Further analysis of the

Topic: Habitats and species

Question 1: How effective is FCERM habitat creation in delivering Habitats & Bird Directives, WFD Requirements and the England Biodiversity Strategy?

performance of the quality of habitat creation sites against relevant conservation objectives that, in turn, informs review and revision of advisory guidance, would enable practitioners to build on lessons learned from monitoring of completed habitat creation sites. In addition, few advisory guidance items have adequately considered how adaptive management can reduce future risks related to (for example) FCERM, hitting obligatory targets for habitats, climate change, unintended consequences etc.

Research gaps identified for this question:

- HS Q1a) More systematic long term monitoring and post project appraisal to develop the evidence base to simultaneously meet FCERM, WWNP and biodiversity target needs.
- HS Q1b) Guidance on the nature (empirical or modelled) and the level of confidence that must be attained in evidence in order for it to provide the science basis needed for development and acceptance (by sceptics) of more robust business cases for FCERM projects and actions that integrate habitat conservation, enhancement and/or creation at a range of scales, during plan/project development.
- HS Q1c) Developing sound, risk-based guidance that encourages a more holistic approach to FCERM planning, design, implementation and monitoring and that enables costs, benefits, hazards and management/maintenance issues to be clearly communicated to decision makers.
- HS Q1d) New advisory guidance that is accurately informed by outcomes and lessons learned from monitoring and post-project appraisal of exiting projects and which is periodically reviewed and refreshed as necessary to keep it at the forefront of best practice nationally and internationally.

HS Q2: Habitats and species

Topic: Habitats and species

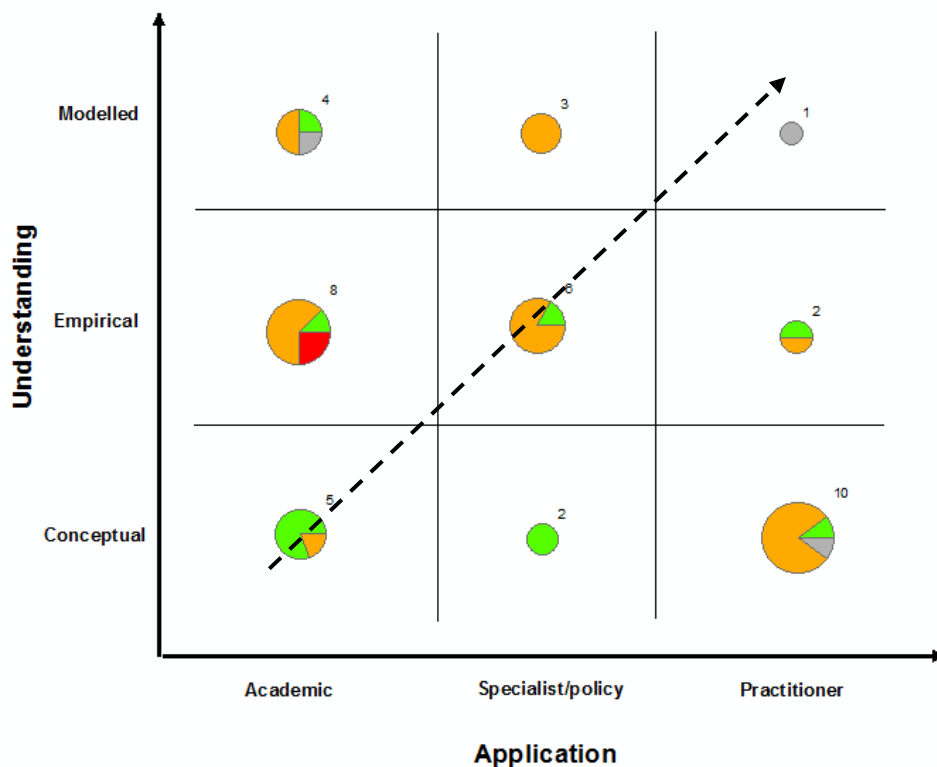
Question 2: How effective are we at being able to manage riparian, marginal and aquatic vegetation to reduce flood risk by using WWNP to achieve wider environmental and socio-economic benefits?

Summary of question

This question focuses on understanding how vegetation affects FCERM asset performance and how knowledge of riparian, marginal and aquatic vegetation management approaches and techniques can be applied to best work with vegetative processes through FCERM that WWNP. This includes results from Environment Agency evidence reviews, peer reviewed, academic research and monitoring papers, experimental research trials, case studies, and river and land drainage channel habitat management documents (guides, manuals and tools). Evidence is required for vegetation management in fluvial, estuarine and coastal environments and for natural, managed and heavily modified water bodies, across a variety of spatial scales.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of data/research relevance to the question, and how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).



The R&D Spectrum plots indicates that the majority of research into vegetation management has been completed at the empirical level within the academic and

Topic: Habitats and species

Question 2: How effective are we at being able to manage riparian, marginal and aquatic vegetation to reduce flood risk by using WWNP to achieve wider environmental and socio-economic benefits?

specialist pools, whilst there are also a number of advisory practitioner guides at the operational level. A greater number of studies appear to be complete or underway in the academic pool. The numbers of studies in the specialist and practitioner pools are lower.

Academic, conceptual research into the range of techniques that work with natural processes for riparian, marginal and aquatic vegetation management appears to be well established (although it is noted that a small proportion of the work has been undertaken in the last 15 years). However, the majority of empirical studies in both the academic and specialist fields do not directly link vegetation management to FCERM outcomes or WWNP.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

The over arching question was derived from LWEC WP11's statement of the need for research to ensure that vegetation maintenance is optimised from both performance and cost perspectives, particularly in light of potential climate change impacts on ecosystem composition, seasonality and growth rates. The role of vegetation in flood risk management needs to be clarified and simple practical guidance provided. The WWNP stakeholder workshop and FCERM staff stated needs that underpin this question to include:

- The need to more deeply understand and have greater confidence concerning the role of vegetation management (including that of invasive species) in managing flood risk.
- The need to understand whether additional tools (such as predictive modelling) are required to determine when to undertake active (i.e. cutting/clearing) vegetation management.
- The need to understand where in fluvial and estuarine systems woody debris provides the greatest benefits and lowest costs, while keeping risks to property to an acceptable level and avoiding risks to life entirely.
- The need to determine whether there is sufficient evidence to support integration of effective/multi-benefit vegetation use and management into routine FCERM asset design and maintenance, or whether this remains specific to projects and actions intended to WWNP.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph suggests limited coverage of relevant data/research for predictive analysis/modelling of the role of vegetation management in FCERM. In addition there

Topic: Habitats and species

Question 2: How effective are we at being able to manage riparian, marginal and aquatic vegetation to reduce flood risk by using WWNP to achieve wider environmental and socio-economic benefits?

is limited provision of risk-based guidance covering the range of vegetation management techniques available.

Further scrutiny of the DER indicates that the majority of guidance takes a precautionary approach, with the precautionary nature dependent on the aim of the author i.e. FCERM guidance focused on conveyance uses doubt as a driver for active vegetation management/removal, while Wildlife Trust guidance recommends removal of woody debris only after hydraulic modelling has been used to identify/verify that it poses an unacceptable risk to people or property. Lack of coverage in these sectors of the R&D spectrum may result from limited availability or access to empirical evidence focused on the interaction of vegetation/woody debris with flooding mechanisms and hydromorphological process, a gap noted by stakeholders in the WWNP Workshop. Predictive tools are available to Environment Agency practitioners (i.e. Conveyance Estimation Tool) however it is unknown how widely these are used.

Recent research to generate empirical evidence appears narrowly focussed on variations in mechanical (e.g. flood embankment trials) or chemical control (invasive species control). However, little recent or long-term empirical evidence has been generated in the UK concerning the application and effectiveness of environmental/biological approaches to controlling vegetation for FCERM (e.g. use of shade to limit marginal/aquatic plant growth, planting of low maintenance guilds/species mixes) – which contrasts with the finding on international evidence. Recently commissioned work on Aquatic and Riparian Plant Management Controls may contribute to reducing this gap, however.

Evidence of the role of woody debris and its interaction with flood risk and FCERM is limited and variable, focusing on a) the habitat and biodiversity benefits as a driver for leaving or placing woody debris in channel; and b) specialist empirical and predictive analysis of potential flood storage benefits of floodplain storage associated with woody debris (permanent/ephemeral log jams) in woodland environments. Further evidence is required to improve empirical understanding of the influence of woody debris in areas at low to high risk of flooding and/or coastal erosion, and in understanding the circumstance/conditions when woody debris can be used as part of WWNP in FCERM through, for example, flood storage, flood attenuation and NFM.

Evidence related to the influence of invasive species on biodiversity and on FCERM is well covered in the academic conceptual and empirical evidence. Controls and management to eradicate invasive species are also fairly well covered, while apparent gaps already identified in relation to in-channel interactions between vegetation and flooding are consistent with those identified in the management of native vegetation.

Research gaps identified for this question:

- HS Q2a) Limited recent or long term empirical UK evidence regarding environmental and biological control approaches to controlling vegetation for FCERM, especially compared to international evidence.
- HS Q2b) Risk-based guidance covering the full range of vegetation management techniques is lacking.
- HS Q2c) Conflicts exist between different sources of precautionary guidance on vegetation management due to uncertainty concerning the degree to which in-channel vegetation and its management influences flood risk and the

Topic: Habitats and species

Question 2: How effective are we at being able to manage riparian, marginal and aquatic vegetation to reduce flood risk by using WWNP to achieve wider environmental and socio-economic benefits?

costs, benefits and outcomes of either removing vegetation, leaving it in place or planting it.

HS Q2d) Limited empirical understanding of woody debris as either contributing to flood risk (e.g. through blocking grey infrastructure) or as a component of NFM (e.g. through attenuating flood waves or storing flood water).

