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Water as a Resource

A socio-economic impact assessment of NERC funded research

July 2016

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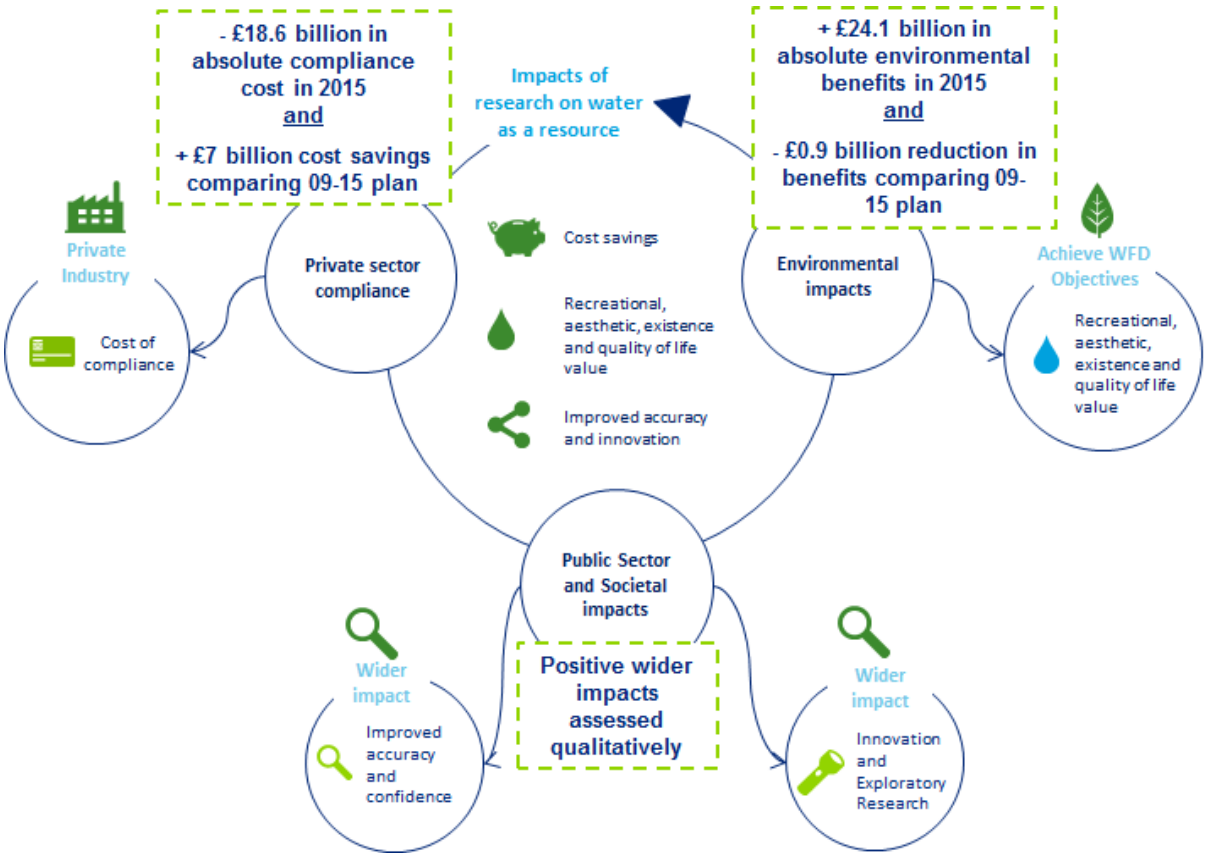
Executive Summary

The Natural Environment Research Council (NERC) has made material scientific contributions in the area of water quality through setting of the quality standards for the Water Framework Directive (WFD). The WFD is a European Union directive which commits member states to achieve good qualitative and quantitative status of all water bodies. The WFD is implemented in the UK through the River Basin Management Plan (RBMP), which set out how the objectives set for a specific river basin will be reached. These plans must include an economic analysis of water use within the river in order to assess cost-effectiveness of the various measures. The RBMP and its 2015 update have allowed Government to avoid undertaking a range of projects with a negative return on investment, leading to real savings.

The implementation of actions to improve water quality led to real benefits. On average, NERC invests in the region of £65m per annum on research that is related to freshwater. This has contributed to significant benefits. In absolute terms, the 2015 RBMP yields a total present value benefit of £24.1 billion and a PV cost of -£18.6 billion. The RBMP 2015 therefore delivers net benefits of £5.5 billion (2016 prices) over the period 2015-2051.

Absolute and relative net benefits supported by the 2015 update to the RBMP, £ millions



Source: Deloitte. Note that figures may not sum due to rounding.

This is a considerable improvement compared to the cost benefit ratio in the 2009 RBMP, which was based purely on standards to be achieved on the basis of the WFD. The updated Plan delivers a cost savings of £7.0 billion and a slight reduction in benefits of £0.9 billion. This yields a positive net impact of £6.1 billion over the appraisal period compared to the 2009 Plan.