HS Q3: Habitats and species

Topic: Habitats and species

Question 3: How well are we able to measure and predict the range of FCERM and other benefits that small to large scale habitat creation/restoration provides?

Summary of question

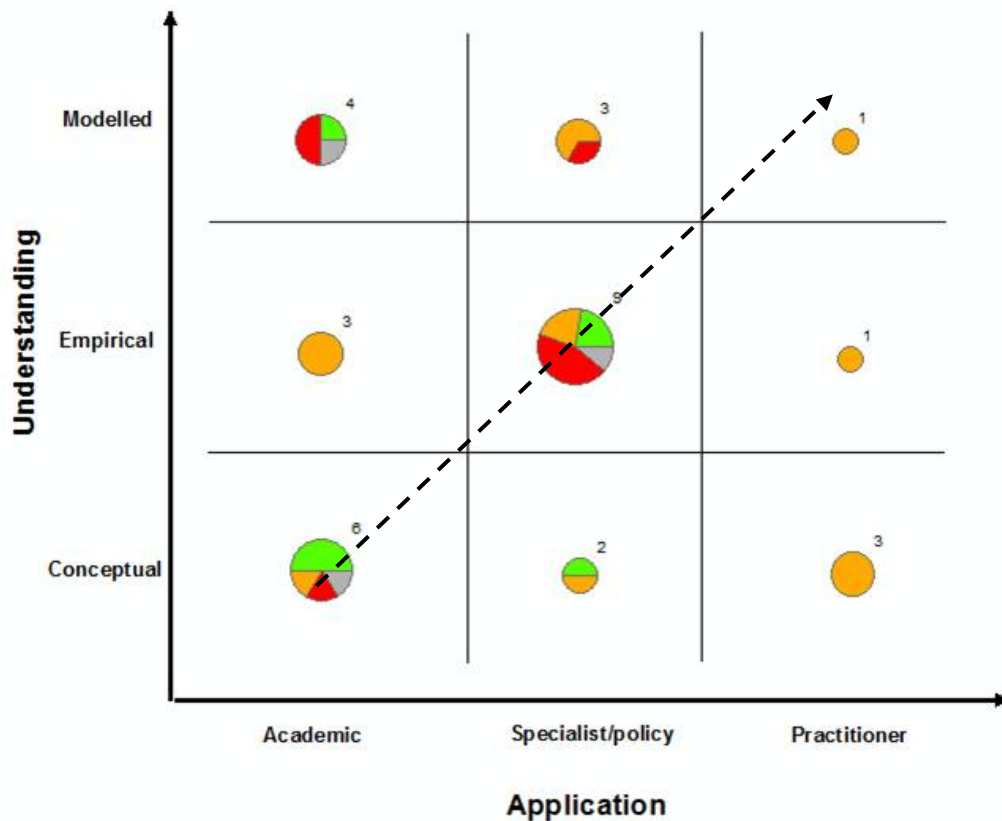
This question concerns the understanding of how well we are able to identify, understand and predict the range of FCERM and additional benefits provided by WWNP to conserve, restore and create fluvial, estuarine and coastal habitats. This question supports/underpins how we are able to evaluate those benefits, communicate them to stakeholders and provide the data and confidence needed to inform and support incorporation of ecosystem services analysis into FCERM business cases. This includes results from independent academic, peer reviewed research and monitoring papers, case studies, and river restoration and land drainage channel habitat documents (management guides, manuals and tools). Evidence is required for fluvial, estuarine and coastal environments, in urban and rural settings, and for natural, managed and heavily modified water bodies, across a variety of spatial scales.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of data/research relevance to the question, and how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).

Topic: Habitats and species

Question 3: How well are we able to measure and predict the range of FCERM and other benefits that small to large scale habitat creation/restoration provides?



The graph shows that majority of the research associated with this question has been undertaken in the specialist and academic arenas. There is little evidence in the practitioner arena. The greatest weight of evidence comprises reports and documents that provide either singular or collated case studies, completed by a range of authors from academic and research institutions, Environment Agency research projects and the private and third sectors.

The conceptual research presented appears most complete in relation to identification of potential benefits. However, the strength of research beyond the conceptual level is variable and reflects the fact that identification, measurement and prediction of the multi-objective benefits from habitat conservation, restoration and creation is not the primary aim of the majority of the available research outputs.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

The over arching question was derived from LWEC UR14, which identifies the need to understand the true benefits of FCERM to people, property, institutions and the environment. The question also contributes/underpins the needs expressed in UR13 and UR17 for a multi-objective ecosystems approach to FCERM.

Topic: Habitats and species

Question 3: How well are we able to measure and predict the range of FCERM and other benefits that small to large scale habitat creation/restoration provides?

Participants in the WWNP workshop and FCERM staff stated that needs that underpin this question also include:

- What do we already understand about ecosystem services and how can we quantify the benefits ecosystem services provide?
- How do we adopt an ecosystems services approach to FCERM planning, design, implementation, maintenance, and mitigation in practice?

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

Matching the stated needs against the profile of evidence on the R&D spectrum highlights that there is a gap in focussed research which translates the benefits of habitat creation into a form that can be readily used for an ecosystems services assessment, or that can be readily convey to decision makers/stakeholders other than it being a “good thing to do”. The existing guidance focuses more on how to identify benefits, and less on how to monitor, measure or assess what the resulting benefits are beyond identifying a narrow range of conservation outcomes and targets.

There is a need to prioritise research into the benefits that different habitats are able to provide in different settings (i.e. urban vs rural, fluvial vs estuarial and coastal), because research and monitoring appears to be more mature for some habitats than others (i.e. intertidal habitats have received significantly more attention than other habitats).

In general, wide variability in the empirical evidence leads to lack of confidence in the benefits to be gained from investing in habitat creation and the measurable gains it can deliver for WWNP in FCERM. This extends to reluctance to make the kinds of long-term commitments necessary to deliver the full range of benefits, because of uncertainty about just how long it would take for such benefits to be realised in practice.

Research gaps identified for this question:

- HS Q3a) Gap in focused research that translates ecosystem services into FCERM and other, multiple, benefits.
- HS Q3b) Varying levels of understanding of the benefits that different habitats provide: both different habitat types and different habitat locations (prioritising those most relevant to WWNP in FCERM).
- HS Q3c) Reducing uncertainty in our understanding of how long it takes for newly created or restored habitats to provide their full range of benefits.

HS Q4: Habitats and species

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

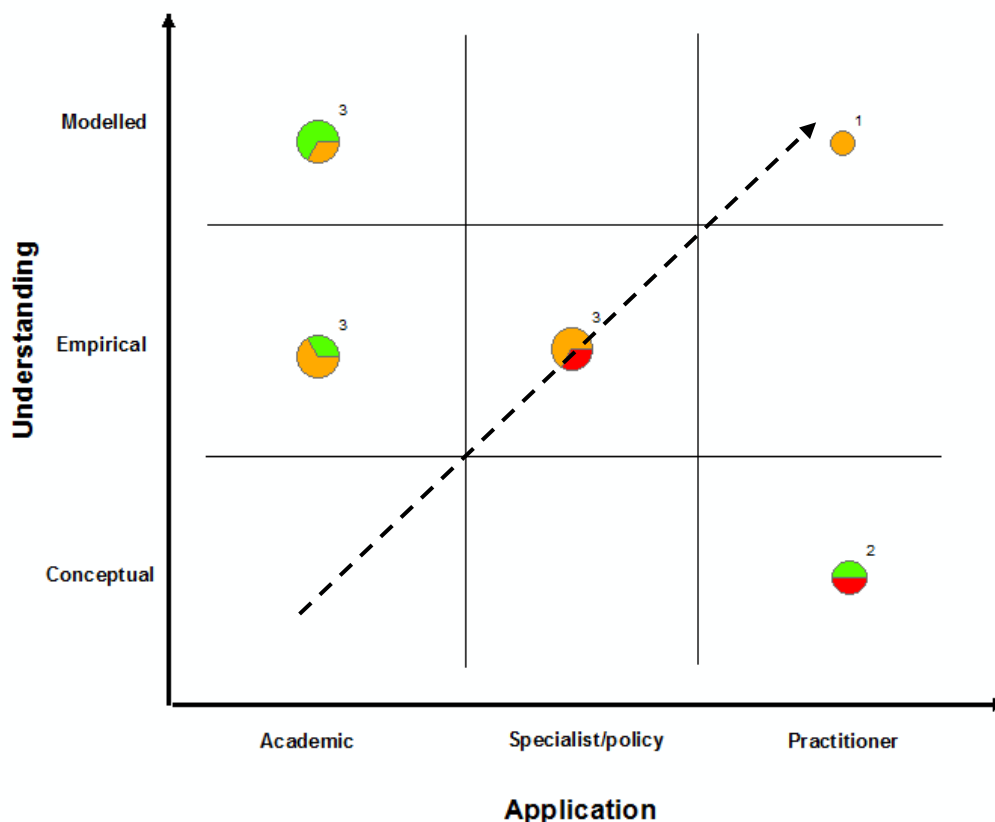
Research Question 4: What methods are available to assess the habitat requirements of fish, in order to deliver FCERM, WFD, eel regulation and SAFFA (Salmon & Freshwater Fisheries Act) objectives?

Summary of question

This is relevant to ensure that habitat conservation, restoration or creation for FRM using WWNP techniques (e.g. re-aligning coastal defences to conserve saltmarshes, or the creation of washlands with embedded wetlands along rivers) will improve (or at least conserve) fish populations to facilitate meeting objectives for WFD, eel regulations and SAFFA (Salmon & Freshwater Fisheries Act).

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer Research Question 4 by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of the evidence in terms of its relevance to the question and how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not complete).