- Private sector compliance: The 2015 RBMP generates a total of £18.6 billion in cost of compliance to the private sector. These costs stem from the measures that the water companies, private industry and agriculture firms must implement in order to meet the water standards stipulated in the RBMP. The 2015 update to the RBMP has resulted in a £7 billion cost savings for the price sector, due to a reduction in compliance costs compared to the 2009 RBMP.
- Environmental impacts: The 2015 RBMP generates improvements in water quality worth £24.1 billion. These benefits are lower than those predicted by the 2009 RBMP, which provided an additional £0.9 billion in environmental benefits. However, this reduction led to a significant reduction in the cost of compliance as highlighted above.

NERC science has also made significant contributions in the area of water quantity by supporting organisations such as the Environment Agency (EA) and the Department for the Environment Food and Rural Affairs (Defra) to set quantity standards and regulate abstraction. For example, NERC science has also supported benefits in the area of water quantity and abstraction. These benefits have been assessed qualitatively through consultations with users of NERC science.

- Improved Accuracy and Confidence: the use of NERC science has given Defra and the EA more confidence that their outputs are as robust and accurate as possible, compared to similar alternatives. NERC's Future Flows dataset has been highlighted as a specific example of NERC's contribution via data and models which have enabled the agencies to provide forecasts on the quantity of water which will exist nearly 100 years into the future. This information will be acted upon by water companies and abstractors to make decisions on water security and supply for the coming decades. Decisions of such critical importance must rely on the highest quality of data, of which there is no substitute to that of NERC's Future Flows dataset.

- Innovation and Exploratory Research: exploratory research has supported innovation and building up of the knowledge base in areas other research funders have not been able to support. Both the EA and Defra noted NERC's business model more easily accommodates exploratory research which could support the creation of new methods and techniques, but which also comes with the risk of failure. NERC's ability to tolerate this risk and fund such areas of exploratory environmental science is extremely valuable to these departments and agencies, who wish to innovate but find it challenging within their funding operating model. Particular value was attributed to exploratory NERC science which has established both a research base and critical mass of specialists in a particular area, regardless of whether a policy-relevant link to the research had been established or not. Without establishing this base, scientific contribution to policymaking would not be possible.

The impact that NERC science has made in the area of water as a resource demonstrates a key takeaway from this analysis: environmental science research can generate direct benefits for the UK environment. In addition, this research can generate benefits for society, including the private and public sectors, by reducing the costs imposed to protect the environment when new findings are made. This important message is reflected in the impact analysis on water quality, whereby benefits to the environment as well as the private sector are supported through NERC science. Furthermore, the case study analysis highlights that important benefits relating to innovation, the UK research base, and improved confidence are further supported through NERC science.

1 Introduction

1.1 Study scope and objectives

The Natural Environment Research Council (NERC) is the leading funder of environmental science research, training and innovation in the UK. The organisation is responsible for promoting and supporting basic, strategic and applied environmental research to advance scientific knowledge and technology in the UK, as well as improving public awareness of environmental issues. NERC science strives to understand how we can benefit from natural resources, build resilience to environmental hazards and manage environmental change, while ensuring the future prosperity and wellbeing of both the UK and global community.

NERC draws on both public and private funding sources to support its scientists, with public funds primarily sourced from the Department for Business, Innovation and Skills (BIS). It is important for NERC to demonstrate accountability to both BIS as well as HM Treasury for the impact of the public funds it receives and distributes, since its activities and funding decisions are independent of government.

It is within this context that NERC commissioned Deloitte in spring 2016 to undertake an assessment of the socio-economic and environmental impacts of NERC science in two specific research areas: biofouling and water as a resource. This report presents the findings and methodology relating to NERC's research on water as a resource, accounting for both water quality and water quantity. A separate report has been produced which presents the findings relating to biofouling.

1.2 Study Method

A discrete impact analysis has been undertaken by Deloitte in each of the two topic areas set out above: TBT and water as a resource. Each study is independent in that it does not consider impacts outside the remit of, or the interaction between, each topic area.

Evidence on each area's economic and wider impacts is based on an analysis of individual Research Excellence Framework (REF) submissions and case studies, reports by NERC, secondary research papers and interviews with industry experts. The collected evidence was then applied to a theory of change logic framework in order to map research outputs to outcomes and impact. In doing so, the focus has been on identifying the 'final good' which was produced by actors in the economy using NERC science. Impacts have been assessed with respect to whether they accrue to the public sector, private sector and environment. The specific assumptions and methodology underpinning the impact assessment is provided in the subsequent chapters.

The impact analysis undertaken and tools and techniques applied have drawn on the principles of appraisal and evaluation as set out in the Government's Green and Magenta Books. To this end, the analysis makes considerations for factors such as net benefits and additionality. However, there are a number for reasons for why this analysis cannot be fully Green Book compliant. Most notably, the fact that science is cumulative and the outcomes of individual pieces of research are very difficult to isolate, given the various sources of knowledge upon which impact has been generated. As such, attributing the benefits of science to a single 'input' is extremely difficult and any such attribution can only be regarded as speculative. In addition, the evaluation of impacts relating to science differs from standard evaluations as the outcomes of scientific research are uncertain and unpredictable. Such research is exploratory and scientists are judged not against a pre-agreed set of deliverables, but rather the quality of their research methodology.

1.3 Acknowledgements[1]

Deloitte would like to acknowledge and thank the following people for their contributions to this report:

- Dr. Massimiliano Volpi, NERC;
- Alex Duffey, NERC;
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- Ian Johnson, Environment Agency;
- Damian Crilly, Environment Agency.
- Henry Leveson-Gower, Defra.

1.4 Limitations of the research

The scope of this analysis is limited to the thematic area agreed between NERC and Deloitte. As a result, impacts associated with other areas of NERC research are not considered and those impacts presented cannot be interpreted as being the total contribution of NERC science.

In addition, primary research and data collection to evaluate impact of individual research projects fell outside the scope of this project. As such, identified impacts and their quantification are based on existing evidence and discussions with stakeholders – data and evidence received has not been validated by Deloitte. The suite of impacts identified and assumptions used are therefore guided by the existing, available evidence, not necessarily comprehensive, but should be treated as indicative.

Equally, it should be noted that while NERC-funded research is making a material contribution to achieving impacts, this study recognises that other research and funding bodies are also contributing to the knowledge stock in these areas. This study takes a conservative approach of only quantitatively apportioning impacts to NERC when there is clear evidence to demonstrate a causal link and measure additionality. In absence of such evidence, the analysis states the material contribution that NERC science made, while also acknowledging the other actors involved, in achieving said impacts.

On a technical note, where data is available, the quantification of impacts accounts for both costs and benefits and is presented as net impacts. Further, the figures quoted on NERC funding for research in each thematic area should be considered indicative and not exact, due to both availability of funding data and inherent overlap in thematic areas.

[1] Note that while members of BIS, the EA and Defra were consulted as part of this analysis, they have neither reviewed nor endorsed the study's findings.

2 Water as a Resource

2.1 Introduction to water quality and quantity

Almost all human wellbeing and activities are dependent upon the natural environment and the ecosystem services it provides. Defra defines ecosystem services as services provided by the natural environment that benefit people.[2] The water environment is a core component of these services, which plays a vital role in providing food, fuel, and cultural services through recreation and appreciation of nature, amongst other services.

Despite the services provided by the UK's water environment, it is a public good for which individuals do not have enough incentive to protect to a socially optimal level. The water environment provides a host of benefits, many of which depend on the availability and high quality of the water. Nevertheless, these factors are at risk of detriment from human activity such as pollution and over abstraction. As a result, some form of publically coordinated collaboration is necessary to ensure that water quality and quantity are not compromised to a point where they can no longer provide the services on which people depend now and into the future.[3]

Historically, the water industry has been highly fragmented, both in terms of water supply as well as regulation. After the Second World War, there were more than 1,000 bodies involved in water supply and 1,400 responsible for sewerage in the UK. This compares to 10 water and sewerages companies and 13 water only companies in operation today.[4] Resource planning and regulation were historically managed at a very local level, with minimal coordination across localities and at a regional or national level. When the water industry was privatised in 1989, three separate bodies were established to regulate the activities of the water and sewerage companies: the national Rivers Authority (new succeeded by the Environment Agency), the Drinking Water Inspectorate and the Water Service Regulation Authorities (Ofwat). Natural Resource Wales is now also a fourth body tasked with water regulation in the UK.

Today, water regulation is guided at both the European Union (EU) level as well as nationally. The EU sets standards and legislation through the Water Framework Directive (WFD), which is legally binding. The WFD came into force in 2000 and requires that all inland and coastal waters reach 'good status' by 2015, unless good status cannot be reached, for example for heavily modified water bodies which only require good ecological potential, or unless the cost of achieving good status is disproportionately expensive.[5] A number of other objectives are operationalised within individual EU Member States via the WFD:

- Good status for all Waters: water quality objectives that should be achieved through the WFD are linked to: ecological status, quantitative status, chemical status and protected area objectives and these must be applied to each river basin district.
- Management by River Basin: a river basin is the natural geographical and hydrological unit for water bodies, rather than administrative and political boundaries. The WFD required that by 2003 Member States identify River Basin Districts and Authorities with the purpose of managing such water bodies according to these structures.
- River Basin Management Plans: The WFD requires that a River Basin Management Plan (RBMP) is developed for each river basin district by 2009. These plan set out how the objectives set for that river basin (relating to ecological status, quantitative status, chemical status and protected area objectives) will be reached. These plans must include an economic analysis of water use

[2] Defra (2007), An introductory guide to valuing ecosystem services. Accessed at: http://ec.europa.eu/environment/nature/biodiversity/economics/pdf/valuing_ecosystems.pdf.
[3] Defra (2015), Update to the river basin management plans for England's water environment.
[4] Defra and Ofwat (2006), The Development of the Water Industry in England and Wales. Accessed at: http://www.ofwat.gov.uk/wp-content/uploads/2015/11/rpt_com_devwatindust270106.pdf.
[5] Ibid.

within the river in order to assess cost-effectiveness of the various measures.[6] The WFD stipulates that the 2009 plans are to be updated in 2015, 2021 and 2027, which is the final deadline for meeting the objectives.[7]

Directives are applied at the national level, where their implementation in national legislation is subject to some lee-way. For example, the definition of the standards of what exactly constitutes good ecological status is left to the national legislator. So, at the national level, Defra is involved in setting the overall policy framework in England and Wales, which involves standard setting and drafting of legislation.[8]

These policies are then implemented by Defra's agencies. For example, the Environment Agency (EA) and Natural Resource Wales are responsible for managing the River Basin Districts in England and Wales. These same bodies are also responsible for regulating water abstraction as well as the treatment and discharge of wastewater, sewerage and sewage sludge back into the environment. The EA regulates abstraction by managing existing licenses and grants new ones and using Catchment Abstraction Management Strategies (CAMS) and abstraction licensing strategies to do this. These bodies also provide guidance to water companies to help manage their supply and drought planning.[9]

NERC science has directly contributed to helping the regulatory bodies implement these policies through a variety of channels, which are explored in further detail below.