Some research has been completed in the academic arena, with smaller amounts having been undertaken in the specialist/policy and practitioner arenas. However, the small pie charts in the graph suggest that the evidence base is thin. It is important to

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

Research Question 4: What methods are available to assess the habitat requirements of fish, in order to deliver FCERM, WFD, eel regulation and SAFFA (Salmon & Freshwater Fisheries Act) objectives?

note that the literature review used to populate the graph was not exhaustive, but intended to identify the most relevant literature and methods identified during the gap analysis.

Conceptual research is, according to the graphs, unavailable in the academic and specialist/policy arenas, though some does appear in the practitioner arena. The bulk of the modelling research is, perhaps unsurprisingly, undertaken in academic circles, with no evidence of such modelling being undertaken by specialists or policymakers, and only limited modelling research by practitioners. Modelling research may be available from practitioners, but this is likely to be in grey literature, which was not readily available for review.

Empirical research features in the academic and specialist policy arenas, but is likely to be available from practitioners only in grey literature that was not readily available or accessible.

Whilst the amount of evidence is very limited, much of that available is relevant to WWNP in FCERM (as depicted by the green coloured areas). Hence, it should be useful in addressing the research question and supporting WWNP in a FCERM business case.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP stakeholder workshop in September 2013.

This research question was derived from several sources:

- An internal Environment Agency workshop held in October 2012, which specifically identified a research need in relation to the value of saltmarsh in England, including for example, providing nursery habitat for fish and eels.
- The LWEC FCERM Strategy, which specifically identified a research need in relation to increased understanding of habitat quality.
- The WWNP Stakeholder Workshop held on 24th September 2013, which specifically identified a research need to effectively understand how different habitats support genetic diversity in fish, and how changes in habitat affect fish populations.

This question is needed to evaluate the currently available resources and tools for understanding fish habitat requirements in different types of waterbody, how habitat can successfully be enhanced, as well as the impacts on fish of altering habitat (e.g. what are the resulting benefits/disbenefits and how can these be modelled and monitored). Such understanding is required to evaluate habitat issues (e.g. habitat bottlenecks limiting species recruitment) such that they can be addressed to meet WFD targets and in ways that are aligned with FCERM. This is essential to allow FCERM to deliver multiple-benefits related to fish habitats and, ultimately, fish populations (via e.g. managed realignments) as well as reductions in flood risk to communities and key

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

Research Question 4: What methods are available to assess the habitat requirements of fish, in order to deliver FCERM, WFD, eel regulation and SAFFA (Salmon & Freshwater Fisheries Act) objectives?

infrastructure.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and outputs from the WWNP Stakeholder Workshop. This has been peer-reviewed.

The graphs indicate highly limited coverage of relevant data and research suitable for assessing fish habitat requirements across all arenas. The Data & Evidence Register indicates that the majority of available information relates to peer-reviewed published literature (which was also highlighted during the Stakeholder Workshop) of which there is a relatively large resource base. The extent and quality of evidence varies between individual species, reflecting a “salmon-centric” bias. Conversely, relatively little is known about estuarine and coastal fish guilds, which are also indicator species in transitional and coastal waters under the WFD. The research is also biased towards a limited number of riparian habitats. Consequently, it does not support consideration of connections between the coastal, estuarine and riparian habitats used by anadromous fish species. Furthermore, much of the information available appears to focus on habitats with limited extents. Consequently, the conceptual evidence available does not provide the over-arching knowledge required to support empirical studies and models for species with needs and ranges that change seasonally or during different life stages. As previously mentioned, some data may be available from the outcomes of post-project monitoring and appraisal of existing schemes, but this is likely to be in the form of grey literature that is not readily available.

This exercise has therefore highlighted a need to translate available scientific literature into practical guidance and assessment tools which can be applied for specific species and in the policy/specialist practitioner arenas.

Research gaps identified for this question:

- HS Q4a) A need for comprehensive reviews of habitat requirements for different species/species guilds. Whilst this may be available, at least to some extent, for salmonid species there is a need for a greater understanding of requirements for other species, especially eels, and how a lack of access to particular functional habitat types may create recruitment bottlenecks, thus limiting the potential to achieve WFD and of species-specific targets.
- HS Q4b) There is a need for available information on fish and eel habitat requirements to be transcribed into useable guidance for practitioners, specialists and policy makers. Standardised, auditable approaches to habitat assessment and the design, funding and implementation of habitat improvements are necessary to facilitate progress towards WFD compliance and meeting targets for fish populations (e.g. eel regulations and SAFFA (Salmon & Freshwater Fisheries Act) through actions and projects that are properly aligned with FCERM. This is essential to avoid potential conflicts between river, estuary and coastal management for conservation and for flood/coastal erosion. In the case of WWNP as part of delivering sustainable FCERM, standard approaches to habitat

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

Research Question 4: What methods are available to assess the habitat requirements of fish, in order to deliver FCERM, WFD, eel regulation and SAFFA (Salmon & Freshwater Fisheries Act) objectives?

assessment, conservation, restoration and creation are clearly indispensable to delivering multiple project functions simultaneously and sustainably.

HS Q4c) There is a requirement to monitor assess the success and failures of completed schemes (i.e. advancing best practice from successes, learning lessons from failures) to produce improved future implementation and policy guidance for habitat restoration in relation to improving fish and eel habitats when undertaking FCERM projects.

HS Q5: Habitats and species

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

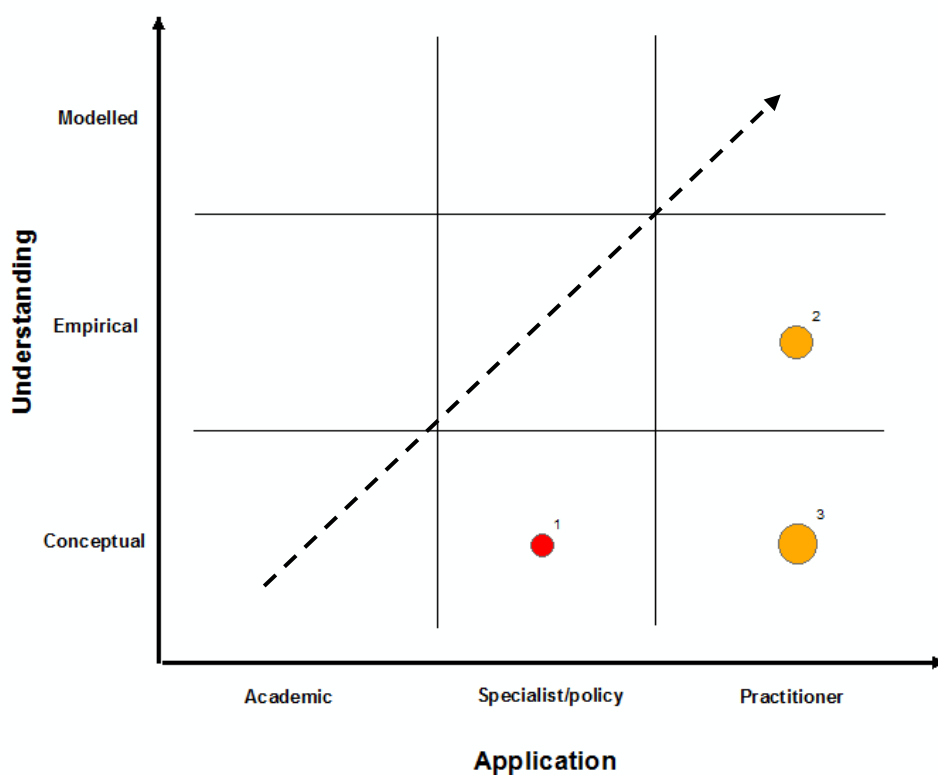
Research Question 5: What is our understanding of the effectiveness of engineered to more natural fish passage and screening techniques that might be used in delivery of WWNP, to meet the eel regulations and SAFFA (Salmon & Freshwater Fisheries Act) requirements?

Summary of question

This refers to instances where WWNP techniques will require more natural (termed 'volitional') fish passage solutions at, for example, pumping stations, diversions, weirs, sluices and tide gates). It aims to determine the knowledge available on alternatives for restoring volitional fish passage through solutions that are feasible in practice and which satisfy the requirements of the SAFFA and eel regulations.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer Research Question 5 by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in the main report). The colours represent the strength of the evidence in terms of its relevance to the question and how well it could help support or justify the business case for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known as research not complete).



The graph shows that there is very little research material available with regard to protecting, restoring or creating volitional fish and eel passage. Of the research that was identified, the majority came from the Practitioner arena, where it was

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

Research Question 5: What is our understanding of the effectiveness of engineered to more natural fish passage and screening techniques that might be used in delivery of WWNP, to meet the eel regulations and SAFFA (Salmon & Freshwater Fisheries Act) requirements?

predominantly conceptual research supported by limited numbers of empirical studies. The size of the pie charts is indicative of small volume of research while the colour (amber) illustrates that although the research is not highly relevant, it is still applicable to answering the research question.

Very little research material was identified in the Specialist and Policy arenas and its lack of relevance to the question is indicated by its red colour.

In this survey, no research was identified in the Academic arena. However, it is likely that there are some potentially relevant published articles which may become apparent via more detailed interrogation of available publications. For example, a significant amount of research with potential applicability to the UK may be available in the USA, Australia and New Zealand, but identifying this will require a focused literature search.

Understanding of need for this question:

R&D needs were identified from a review of the LWEC FRM Strategy & Mapping Exercise, outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the WWNP stakeholder workshop in September 2013.

Research Question 5 was derived from several sources as detailed below:

- An internal Environment Agency workshop held in October 2012, which specifically identified a research need in relation to the efficiency of fish and eel passage facilities
- The LWEC FCERM Strategy, which specifically identified a research need in relation to determining the effectiveness of behavioural fish screens, and assessing techniques to enable fish movement in washlands
- The WWNP stakeholder workshop held on 24th September 2013, which specifically identified a research need to undertake basic studies of fish and eel behaviours in relation to structures and improving passage and connectivity.