2.2 Regulatory measures and the contribution of NERC science

NERC science has made a wide range of contributions to supporting and improving the way in which this regulation is decided and managed. On average, NERC invests in the region of £65m per annum on research related to freshwater.[10] Specifically, NERC science has been used to underpin core components of water quality and quantity regulation in the UK:

- Setting standards: the UK Technical Advisory Group (UK-TAG) makes recommendations to the Government on standards for implementing the WFD. Biological standards in particular are used to measure the ecological quality of water and are used to classify the status of rivers, lakes, estuaries and coastal waters. These standards are used in the RBMP and are updated in the 2015 version. NERC science has made significant contributions to the standards set by UK-TAG, both those included in the 2015 RBMP as well as the preceding versions. These contributions are set out in more detail in the proceeding section.
- Quantifying the value of ecosystem services: as noted above, the WFD allows RBMPs to only include those actions that are not disproportionately expensive[11]. This requires the ability to measure the environmental benefits supported through compliance, in addition to measuring the costs of the proposed actions to achieve good environmental status. Without the ability to accurately quantify benefits, regulations could be enforced which are not delivering value for money in relation to the benefits they support. NERC and ESRC have funded, together with Defra and others, the research that permits the quantification of these benefits. The economic quantification of these benefits also relies on an in depth knowledge of the natural environment.
- Informing abstraction standards, reform and understanding: NERC science has supported water abstraction standards, reform and understanding both directly through the provision of datasets such as Future Flows, and also indirectly through innovation and exploratory research in

[6] European Commission (2016), Introduction to the new EU Water Framework Directive. Accessed at: http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm.
[7] European Commission (2016), WFD: Timetable for implementation. Accessed at: http://ec.europa.eu/environment/water/water-framework/info/timetable_en.htm.
[8] Defra and Ofwat (2006)
[9] Defra (2013), Water Bill – The Structure and regulation of the water industry. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/259664/pb14058-water-bill-industry-structure-regulation.pdf.
[10] NERC's input has been estimated through a review of expenditure in 2013/14 and 2014/15 on research and studentship grants that are related to freshwater.
[11] WFD article 4.

abstraction-related areas. NERC's contribution related to abstraction is assessed qualitatively through a case study approach based on interviews with users of NERC science. Further information on this third contribution is presented in section 4.3.

2.2.1 Setting Standards

The UK Technical Advisory group (UK TAG), chaired by the Environment Agency, recommends the standards which would be used in order to implement and adhere to the WFD in the UK.

UK TAG has set these standards since the WFD was introduced and has consistently been relying substantially on NERC science. Due to space limitations, here it will suffice to provide an outline of the contributions that science from NERC made to the standards set by UK TAG for the 2015 update to the RBMP. However, it should be noted that NERC has contributed to all the versions of the standards, including those preceding the 2015 RBMP. NERC also influenced the core idea in the WFD of comparing the predicted presence of macro-invertebrates for Reference Rivers to their actual presence, as a way of measuring which water bodies are in good ecological conditions.[12]

The 2015 update to the RBMP notes that much progress has been made to better understand the water environment. In particular, there have been improvements in the systems and techniques used to establish the classification baseline in the updated plans including new and improved biological assessment tools. The specific contributions are listed in the table below.

[12] References on the relevant River Management Timelines available from NERC on request.

Figure 1 NERC Contribution to Updated Biological Assessment Methods to be used in 2015 RBMP

Water body	Biological assessment methods	NERC Contribution
Rivers	Larger rooted or floating plants (macrophytes)	The standards and methods have been updated in the 2015 RBMP and NERC funded research has supported these updates. The Centre for River Ecosystem Science at the University of Sterling (CRESS) has developed the official tools that are now used to determine the status of freshwaters and structure catchment management plans.[13] A number of NERC grants have supported the research at CRESS as well as their knowledge exchange programmes.
	Combined new macrophytes and phytobenthos methods	These standards have been updated in the 2015 RBMP and were informed by NERC research. Willby (2012) conducted research relating to the bioassessment of large rivers in the absence of near-natural reference conditions. This work was noted by the Scottish Environmental Protection Agency as having influenced the application of biological assessment methods for implementation of the WFD at the UK and EU level.[14] Willby is an academic staff member at CRESS, which has received NERC funding to support its activities.
	Acid-sensitive bottom-living invertebrate animals	This method is a new addition to the 2015 update. Work by Murphy (2013) on assessing acidity in sensitive streams in Britain is cited in the UKTAG Final Recommendations on New and Updated Biological Standards (2013).[15] Murphy is affiliated with the Centre for Ecology and Hydrology (CEH), which is one of NERC's research organisations.
	Fish: barriers to fish	The standards for barriers to fish migration were a proposed introduction to the 2015 update. NERC science supported these standards through research undertaken at the University of Stirling which developed and validated geomorphological tools for assessing the passability of artificial barriers to fish.[16]
Lakes	Microscopic plats in water column (phytoplankton)	Standards are updated in the new RBMP and NERC science informed these updates. The Aquatic Environment Research Centre provided evidence on the sources of nutrient enrichment which fed into the EA and Defra's monitoring approaches, informed catchment management policy and supported compliance with the WFD.[17] This Research Centre at the University of Reading has received over £4.8m in funding from NERC since 1995.[18] In addition, CEH developed site-specific lake standards that were adopted by the UK and used to info the WFD.[19]
Coastal Waters	Microscopic plants in water column (phytoplankton)	The phytoplankton tool for coastal waters has been updated in the 2015 RBMP and has used research by Tett (2012), which incorporates findings from the University of the Highlands and Islands on monitoring programmes developed from research into harmful algal blooms.[20] A NERC funded grant supporting research into "toxic and non-toxic ribotypes of the harmful

[13] University of Stirling (2014), Protecting and restoring aquatic systems. REF Impact Case Study.
[14] University of Stirling (2014), Protecting and restoring aquatic systems. REF Impact Case Study.
[15] UK Technical Advisory Group on the Water Framework Directive (2013), Final recommendations on new and updated biological standards.
[16] University of Sterling (2014), Protecting and restoring aquatic systems. REF impact case study.
[17] University of Reading (2014), Developing modelling tools to support integrated catchment management. REF Impact Case Study.
[18] Ibid.
[19] Edinburgh Napier University (2014), Defining and sustaining healthy seas. REF Impact Case Study.
[20] University of the Highlands and Islands (2014), Safeguarding human health and sustainable aquaculture through monitoring programmes developed from research into harmful algal bloom dynamics. REF Impact Case Study.

		dinoflagellate" is cited as a key grant supporting this research.[21]
	Bottom living invertebrate animals	The coastal waters benthic invertebrates standards were updated in the 2015 RBMP. The Environmental Agency's report on the Infaunal Quality Index[22] references the contribution of Plymouth Marine Laboratory for their contribution to developing the index.

Source: Deloitte and NERC

These standards are replied upon by the investigations carried out to determine whether or not water bodies are meeting 'good status' under the WFD. In addition, they inform the improved risk assessments referred to in the updated RBMP Impact Assessment.

2.2.2 Quantifying the value of ecosystem services

In addition to contributing to the updated biological standards, NERC science supported the improved valuation of ecosystem services. The updated RBMP notes that updates reflect better estimates of relevant costs and benefits, which have been applied to bring the plans in line with the government White Paper 'The Natural Choice'.

NERC science made significant contributions to this report largely through the work of Bateman, a NERC funded researcher at University of East Anglia. Bateman's research at the Centre for Social and Economic Research on the Global Environment (CSERGE) focused on developing methods for valuing ecosystem services and incorporating them into policy decision making.[23]

This research has been used and applied in several ways. First, Bateman led the UK National Ecosystem Assessment (UK-NEA) Economics team. The UK-NEA was the first analysis of the UK's natural environment in terms of the benefits it provides to society and continuing economic prosperity.[24] He is recognised as a lead author in the areas relating to: Economic values, Valuing changes and Conceptual framework and methodology.[25] As one of the funders of the UK-NEA NERC science made a significant contribution to the assessment, with the work of multiple scientists linked to NERC, in addition to Bateman, cited in the document. The UK-NEA became the empirical basis of the Government's White Paper to which the 2015 RBMP is aligned.

In addition, the work of Bateman has also been linked to the benefit and cost assessment values used in the 2015 RBMP to value the environmental impacts. Specifically, the environmental benefits supported through the RBMP were estimated by the EA using the 2007 National Water Environment Benefit Survey's willingness to pay values. These figures were updated to 2012 values in a report by Metcalfe[26], which was cited in an EA briefing note[27] along with an additional paper by Metcalfe et al., including Bateman.[28] The Metcalfe et al. (2012) report, of which Bateman is also an author is cited in Bateman's original NERC funded ChREAM project, which cites said paper under the section on plans for disseminating the outcomes and results of the research.[29] To

[21] Ibid.
[22] EA (2014), Infaunal quality index: Water Framework Directive classification scheme for marine benthic invertebrates.
[23] University of East Anglia (2014), Costing the Earth: Influencing Government Policy for Ecosystem Services. REF Impact Case Study.
[24] UK National Ecosystem Assessment (2016), What is the UK National Ecosystem Assessment? Accessed at: http://uknea.unep-wcmc.org/.
[25] Ibid.
[26] P. Metcalfe (2012), Update of CRP WFD Benefit Values – Economic Component. A Draft Report for the Environment Agency.
[27] Environment Agency (2013), Valuing Environmental Benefits – External Briefing Note. Accessed at: http://www.thames21.org.uk/wp-content/uploads/2013/12/NWEB-Briefing-Notes.pdf.
[28] P. Metcalfe et al. (2012), An Assessment of the nonmarket benefits of the Water Framework Directive for households in England and Wales. 28 March 2012, Water Resources Research, Vol. 28.
[29] Bateman et al. (2011), Catchment Hydrology, Resources, Economics and Management (ChREAM): Integrated Modelling of WFD Impacts upon Rural Land Use and Farm Incomes. Accessed at:

summarise these linkages, Bateman's work under the ChREAM project, which was joint funded by NERC, was subsequently used in conjunction with Metcalfe's work related to the nonmarket benefits of the WFD, used by the EA in the RBMP.