The question is needed to evaluate the currently available resources and tools for understanding the need for volitional fish and eel passage protection, restoration and creation solutions, the options available, their efficacy and their applicability/feasibility in different FCERM contexts. Such understanding is required to inform future fish and eel passage and protection feasibility studies such that sustainable solutions can be optimised in a way that ensures compliance with eel regulations and SAFFA.****

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and outputs from the WWNP Stakeholder Workshop. This has been peer-reviewed.

The graphs indicate a distinct lack of sufficient and relevant research suitable for informing volitional or renaturalised fish passage, protection feasibility assessments

Topic: Habitat and species management (including managing vegetation, meeting biodiversity targets, fish and eel passage)

Research Question 5: What is our understanding of the effectiveness of engineered to more natural fish passage and screening techniques that might be used in delivery of WWNP, to meet the eel regulations and SAFFA (Salmon & Freshwater Fisheries Act) requirements?

and studies investigating the efficiency of such solutions. There is little information available specifically assessing the effectiveness of solutions in the field. However, it is likely that there is some additional academic research (in the form of peer-reviewed scientific, as well as grey literature) which was not identified at this stage of the project, but which is likely to prove relevant. Notwithstanding this, it is important that the necessary resources (likely to be sourced internationally) are identified and evaluated so that they can be transcribed into practical tools and guidance for use in both the practitioner and policy/specialist sectors.

Research gaps identified for this question:

HS Q5a) A need for a comprehensive review of available, peer-reviewed and grey literature pertaining to volitional and renaturalised fish passage and protection solutions, including their utility to different species and applicability to different river, estuarial and coastal settings and geographical locations (with particular emphasis on sourcing literature in an international context).

HS Q5b) A need for academic research to be transcribed into usable guidance for practitioners, specialists and policymakers. This will facilitate a standardised approach to appraising volitional and renaturalised fish passage and protection solutions, and facilitate implementation of solutions which meet the requirements of the eel regulations and SAFFA.

Appendix E1 – Data and evidence for Natural Flood Management

Topic: Natural Flood Management and Land Use Change

What does this topic cover?

Existing and on-going research and evidence in WWNP and FCERM relevant to:

- Benefits and effectiveness of natural flood management, including catchment land-use and land-use management;
- Implementation guidance;
- Stakeholder participation and decision making.

What is included in the Data & Evidence Review? (Part 1)

Each piece of evidence has been documented including basic information such as title, author, year published, organisation etc:

64 pieces of evidence have been received from various sources including the Environment Agency, Defra and The Hutton Institute. 51 were deemed relevant to both FCERM and WWNP. Of these, 46 are completed documents/reports/papers published between 1993 and 2013. 4 are in draft or yet to be published.

What types of evidence are included in the Data & Evidence Review? (Part 2)

The evidence has been categorised to interpret its spread and coverage in the following ways:

Number of pieces of evidence delivered through Joint Defra/EA Flood & Coastal Erosion Risk Management R&D programme: 10 of 51

Number of pieces of evidence by R&D Category (of 51):

- Basic (concepts & philosophies) – 6
- Applied (methods & approaches) – 9
- Dissemination & training (software, guide, training) – 6
- Development & pilots (tools, case studies) – 21
- Implementation (better decision) – 9
- Not known – 0

Number of pieces of research by output type (of 51):

- Report – 27
- Data – 0
- Tool – 2
- Guidance – 9
- Paper – 12
- Other/not known – 1

Number of pieces of research by geographical coverage (of 51):

- Site specific – 0
- Local – 0
- Regional – 10
- National – 39
- Global – 1
- Not known – 0

Topic: Natural Flood Management and Land Use Change

Number of pieces of research by principal data type (of 51):

- Primary quantitative – 24
- Primary qualitative – 6
- Secondary quantitative – 6
- Secondary qualitative – 2
- Not applicable/not known – 13

Number of pieces of research by target audience (of 51):

- Academic – 8
- Policy/specialist – 30
- Practitioner – 13
- Not known – 0

Number of pieces of research by type of understanding (of 51):

- Conceptual (or theoretical) – 20
- Empirical (based on actual observation) – 15
- Modelled (predicted behaviour based on observation elsewhere) – 16
- Not known – 0

Popular or additional evidence for this topic from stakeholder workshop

At the workshop held in September 2013, attendees were asked to list the existing information (reports/tools/guidance etc.) that they use primarily to deliver WWNP in FCERM under this topic. Key documents used by stakeholders under this topic (list of attendees given in Appendix C) are:

- Reports on results from pilot and demonstration projects where NFM has been implemented such as the Belford, Hodder, Eddleston Water, Holnicote, Pickering, Pont Bren and Derwent catchments;
- Guidance documents such as CREW's NFM database and Scottish Rivers Handbook, SEPA's NFM Handbook (to be released shortly), the Forestry Commission's work on woodland creation and planting guidance, the Upland Hydrology Group's work on peatlands, and Newcastle University's Floods and Agriculture Risk Matrix (FARM); CIRIA (2013) research report, 'Land use management effects on flood flows and sediments – guidance on prediction'.

Appendix E2 – Gap analysis for Natural Flood Management

NFM Q1: Natural flood management and land use change

Topic: Natural flood management and land use change

Question 1: What evidence is there to support the development and promotion of landuse-based flood mitigation at a range of spatial scales?

Summary of question

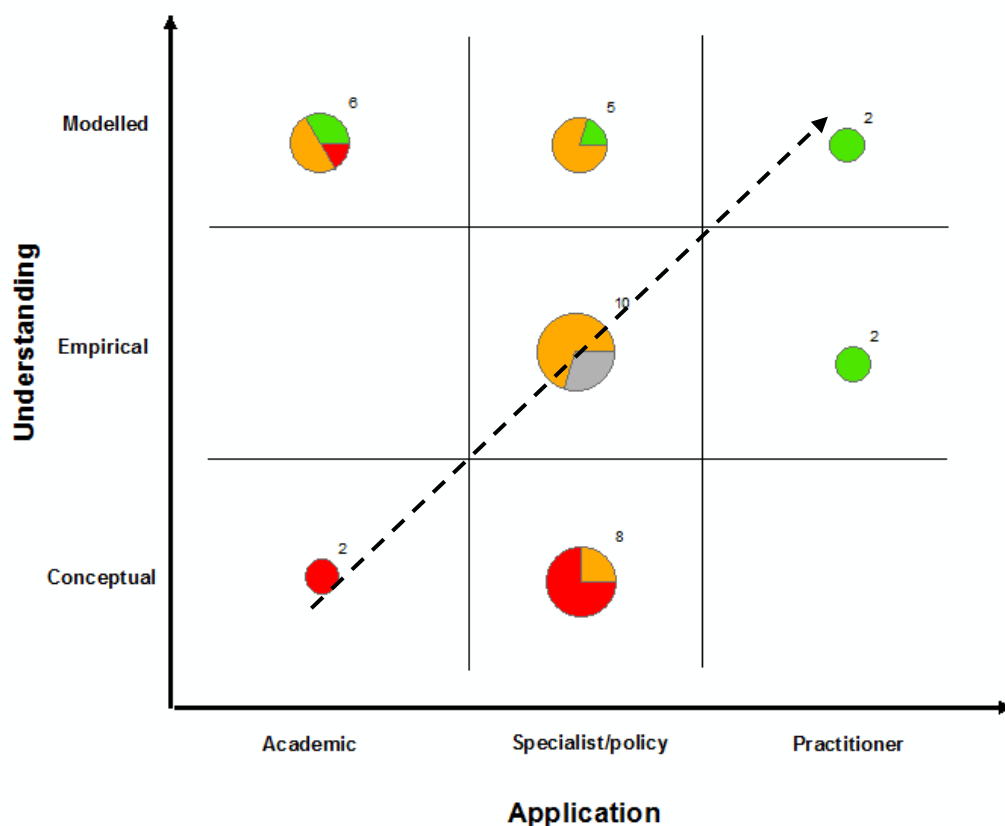
This question is about understanding the impact of natural flood management and landuse change. This includes results from experimental research in pilot studies and if predictive modelling of potential changes is possible. Evidence is required for a range of catchment types and sizes.

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of data/research relevance to the question, and how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).

Topic: Natural flood management and land use change

Question 1: What evidence is there to support the development and promotion of landuse-based flood mitigation at a range of spatial scales?



The graph shows that much of the research has been focussed at the specialist/policy level. The largest pie chart is for specialist, empirical studies, such as observations from pilot catchments. To date, there are few pieces of research directly applicable to practitioners, although those that are available give good support to justifying the business case. Modelled predictions are available for all three types of application.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

This question was developed from:

- The LWEC need for evidence-based guidance on optimising landuse for flood mitigation;
- The EA's R&D needs related to catchment-scale benefits of land management, mapping locations of implemented techniques and potential sites, and developing a land management tool;
- CIRIA (2013) report identifying the need for further catchment trials for different land-uses, and different types and sizes of catchment;
- WWNP stakeholder workshop's identification of the need to assess the efficiency of alternative flood water retention measures.

Topic: Natural flood management and land use change

Question 1: What evidence is there to support the development and promotion of landuse-based flood mitigation at a range of spatial scales?

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph suggests that only four of the research outputs to date provide good support to justify the business case for this question. Examining the Data & Evidence Register shows that these pieces of evidence include case studies for flood water retention features, resilient grass types and woodland management but the key item is the CIRIA report on 'Land use management effects on flood flows and sediments – guidance on prediction' as it is based on seven years of intensive monitoring at Pont Bren, coupled with advanced hydrological and sediment modelling and provides an overall summary of existing research. This CIRIA report also includes a knowledge gap analysis that identifies the following areas relevant to this question, which mainly relate to data collection and analysis:

- More catchment trials to capture additional landuses and catchment types;
- Longer term monitoring (over decades) to build the evidence base as short-term climate variability obscures the effects of land-use management;
- Methods for transferring predicted effects across different catchment scales;
- Evidence of practical effectiveness of buffer strips and shelter belts in reducing sediment yields as well as surface runoff.

Additional research priorities were identified by participants at the WWNP Stakeholder Workshop, with greater focus on development of prediction tools. The main areas identified relevant to this question were:

- Prediction tools and models - 'better tools and models to show how catchments are managed', 'predicting the impacts of Natural Process interventions at the on-farm, floodplain and catchment scales', 'tools for linking multiple benefits', 'more integrated models to encompass greater range of processes', and 'new practitioners' tools appropriate to the user group';
- Monitoring - 'Multi-scale monitoring of impacts of multiple interventions in a catchment - evidence of effectiveness', 'Research into peat pipes in moorlands', 'evidence (field monitoring) that over-intensive farming increases runoff', and 'data/quantitative evidence to support the case for WWNP';
- Develop an integrated approach – 'WWNP...integrated with other catchment benefits', 'linking with flood defence work through the EU', 'governance issues associated with multi-interventions', 'breaking down institutional silos', 'integration of multiple benefits for FRM', 'guidance that better draws together the benefits of WWNP other than those to FCERM', 'better designs...that are multi-functional', 'quantify and value multiple benefits', 'need for better integration of WFD and FCERM in planning guidance and support', and 'more integrated catchment management';
- Funding mechanisms – 'who will pay for maintenance?', 'lack of integrated funding, articulating benefits incentives', 'funding for FCRM schemes too focussed on traditional defences', and 'farmers need better incentives'.

Topic: Natural flood management and land use change

Question 1: What evidence is there to support the development and promotion of landuse-based flood mitigation at a range of spatial scales?

Research gaps identified for this question:

- NFM Q1a) Monitoring and catchment trials to provide the evidence base needed to increase confidence in NFM across a sufficiently wide range of catchment types, sizes and timeframes.
- NFM Q1b) Proven tools and models to predict the impact of potential NFM techniques at a range of spatial scales that suitable for use by practitioners.
- NFM Q1c) Develop an approach that links up the many drivers for NFM and allows all its benefits to be included and considered in decision-making processes.
- NFM Q1d) Identify effective NFM funding mechanisms, partnerships and incentives.

NFM Q2: Natural flood management and land use change

Topic: Natural Flood Management and Land Use Change

Question 2: Are there effective techniques to apply Natural Flood Management in FCERM?

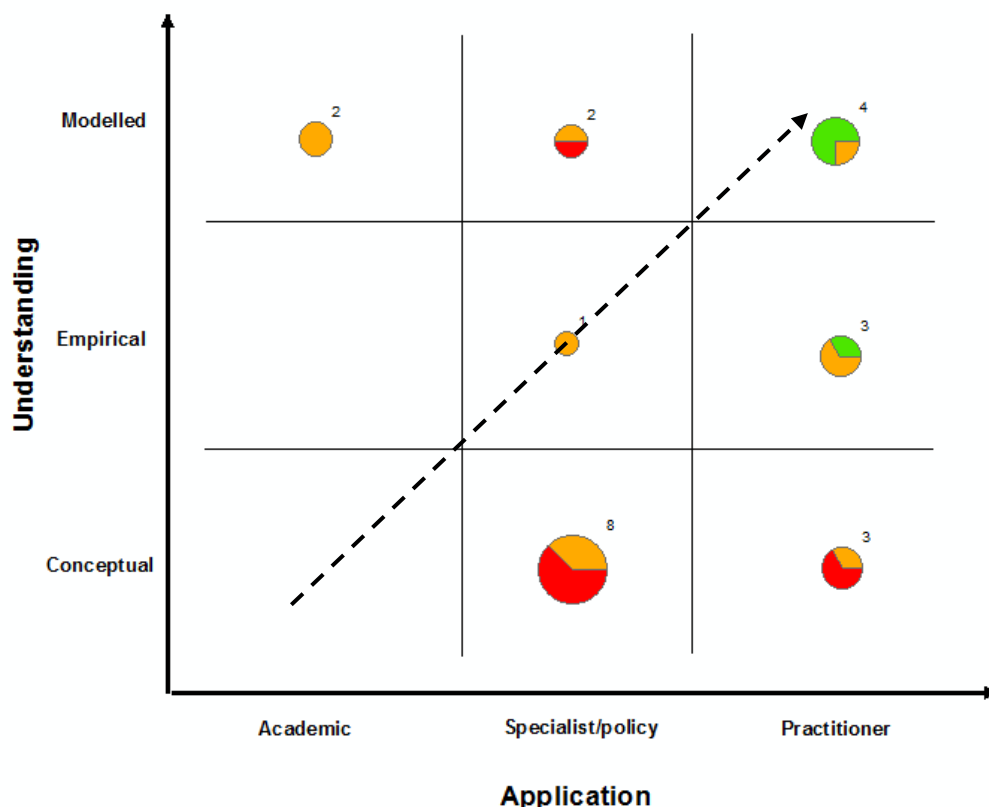
Summary of question

Is sufficient guidance available on how to select and implement Natural Flood Management techniques? For any specified catchment:

- What are the techniques that could be used?
- Will they work in this case?
- How should they be applied?

Coverage of the evidence relevant to this question (from Part 3 of the Data & Evidence Review):

The graph below maps the existing evidence available to help answer this question by 'understanding' and 'application'. This categorises the evidence into nine types (see Section 3.4 in report). The colours represent the strength of evidence in terms of data/research relevance to the question, and how well the data/research could help support the justification (or business case) for WWNP in FCERM (Red = poor, Amber = partially, Green = good, Grey = not known).



The graph shows that most research is focussed on the needs of specialists and practitioners. This covers conceptual, empirical and modelled understanding, although the number of items in each category is relatively small. The items of research that give good support for the business case are mainly aimed at practitioners,

Topic: Natural Flood Management and Land Use Change

Question 2: Are there effective techniques to apply Natural Flood Management in FCERM?

incorporating modelled/predictive tools.

Understanding of need for this question:

Stated R&D needs were identified in the LWEC FRM Strategy & Mapping Exercise, and outputs from an internal Environment Agency workshop and reviews of R&D needs (for example from previous frameworks). The understanding of need was further developed and explored at the stakeholder workshop in September 2013.

This question was developed from:

- The need LWEC recognised by for further research into the efficacy of NFM techniques and guidance on their application;
- The need identified at the WWNP stakeholder workshop to link flood data and management approaches.

Gap analysis for this question (based on the Data & Evidence Review):

The graph above indicates coverage and not necessarily research gaps. To identify research gaps, coverage is compared to need and summarised here. This has been supported by further interrogation and interpretation of the Data & Evidence Register and has been peer-reviewed.

The graph suggests that only four of the research outputs identified in the literature survey address this question. This includes the CIRIA (2013) report, Newcastle University's 'Farms and Agricultural Risk Matrix' and their guide to runoff attenuation features - developed from the Belford trials. The knowledge gap analysis in the CIRIA report identified the need to create realistic scenarios for land-use futures in hydrological modelling.

Participants at the WWNP Stakeholder Workshop identified the following gaps:

- Decision making tools - 'A decision making tool for practitioners – natural processes options: what's most effective, what should or should not be considered', and 'Improved guidance for practitioners that provides a balance for decision makers not just FCRM';
- Knowledge sharing – 'range of models are available... there is a lack of awareness that they exist, how they perform and which are best to use', and 'information exists on peatlands, woodlands etc.... not how these bits all fit together';
- Communication – 'evidence/key messages for practitioners to sell/overcome awkward situations with flooded communities', 'social research about community acceptance of measures', 'working/communicating with land managers', 'need to sell NFMs multi-functionality', and 'communication about NFM to public must improve'.

Research gaps identified for this question:

NFM Q2a) Guidance to identify the NFM techniques that are available and to what situations they are suited;

NFM Q2b) Guidance on what prediction tools should be used for assessing the effectiveness of of options for NFM, and the scenarios that should be used

Topic: Natural Flood Management and Land Use Change

Question 2: Are there effective techniques to apply Natural Flood Management in FCERM?

in testing their resilience and adaptive capacity in an uncertain future.

NFM Q2c) Guidance on how to communicate the benefits of NFM to stakeholders, including farming communities, land managers, land owners and downstream communities who benefit from flood risk reductions due to NFM should contribute to the costs of installing and maintaining them.

Appendix F1 – WWNP workshop attendees

Working with Natural Processes workshop (24th Sep 2013) attendees

Name	Institution
Group 1 - Geomorphology (estuary, coasts and fluvial)	
Facilitator - Janet Hooke	Liverpool University
Paul Sayers	Sayers and Partners
Andy Large	University of Newcastle
Marc Naura	University of Southampton
Roy Richardson	SEPA
Lucy Pizer	Environment Agency
Jon Williams	ABPMER
Peter Worrall	Penny Anderson Associates
Group 2 - Geomorphology (estuary, coasts and fluvial)	
Facilitator - Jenny Mant	RRC
Steve Colclough	Colclough & Coates
Kevin Skinner	Atkins
Gareth Old	CEH
Helena Parsons	Jacobs
Greg Whitfield	Environment Agency
Niall Jones	Environment Agency
Tori Janes	Cranfield University
Group 4 - Kenwood Hall – Fish & Eels	
Facilitator - Graeme Peirson	Environment Agency
David Sear	University of Southampton
David Fraser	WWT/APEM
Ian Cowx	University of Hull/REFORM Project
Jim Lyons	Environment Agency
Mark Owen	Angling Trust
Group 5 - Kenwood Hall – Habitats and species	
Facilitator - Judy England	Environment Agency
Fola Ogunyoye	Royal Haskoning
George Heritage	JBA
Rebecca Ratcliffe	Penny Anderson Associates
Vince Carter	Forestry Commission
Nev White	Environment Agency
Ellyse Maddocks	Environment Agency
Group 6 - Kenwood Hall - Biodiversity	
Facilitator - Matt Clegg	Black & Veatch
Fiona Bowles	Wessex Water
Phil Roxby	Darlington Borough Council
Lyn Jenkins	Environment Agency