2.3 Implications of water regulation

As highlighted above, the regulation and control of the quality and availability of the UK's water supply generates material impacts in the public sector, private sector, to the environment, and the general public. Those impacts assessed as part of this study are detailed below.

2.3.1 Compliance: Public and Private Sector Implications

Both costs and benefits accrue to the public and private sector stemming from the need to comply with the RBMP. These benefits accrue in both absolute and relative terms. Absolute benefits are supported through compliance with the RBMP, which improves water quality generating positive environmental benefits. Relative benefits, to the private sector, are also supported through the update of the 2009 RBMP to the 2015 version. Those impacts considered as part of this study are detailed below.

- Cost of compliance: public and private sector organisations are required to carry out specific actions, often associated with their specific industry, which will ensure compliance with the RBMP. This will involve schemes which mitigate impacts and ensure that the WFD objectives are achieved. There is a cost associated with the schemes that industries must implement, which yields the absolute cost of compliance.
- Cost savings: cost savings are generated when the 2015 update to the RBMP is compared to its previous version. The elimination of certain schemes which are deemed to not deliver positive value for money – where benefits generate do not justify costs incurred – has led to the reduction of compliance costs in the updated Plan. The reduction of costs, which have a negative impact on the impact assessment, yields a net positive or net benefit in cost savings.

2.3.2 Water quality: Environmental Implications

The environmental impacts are considered within the context of water quality and the River Basin Management Plan (RBMP). The purpose of the RBMP is to achieve the environmental objectives of the WFD, which generates environmental benefits. The environmental benefits quantified as part of this study include the 'cultural and quality of life benefits', including changes to recreation (bathing, fishing, walking), aesthetic value and existence value (environment and wildlife) that result from improvements in water quality.

2.3.3 Wider benefits: Public Sector and Societal Implications

Public sector and societal impacts are considered in relation to the NERC science that has supported water abstraction regulation and policy. These impacts accrue to both Governmental bodies such as the Environment Agency (EA) and the Department for Environment, Food and Rural Affairs (Defra), as well as the UK's research base. A qualitative approach is taken to measure these impacts due to constraints on quantifying impact given the number of organisations that have been involved in passing specific legislations and standards. The rationale for using a qualitative methodology is further explained in Chapter 4. The public sector impacts included as part of this study are set out below.

- Improved accuracy and confidence: NERC science has been used by Defra and the EA to improve the accuracy of and confidence levels in their work. Improved confidence and accuracy is value add, which has been supported by NERC science.
- Innovation and exploratory research: new techniques and methods have been developed through NERC science. Despite being open to innovation, governmental organisations find it challenging to fund projects which have a high risk of failure – a necessary component to innovation. In addition, NERC science has expanded the UK research base in previously under-

http://www.cserge.ac.uk/sites/default/files/110616%20-%20ESRC-RELU%20proforma%20report%20-%20Revised.pdf.

developed areas. The UK research base is recognised as a key contributor to long-term economic growth and productivity.[30]

This chapter has provided the context within which the impact assessment has been undertaken. In addition, the materiality of the contribution that NERC science has made in the area of water quality and water quantity has been evidenced. This is an important underlying assumption that is carried through the remainder of this report.

[30] HM Treasury (2015), Fixing the foundations: Creating a more prosperous nation. Crown Copyright 2015. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/443898/Productivity_Plan_web.pdf.

3 Impact assessment methodology

The methodology used to conduct this impact analysis follows the principles of the HM Treasury's Green and Magenta Books. Impacts relating to water quality have been quantified and the methodology accounts for factors such as gross to net benefits, additionality and discounting where appropriate. Impacts relating to water quantity have not been quantified and instead of been explored qualitatively using a case study approach. Further details on the assumptions underpinning these approaches and their rationale are provided in the sections which follow.

In addition, the structure of the impact analysis is informed by an impact assessment framework. The purpose of the framework is to establish the 'theory of change', which links NERC research to outcomes and impacts, and to scope out the market and non-market costs and benefits associated with these impacts.