Name	Institution
Mark Ross	Environment Agency
Jack Rhodes	RSPB
Paul Murby	DEFRA
Sacha Rogers	Penny Anderson Associates
Rob Cathcart	Natural England
Group 7 - Wostenholm Room – Urban green design	
Facilitator - Adam Baylis	Environment Agency, F&C
Colin Thorne	University of Nottingham
John Oldfield	IDB
Lan Hoang	University of Leeds (now at Cambridge University)
Ross Marshall	Environment Agency
Toni Scarr	Environment Agency
Doug Whitfield	Environment Agency
John Blanksby	University of Sheffield
Larissa Naylor	University of Glasgow
Group 8 - Wostenholm Room – Natural Flood Management & rural land use	
Facilitator - Lydia Burgess-Gamble	Environment Agency
Andy Disney	Environment Agency
Charles Forman	Environment Agency
Enda O'Connell	Newcastle University
Mark Wilkinson	Hutton Institute
Paul Quinn	Newcastle University
Phil Procter	Environment Agency
Group 9 - Wostenholm Room – Natural Flood Management & rural land use	
Facilitator - Ulrika Åberg	River Restoration Centre
Robert Brotherton	Environment Agency
Ruth Ashton-Ward	DEFRA
Steve Rose	JBA
Tom Nisbet	Forestry Commission
Ian Moodie	NFU
Group 10 - Terrace Room – Ecosystem Services & ecosystem approach	
Facilitator - Fran Moore	Black & Veatch
Mark Everard	Environment Agency
Heather Shepherd	National Flood Forum
Jessica Lamond	University of the West of England
Jim Rouquette	University of Northampton
Liz Sharp	University of Bradford
Andy Graham	WWT

Appendix F2 – WWNP workshop project list

The following list of projects was identified in a scoping exercise conducted at the WWNP stakeholder workshop in September 2013. The stakeholders together in small groups brainstormed potential projects that would fit the research gaps identified at the workshop.

Topic	Project Idea Name (if clearly stated)	Person
Fluvial and Coastal Geomorphology	Analysis and modelling of effects of flood event sequences and phases	Janet Hooke
	Research - Valuing the sediment system to link to assessment of flood risk management benefits	Kevin Skinner
	FRM valuation for sediment management tools and guidance	Roy Richardson
	How does sediment increase flood risk. How does it reduce flood risk	Paul Sayers
	National scale methods for evaluating the opportunities for WWNP in FCERM	Paul Sayers
	Working with natural processes in FCERM - A conceptual framework.	Paul Sayers
	Expansion of knowledge Base re System Dynamism (long term monitoring and use of existing science base)	Andy Large
	River Observatories	Janet Hooke
	GIS tool for NFM opportunity mapping	Roy Richardson
	Sediment management case studies	Kevin Skinner
	Model of the links between drivers of change, pressures (FRM), hydromorphology and species.	Marc Naura
	Embed the notion of sediment systems in spatial planning	Paul Sayers
	Research project to compile existing data on rates, timescales of response dynamics and variability	Janet Hooke
	Catchment scale assessment of ecosystem service provision from current structure of fluvial systems (Unfunded pilot/proof of concept already underway.)	Andy Large/David Gilvear
	Simplified tools to explore sediment issues	Paul Sayers
	Evaluation of the role of the sediment system in impacting flood risk	Kevin Skinner
	Refine Flow Standards	Gareth Old
	Land Management Guidance	Helena Parsons
	Collation of current knowledge	Gareth Old
	Refining available ecological and hydrological data	Gareth Old
National Ecological/Environmental Database	Pete Worrall	

Topic	Project Idea Name (if clearly stated)	Person
	Rigorous guidance on post project appraisal	Chris Colclough
	Post project appraisal protocol	Pete Worrall
	Post project appraisal tool kit for FCERM	Helena Parsons
	Tool to collect evidence from various flood trials	Niall Jones
	Species-Habitat Relationships	Helena Parsons
	Linking Habitats	Gareth Old
	Ecohydrological Guidelines for riverine Plants and Species	Pete Worrall
	Being serious about sediment in rivers.	Not stated
	Sedimentation and flood risk links	Helena Parsons
	River Sediment Finger printing	Pete Worrall
	Connectivity Research	Not stated
	Connected Rivers	Not stated
Fish/eel	Advocacy Training to influence policy and decision makers	David Fraser
	Alignment of Agri-Environment FCERM and Other Land-Use Policy	David Fraser
	Public Education and Media	David Fraser
	Tools to relate catchment improvement measures to benefits to fisheries	David Fraser
	Comprehensive database or website for all related R&D, case studies, local investigations	Jim Lyons
	Education Programme	David Sear
	Improved buy-in of local authorities/development control to ecosystem services and WWNP	David Sear
Vegetation	Monitoring, less detailed multiple case studies to capture good practices/performance to feed into guidance	Fola Ogunyoye
	Catchment based approach	George Heritage
	What's gone wrong	George Heritage
	Decision Support Tool	Fola Ogunyoye
	Demonstration Tool	George Heritage
	Decision support tool	Louise Carlton
	Decision support tool to understand hydromorphological and ecological response	Judy England
	Catchment based modelling system	Nev White
	Understanding interactions of FCRM activities with other WFD pressures	Judy England
	Guidance on when and where to use Large Woody Debris	Karen Fisher
	Training Course - Community Engagement	Rebecca Ratcliffe
	Training course for practitioners to communicate the benefits of WWNP	Nev White

Topic	Project Idea Name (if clearly stated)	Person
	Guidance for how to use WWNP in project appraisal	Louise Carlton
	Database of what projects are happening where and by who	Ellyse Maddocks
Biodiversity	Toolkit for successful WWNP projects for practitioners and training programme	Lyn Jenkins
	Lessons learned	Paul Murby
	Why do some strategies and projects WWNP while others fail to? Social Science Study / Decision framework	Jack Rhodes
	Best Practice advice	Sacha Rogers
	Comparative case study projects	Lyn Jenkins
	Effects of climate change and biodiversity	Not stated
Green Eng	Explore Barriers and Incentives for Green Engineering	Not stated
	A series of 'open-air' labs/case study sites	Ross Marshall Larissa Naylor
	Doing Flood Risk Modelling and Management Differently by fully engaging stakeholders from start	Colin Thorne
	Next generation flood models	Ross Marshall
	Integrated FCERM using Green Engineering from Theory to Practice	John Blanksby
	CFMPs from Concept to Delivery	Not stated
	General	Not stated
	Development of Workmanship Manual	Not stated
	Develop and Pilot Green Engineering Methodology (preferably adopting something already in use overseas) Green Breeam??	Not stated
	General	Doug Whitfield Larissa Naylor
	Creating R&D opportunities to influence and embed 'green multifunctional' engineering options into flood risk manuals and development plans	Not stated
	Produce guidance on how FCRM planning should change to make best use of green engineering	John Oldfield
	Innovative Assets	Larissa Naylor Ian Huang
	Green Infrastructure Risks	Adam Baylis Larissa Naylor Lan Huang
	Green Engineering "Breeam" Scheme - decision support systems/tools that interact with stakeholders and their risk acceptability.	Lan Huang
	Future Flooding and Its Management	Colin Thorne

Topic	Project Idea Name (if clearly stated)	Person
NFM	The Multi-Functional Catchment Laboratory Collaboratory Project	Mark Wilkinson Enda O'Connell Paul Quinn Lydia B-G Andy Disney Phil Proctor Charles Forman
	Mechanisms to address gaps/needs in WWNP for FRM	Tom Nisbet
	Independent assessment of available models	Steve Rose R. Ashton-Ward Tom Nisbet
	Integration at policy level - WFD/FCERM	Not stated
	Awareness raising	Not stated
Ecosystem Services	Ways of measuring success in engaging	By group
	Toolkit for practitioners to identify, assess and value all ecosystem services	By group
	Experimental (sub) catchment in which an ESS approach is used	By group
	Post review of completed projects - practical rural land management	By group
	Barriers and opportunities	By group
	Review of options available for decision making in FRM and WWNP:	By group
	Uncertainty	By group
	Plurality of values	By group
What do communities value/not value about FRM schemes?	By group	

Appendix G – Development of research gaps

Title of research gap	Description of research gap	Contributing topic (see Appendices A to E)
1. Understanding approaches to community and stakeholder engagement	<p>This research gap identifies the need to review different approaches to community and stakeholder engagement methods to achieve WWNP, including:</p> <ul style="list-style-type: none"> ▪ Engage communities and stakeholders early in options identification and appraisal; ▪ Reflect the ecosystems approach which refers to community and stakeholder engagement (Principles 1, 2, 11 and 12); ▪ Identify a wider range of FCERM options including WWNP; ▪ When communicating and collecting information use a variety of methods such as visual aids, software, group exercises and learning tools; ▪ Consider the multiple benefits of a particular option/proposal and all legislative drivers (e.g. WFD and biodiversity targets); ▪ Enable a two-way communication process which both Informs and educates; ▪ Maximise potential for innovative funding/delivery/maintenance of FCERM (e.g. payment for ecosystem services and partnership contributions); ▪ Demonstrate the benefits of WWNP at a high-level to policy and decision makers; and ▪ Enable WWNP to be more achieved faster and more efficiently (e.g. e.g. changes to building regulations and planning policy). 	<p>ESS Q1 a – An understanding of the different methods and approaches used to engage communities and stakeholders earlier in the options identification and appraisal process (as well as rolling out the ecosystems approach in practice).</p> <p>FCG Q1 c – Education and dissemination to the public, policy makers and practitioners of the benefits of sediment management along our coasts and estuaries to fulfil FCERM requirements (i.e. intertidal habitat creation).</p> <p>NFM Q1 c – Develop an approach that links up the many drivers for natural flood management and allows all its benefits to be included in decision-making process.</p> <p>NFM Q1 d – Identify effective funding mechanisms, partnerships and incentives.</p> <p>NFM Q2 c – Guidance on how to communicate the benefits of natural flood management to the various stakeholders including communities/land managers.</p> <p>HS Q1 c – Developing risk-based guidance that encourages a more holistic approach to FCERM plan and scheme development and enables the benefits, risks and associated management measures to be clearly communicated to decision makers.</p>
2. Understanding cultural and institutional barriers to WWNP in flood risk management authorities	<p>The WWNP stakeholder workshop identified the significant barrier created by working in thematic or institutional silos. This research gap is about identifying cultural or institutional barriers specifically within the public sector, that restrict the delivery of WWNP in flood risk management, and identifying methods to remedy this.</p> <p>Practitioners felt that WWNP is rarely considered in FCERM options appraisal and that this is a barrier to delivering more sustainable solutions to FCERM. This may be because there is a lack of research into evidence of demonstrable benefits.</p> <p>The WWNP stakeholder workshop identified the need to:</p> <ul style="list-style-type: none"> ▪ Establish why the FCERM options appraisal process tends to identify a limited set of options which infrequently includes WWNP; ▪ Identify why local stakeholders and communities are not engaged earlier on in the options identification process; ▪ Establish why decisions about WWNP are primarily based on market-based economic values; ▪ Identify what is holding back full consideration of WWNP techniques in FCERM; and ▪ Demonstrating the multiple benefits of WWNP to decision makers. 	<p>ESS Q1 b – A review of institutional cultural barriers to changing the way decisions are made at policy/funding level and the way options are initially identified. The need to demonstrate the benefits of WWNP in FCERM to policy/legislative makers. What is holding back the identification and appraisal of WWNP measures in FCERM options?</p> <p>ESS Q2 c – review of institutional cultural barriers to changing the way decisions are made. Ways to demonstrate benefits of WWNP to high-level decision makers in local authorities, the Environment Agency and Defra. What is holding back the identification and appraisal of WWNP measures in FCERM options?</p> <p>FCG Q1 c – Education and dissemination to the public, policy makers and practitioners of the benefits of sediment management along our coasts and estuaries to fulfil FCERM requirements (i.e. intertidal habitat creation).</p> <p>GE Q1 c – Legislation to facilitate green engineering within FCERM and to ensure the consistency and alignment of existing policies.</p> <p>HS Q1 c – Developing risk-based guidance that encourages a more holistic approach to FCERM plan and scheme development and enables the benefits, risks and associated management measures to be clearly communicated to decision makers.</p>
3. Guidance and/or training in WWNP/FCERM for practitioners	<p>There is a great need to provide clear and concise guidance to practitioners to enable them to WWNP. This is not always a research gap but can be a signposting exercise to make practitioners</p>	<p>ESS Q2 b – Knowledge of where to go for evidence and monetary data varies among practitioners. Dissemination of knowledge and/or training is required for practitioners. Guidance for practitioners is needed to clearly spell out a) best available evidence to inform assumptions about change in different</p>

Title of research gap	Description of research gap	Contributing topic (see Appendices A to E)
	<p>aware of existing guidance. In other cases, practitioners know evidence exists but need either guidance to:</p> <ul style="list-style-type: none"> ▪ Help them implement it; or ▪ Translate conceptual/new data from the academic/specialist arena into something useable in practice. <p>The following research needs have been identified. Develop guidance that:</p> <ul style="list-style-type: none"> ▪ Indicates where to go for evidence to quantify, value and monetise change in ecosystem services associated with different approaches to WWNP; ▪ Signposts practitioners to proven tools and models to assess impacts of natural flood management at range of spatial scales; ▪ Identifies (with reasonable certainty) the best available evidence to quantify change in ecosystem services associated with different approaches to WWNP; ▪ Specifies the scales (geographical, ecological, hydrological) at which this evidence should and should not be used; ▪ Provides advisory scenarios for ecosystem services to help manage uncertainty; ▪ Identify when new data collection is likely to be needed because it is not known how ecosystems services are likely to change due to a WWNP measure; ▪ Identify what constitutes reasonable scientific certainty when using evidence to make assumptions about benefits of WWNP techniques in FCERM; and ▪ Advises on how to demonstrate the wider environmental benefits of WWNP. 	<p>ecosystem service flows due to different types of WWNP/FCERM measures and b) the best available data for the associated changes in values. It seems to be important to state at what geographical scale (e.g. catchments, RBMPs) it is appropriate to apply this evidence, and for those which it is not and therefore in what situations primary survey data collection is likely to be required due to a lack of data transferable from elsewhere. Guidance on how to undertake full systematic assessments of all ecosystem services affected by a FCERM measure.</p> <p>FCG Q1 c – Education and dissemination to the public, policy makers and practitioners of the benefits of sediment management along our coasts and estuaries to fulfil FCERM requirements (i.e. intertidal habitat creation).</p> <p>GE Q1 d – Ensure techniques and evidence from overseas are made available for application in the UK.</p> <p>NFM Q1 b – Proven tools and models to predict the impact of potential natural flood management techniques at a range of spatial scales for practitioners.</p> <p>NFM Q2 a – Guidance to identify the natural flood management techniques that are available and what situations they are suited to.</p> <p>NFM Q2 b – Guidance on what prediction tools should be used for assessing effectiveness of potential natural flood management techniques and the scenarios that should be applied in them.</p> <p>HS Q1 b – Guidance on the level (certainty) and nature (new or modelled) of evidence required to allow the development and acceptance of more robust business cases for FCERM with integrated habitat creation at a range of scales during plan/project development.</p> <p>HS Q1 c – Developing risk-based guidance that encourages a more holistic approach to FCERM plan and scheme development and enables the benefits, risks and associated management measures to be clearly communicated to decision makers.</p> <p>HS Q2 b – There is a limited provision of risk based guidance covering the full range of vegetation management techniques available.</p> <p>HS Q2 c – Conflicting precautionary guidance resulting from uncertainty over the degree to which in-channel vegetation and its management influences flood risk.</p> <p>HS Q3 a – Gap in focussed research that translate benefits into ecosystem services.</p> <p>HS Q4 b – There is a need for available information on fish habitat requirements to be transcribed into useable guidance for practitioners and specialist / policy makers. This will enable a standardised, formal approach to habitat assessments and the implementation of habitat improvements which facilitate progression towards meeting WFD targets with respect to fish populations, and which also aid FCERM.</p> <p>HS Q5 b – A need for academic research to be transcribed into usable guidance for practitioners and specialist / policy makers. This will facilitate a standardised approach to appraising naturalised fish passage solutions and facilitate the implementation of solutions which meet the requirements of the eel regulations and the Salmon and Freshwater Fisheries Act 2003.</p>
4. Learning lessons from past pilot/case studies	<p>The workshop attendees identified a need to re-visit past pilot projects and case studies to understand benefits achieved and long-term lessons learnt. They also felt such research should be regularly updated. Part of this need will be met by ongoing long-term projects, and the understanding of this 'gap' needs to be refined in Stage 2. Specific research needs identified included:</p> <ul style="list-style-type: none"> ▪ Models or tools to show long-term change in estuary and coastal environments (filling of this gap is partly in progress through CoaEST and iCOAST research programmes); ▪ Evidence for the long-term effects of sediment change/dynamics (e.g. dredging/de-silting) and their effect on FCERM maintenance regimes; ▪ Learning from different types and sizes of catchments over different timeframes; 	<p>ESS Q1 c – A lack of post project learning and monitoring of pilots projects and case studies that have been completed to inform our understanding of what engagement methods work best.</p> <p>FCG Q1 a – Long-term models/tools of estuarine and coastal environments using existing data for practitioners to use to better predict change over time (this is being covered to some degree by the NERC funded projects CoaEST and iCoast).</p> <p>FCG Q3 a – Improve the evidence base (case studies/ post project assessment and monitoring) to better understand long-term change in sediment supply and dynamics so that we can identify better ways to manage it (in particular more evidence to support or amend existing FCERM maintenance programmes i.e. dredging/de-silting).</p> <p>HS Q1 d – Periodically reviewed and refreshed advisory guidance informed by monitoring and post project appraisal outputs/lessons learned.</p> <p>HS Q1 a – More systematic long term monitoring and post project appraisal to develop the evidence base to meet FCERM, WWNP and biodiversity target needs.</p> <p>HS Q2 a – Limited recent or long term UK evidence regarding environmental / biological control approaches for FCERM contrary to international evidence.</p>