3.1 Impact assessment framework

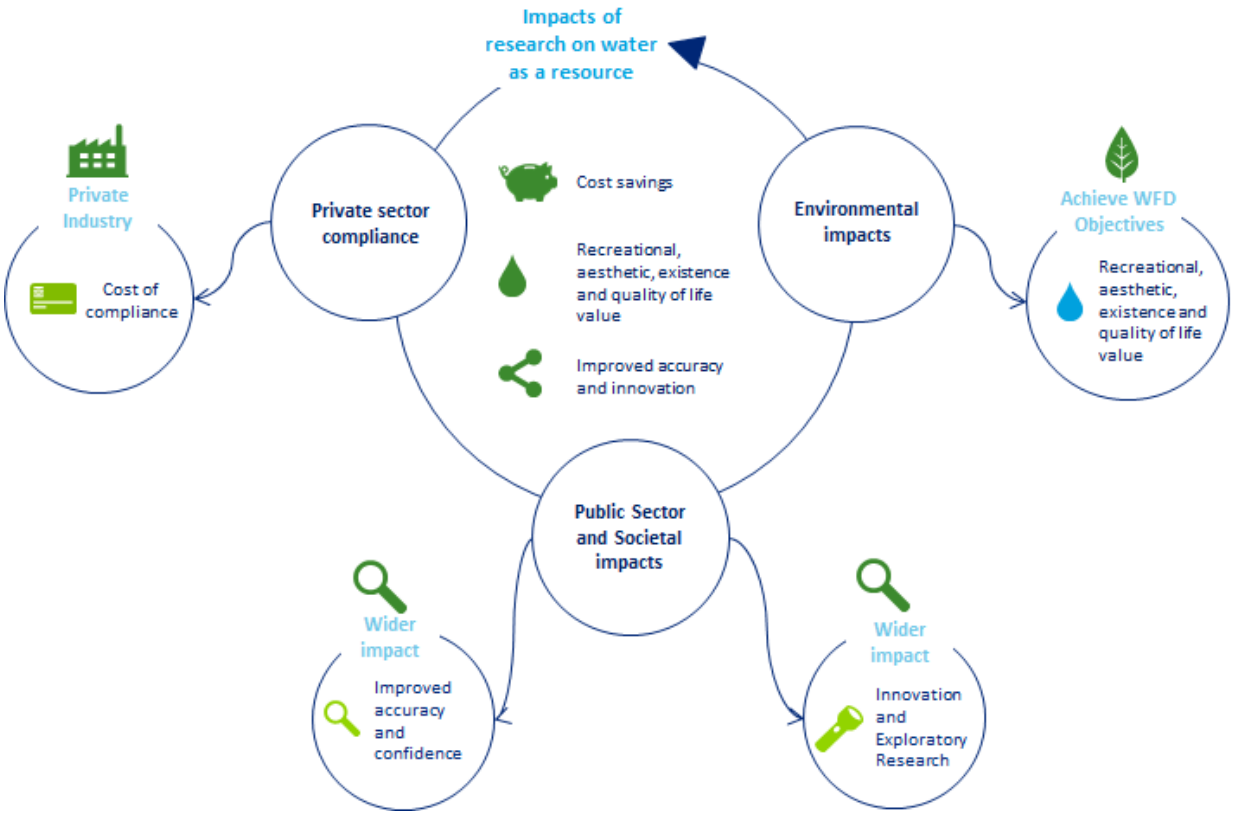
The conceptual impact assessment framework (Figure 2) sets out the range of impacts (costs and benefits) that stem from the regulation of water quality and quantity. Private sector impacts are assessed in relation to the cost of compliance that is incurred by adhering to the River Basin Management Plan (RBMP). These impacts are considered in both absolute terms, as well as the net change in compliance costs comparing the updated 2015 RBMP to its previous version.

Environmental impacts are also considered in relation to the updated RBMP. A total value for economic benefits is provided, which accounts for use-values (e.g. recreation) as well as non-use values (e.g. aesthetic and existence values). These benefits are derived from the achievement of the Water Framework Directive objectives aimed at preventing deterioration of water quality, achieving good status for all water bodies and achieving standards for protected areas.[31]

Impacts that accrue to the public sector and society are considered wider impacts which are not quantified as part of this study. These impacts accrue to both public sector organisations such as the EA and Defra, as well as UK society. NERC research has led these bodies to benefit from improved accuracy and confidence in their work and has also supported innovation and strengthening of the country's research base.

[31] Note that the drivers of environmental benefits are further explored in the detailed methodology of this impact calculation provided in Chapter 4.

Figure 2 Impact Assessment Framework



Source: Deloitte

3.2 Quantitative and qualitative methodology assumptions

The detailed methodological assumptions applied to the quantification of impacts are specific to each impact area are provided in the relevant sections of Chapter 4. Below is a summary of the general assumptions which have been applied across all impact analysis and quantification.

- All prices are stated in 2016 values, re-based using consumer price index (CPI) data from the ONS.
- Water quality impacts are appraised over the period 2015-2051
- Overall impacts are presented as 'net', taking into account both costs and benefits.
- Impacts are presented at the UK level, local and international impacts have not been considered within the scope of this study.
- Quantitative impacts have not been apportioned to NERC and instead are based on the materiality of NERC's contribution established in Chapter 2.

3.3 Structure of impact analysis

Chapter 4 presents the analyses that were undertaken to assess the impact of NERC research in the areas of water quality and quantity. Where necessary, further detail on the methodological assumptions made in assessing individual costs and benefits are provided in Annex 1.

Each impact assessment in the following section is structured as follows:

- **Methodology and rationale**: an overview of the approach taken to measure specific costs and benefits and the rationale underpinning the approach.
- **Assessment of costs and benefits**: where impacts are quantified, a step-by-step description of the quantification of costs and benefits and an interpretation of the findings is presented. Where impacts are not quantified, a qualitative case study is presented.