Title of research gap	Description of research gap	Contributing topic (see Appendices A to E)
	<ul style="list-style-type: none"> ▪ Evidence to demonstrate how to meet multiple policy drivers; ▪ Improve our understanding of environmental/biological control approaches; and ▪ Identify the stakeholder and community engagement methods which have worked best (link to Research Gap 1). 	<p>HS Q4 c – There is a requirement to assess the success and failures of existing schemes to produce future implementation and policy guidance for habitat restoration in relation to improving fish habitat when undertaking FCERM projects.</p> <p>NFM Q1 a – Monitoring and catchment trials to provide evidence base for sufficiently wide range of catchment types, sizes and timeframes.</p>
5. New studies to improve the WWNP evidence base	<p>Re-visiting previous projects and case studies alone was seen as insufficient to fill all research needs. The following new studies are needed:</p> <ul style="list-style-type: none"> ▪ Gather evidence to show how the types of ecosystem services which are achieved vary between different WWNP techniques. ▪ Prioritise evidence collection for ecosystem services, for which there is a lack of evidence about how they change in relation to different WWNP measures. Focus on those that could potentially yield significant values in economic appraisal and so potentially change the outcome of option appraisal and the preferred option; ▪ Develop methods to better and more consistently identify and quantify the benefits that habitat creation has achieved (this is essential to support future WWNP guidance/optioneering and business case development); ▪ Understand the FCERM benefits of sediment management along coasts and estuaries (e.g. beach nourishment, sand dune management and saltmarsh creation); ▪ Quantify the effect of different land uses on ecosystem services, sediment management and FCERM; ▪ Understanding the long-term effects of different WWNP/FCERM approaches on sediment supply and dynamics; ▪ Understand how FCERM activities could benefit volitional and renaturalised fish passage and habitats, demonstrating the wider benefits of WWNP (e.g. affecting other policy/legislative drivers); ▪ Gather evidence of the FCERM benefits of environmental/biological controls, woody debris and green engineering; and ▪ Develop an understanding of the impacts of WWNP on FCERM at the whole catchment scale. 	<p>ESS Q2 a – A need for further evidence at specialist/policy level of how ecosystems services change due to different WWNP/FCERM measures (and how human values associated with these are likely to change – recognising this is often context specific). This is not required for some ecosystem services for which sufficient evidence/toolkits are available. A review is required to identify which ecosystem services are potentially significant and require priority attention. For example, there appears to be a particular need to examine carbon sequestration associated with different WWNP measures (not habitat creation), visitor values for new recreational opportunities associated with WWNP measures and identification of ecosystem services provided by agricultural land (other than crop yields).</p> <p>FCG Q1 b – More evidence/investigation of benefits of sediment management (e.g. beach nourishment, sand dune management) along coasts and estuaries to FCERM.</p> <p>FCG Q2 a – Evidence on the catchment-scale benefits of land management. Understanding the scale of land management required to contribute to reducing flood risk. Improving our understanding (and justification for) sediment management to fulfil FCERM requirements.</p> <p>FCG Q2 b – More case studies on the use of rural sustainable drainage systems, and their contribution to reducing the need for dredging. Evidence to improve our understanding and appreciation of the link between rivers and floodplains in regards to sediment management.</p> <p>FCG Q3 a – Improve the evidence base (case studies/post project assessment and monitoring) to better understand long-term change in sediment supply and dynamics so that we can identify better ways to manage it (in particular more evidence to support or amend existing FCERM maintenance programmes i.e. dredging/de-silting).</p> <p>GE Q1 a – More research to provide a sounder quantitative evidence base to support the application of green engineering in FCERM. This would be used to reduce uncertainty, manage risk and answer challenges.</p> <p>HS Q2 a – Limited recent or long term UK evidence regarding environmental / biological control approaches for FCERM contrary to international evidence.</p> <p>HS Q2 d – Limited understanding of woody debris as both a source of flood risk or as a component of a flood storage/attenuation solution.</p> <p>HS Q3 b – Varying levels of understanding of the benefits that different habitat types can provide - either by type or location (prioritisation of those most relevant to FCERM).</p> <p>HS Q3 c – Reducing uncertainty in our understanding of how long it takes for habitats to provide benefits.</p> <p>HS Q4 a – A need for comprehensive reviews of habitat requirements for different species / species guilds and in particular for those species which are used in the Environment Agency’s Fisheries Classification System 2. Whilst this may be available, at least to some extent, for salmonid species there is a need for a greater understanding of requirements for other species and how a lack of access to particular functional habitat types may create recruitment bottlenecks, thus limiting the potential to achieve WFD targets.</p> <p>HS Q5 a – A need for a comprehensive review of available peer reviewed literature pertaining to naturalised fish passage solutions including their efficiency / applicability for different species and locations.</p> <p>NFM Q1 a – Monitoring and catchment trials to provide evidence base for sufficiently wide range of catchment types, sizes and timeframes.</p>
6. National prioritisation of catchments for WWNP delivery	We need to map (nationally) our catchments to identify those which would benefit most from WWNP measures. By working in priority catchments we will be more likely to establish evidence of the significant benefits of WWNP (especially for sediment management).	FCG Q2 c – Geomorphological profiling and classification of catchments achieved through national / catchment scale sensitivity mapping (morphological-ecological) to help identify catchments sensitive to sediment related FCERM issues. Focussing on ‘vulnerable’ catchments where big gains could be achieved and on characteristics that make them especially vulnerable and sensitive to sediment

Title of research gap	Description of research gap	Contributing topic (see Appendices A to E)
	<p>Prioritising catchments helps achieve value for money and assists with demonstrating to key decision makers the <u>actual</u> benefits of WWNP. This exercise should precede Research Gap 6 and the identification of experimental catchments. The following research requirements have been identified:</p> <ul style="list-style-type: none"> ▪ Catchment profiling (geomorphologically and ecologically) to identify those most sensitive to changes in sediment processes resulting from FCERM activities; and ▪ Identifying where the greatest economic benefits could be gained, in order to demonstrate the benefits of WWNP to decision makers and sceptical stakeholders more generally. 	<p>dynamics. ESS Q1 a – An understanding of the different methods and approaches used to engage communities and stakeholders earlier in the options identification and appraisal process (as well as rolling out the ecosystems approach in practice).</p>
<p>7. Collecting data about natural processes at a catchment scale</p>	<ul style="list-style-type: none"> ▪ Test catchments to trial the application of multiple WWNP measures and understand how they interact synergistically to achieve multiple benefits; and ▪ The test catchments should: <ul style="list-style-type: none"> ○ Include a range of land management/uses; and ○ Include a range of WWNP measures; ○ Observe changes in natural processes; ○ Assess whether WWNP reduces flood risk, FCERM capital requirements and maintenance needs (e.g. the impact of rural SUDS at catchment scale); ○ Provide learning opportunities to visiting researchers and practitioners; and ○ Learn from existing pilot projects and case studies. 	<p>ESS Q2 d – Experimental application of ecosystems approach/ecosystem services assessment in catchments to identify most appropriate methods to achieve multiple policy/legislative wider benefits i.e. FCERM, WFD, water quality, biodiversity targets. NFM Q1 a – Monitoring and catchment trials to provide evidence base for sufficiently wide range of catchment types, sizes and timeframes.</p>
<p>8. Developing more adaptive/resilient green engineering technologies</p>	<p>The research need included:</p> <ul style="list-style-type: none"> ▪ Developing green engineering techniques that can adapt more readily to future uncertainties (e.g. climate and land-use change). 	<p>GE Q1 b – Developing more adaptive/resilient green engineering to manage uncertainty and risk (i.e. the future is not just uncertain it is unknowable).</p>

Appendix H – WWNP project short-list and scoring

WWNP Projects	WWNP Research Gap	Indicator (scored out of 1-4)						Ability to attract funding	Overall importance
		Justification	Funding potential	LWEC Strategy fit	User relevance	Transferability	TOTAL (5-20)		
National mapping of priority catchments for WWNP	1.6	3	1	3	4	4	15	8	H
Attitudes, cultural and scientific barriers to WWNP	1.2	3	3	1	3	3	13	7	M
WWNP Catchment Laboratories - Scoping stage	1.4/1.7	4	4	4	4	4	20	12	H
WWNP Catchment Laboratories (fluival, estuarine and coastal)	1.5/1.7	4	4	4	4	4	20	12	H
Catchment Labs sub-project 1 - Sediment Monitoring and Tool Development	1.4/1.5/1.7	3	4	4	3	3	17	11	H
Catchment Labs sub-project 2 - Incentivising WWNP	1.1/1.2	3	3	4	3	3	16	10	H
Catchment Labs sub-project 3 - Hybrid WWNP approaches	1.8	3	4	3	4	3	17	11	H
Catchment Labs sub-project 4 - Catchment land use trials	1.5/1.7	3	3	4	3	3	16	10	H
Catchment Labs sub-project 5 - Woody Debris tools	1.5/1.7	3	3	3	4	3	16	10	H
Modelling effects of WWNP measures on flood risk	1.5	3	2	4	3	3	15	9	M
Ecosystem Approach for funding opportunities in WWNP	1.1/1.2	2	2	3	3	3	13	8	M
Review of WWNP delivery in past FCRM schemes	1.4	2	1	2	3	2	10	6	L
Developing operational guidance to deliver FCERM using WWNP	1.3	3	1	2	4	3	13	7	M
Developing a 'Green Engineering Rating' and Design Guide for FCERM	1.8	3	3	3	3	3	15	9	M
Effect of natural processes during extreme events on FCRM (fixing the 'damage' or natural evolution)?	1.5	1	1	4	1	1	8	6	L
How to join up delivery of Water Framework Directive and Floods Directive	1.4	4	1	1	3	3	12	5	M
Costs and benefits of fish and eel screening measures on FCERM structures	1.4/1.8	2	1	2	3	3	11	6	M
Average of projects		2.9	2.4	3.0	3.2	3.0	14.5	8.6	

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List of abbreviations: appendices

ADA	Association of Drainage Authorities
B&V	Black & Veatch
BGS	British Geological Survey
BSG	British Society for Geomorphology
CREW	Centre of Expertise for Waters
CoRDDi	Coastal Research Development and Dissemination
DER	Data & Evidence Register
Defra	Department for the Environment Food and Rural Affairs
ESRC	Economic and Social Research Council
ESS	Ecosystem services (including ecosystems approach) topic
FCERM	Flood and Coastal Erosion Risk Management
FCRM	Flood and Coastal Risk Management
FCG	Fluvial and coastal geomorphology topic
GE	Green engineering topic
HS	Habitats and species topic
IDB	Internal Drainage Boards
LLFA	Lead Local Flood Authorities
LWEC	Living with Environmental Change
NERC	Natural Environment Research Council
NFM	Natural flood management topic
NRW	Natural Resources Wales
NGO	Non Governmental Organisations
PAG	Project Advisory Group
R&D	Research & Development
RRC	River Restoration Centre
SuDS	Sustainable Drainage System (urban or rural)
WFD	Water Framework Directive
WwNP	Working with Natural Processes

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