4 Benefit cost assessment

4.1 Overview of benefit cost assessment

The impacts of water as a resource are assessed in the following sections. The benefits and costs of regulation relating to water quality are assessed quantitatively, while a case study approach is used to assess the wider impacts of NERC research in the area of water quantity and abstraction regulation. The detailed method and calculations which have been undertaken for each of these analyses are set out below.

4.2 Water quality benefit cost assessment

4.2.1 Methodology and rationale

As highlighted in Chapter 2, adherence to the River Basin Management Plan improves and protects water quality. This approach focuses on measuring the impacts that are supported through implementation and update of the RBMP. These impacts accrue to both the private sector and the environment. The private sector incurs a cost of compliance to adhere to the RBMP, which can be understood in both absolute terms as well as relative, by comparing the updated RBMP to its previous version. Environmental impacts are generated through the improvement in water quality achieved through compliance and can also be assessed in absolute or relative terms.

The approach used to quantify the benefits and costs of the RBMP in both absolute terms and in relation to its update is based on the 2015 regulatory impact assessment, *Update to the River Basin Management Plans for England's Water Environment.*[32] The evidence presented in Chapter 2 highlighted the material contributions that NERC science made towards updating the biological standards, as an example of NERC's contribution to standards, and to valuing the costs and benefits of measures included in the RBMP. However, given the other actors who also made material contributions, which together with NERC, led to the 2015 update of the RBMP, the impacts cannot be wholly attributed to NERC, nor can they be apportioned to NERC according to their specific contribution.

4.2.2 Quantification of Benefits and Costs

Several initial steps were taken in order to be able to use the regulatory impact assessment (IA) as the basis for this benefit cost analysis.

First, all the benefits and costs that are accounted for in the IA were delineated in order to understand the full scope of impacts included in the assessment. The actions included in the RBMP are intended to achieve the environmental objectives of the WFD by focusing on three specific areas[33]:

1. Preventing deterioration of the status of surface waters and groundwater
2. Achieving objectives and standards for protected areas
3. Achieving good status for all water bodies or, for heavily modified water bodies and artificial water bodies, good ecological potential, and good surface water chemical status[34].

Both benefits and costs are associated with the actions required to achieve these three objectives.

[32] Environment Agency (2015), Update to the river basin management plans for England's water environment,
[33] Ibid.
[34] Note that measures specifically relating to achieving good surface water chemical status are not included in the appraisal due to the high uncertainty in scale and cost of the measures if they were implemented. Source: Environment Agency (2015), Update to the river basin management plans for England's water environment.

Compliance costs fall on both the public and private sectors, with the majority borne by private industry. The table below outlines the different sector groups which incur a compliance cost as well as the cost drivers.

Figure 3 Delineation of compliance costs

Sector where Action Required	Driver of Compliance Cost
Water industry	• Improve sewerage systems and sewage treatment works • Reducing the amount of water abstracted from sensitive locations by taking water from alternative locations and/or by reducing demand for water • Reducing the number of sewerage misconnections • Installing fish passes around physical modifications they own
Industry, services and infrastructure	• Industry – improve treatment plants, efficiency of water use and reduction of contamination of surface water drains • Urban/domestic – improve private sewerage systems and treatment plans. Use of sustainable drainage systems to reduce pollution from roads and urban areas • Waste treatment, transfer, storage and disposal – improve collection and treatment systems or off-site disposal. • Ports and navigation – improve dredging plans, install fish passes and mitigate other environmental impacts of physical modifications.
Rural land management (including farming)	• Improve soil management • Improve management of animal manure • Improve use of pesticides to reduce water pollution • Reduce amount of water abstracted from sensitive locations through improved efficiency • Prevent livestock from freely accessing watercourses
Government	• Mitigation of impacts of infrastructure, such as roads, flood defence and coastal erosion • Habitat improvements on orphaned physical modifications, such as weirs associated with historic abstractions[35] • Treating contaminated minewater from abandoned coal and metal mines • Action to reduce the spread and impact of invasive non-native species • Seaweed clearance, bird and dog control to protect bathing waters

Source: Environment Agency (2015), Update to the river basin management plans for England's water environment

As stated, the compliance costs which stem from the required actions outlined above are assessed in both absolute terms, as well as the relative change between the 2015 RBMP and its previous version.

The benefits supported by the RBMP are quantified in the IA by taking into account the 'cultural and quality of life benefits', including changes to recreation (bathing, fishing, walking), aesthetic value and existence value (environment and wildlife) that result from improvements in water quality.[36] Note that while benefit valuation studies were used to monetise the majority of the first order benefits, non-monetised benefits will also accrue to all sectors of the economy and society.[37]

[35] A weir is a barrier across a river used to alter the flow of the river. They tend to be smaller than dams and are obstructions placed in rivers to manage flow, prevent flooding or measure discharge.

[36] Environment Agency (2015), Update to the river basin management plans for England's water environment,

[37] Non-monetised benefits that are expected to materialise but which have not been quantified in the IA include the following: mitigation of droughts and floods, climate change adaptation, some market benefits, soil protection, and aesthetic and existence value of the wider landscape. In addition, some benefits of protecting some wildlife sites of national and international importance were not fully monetised. Source: Environment Agency (2015).

After delineating the benefits and costs, the technical assumptions underpinning the impact assessment were outlined in order to reconstruct the calculations and ensure consistency. These are noted as follows:

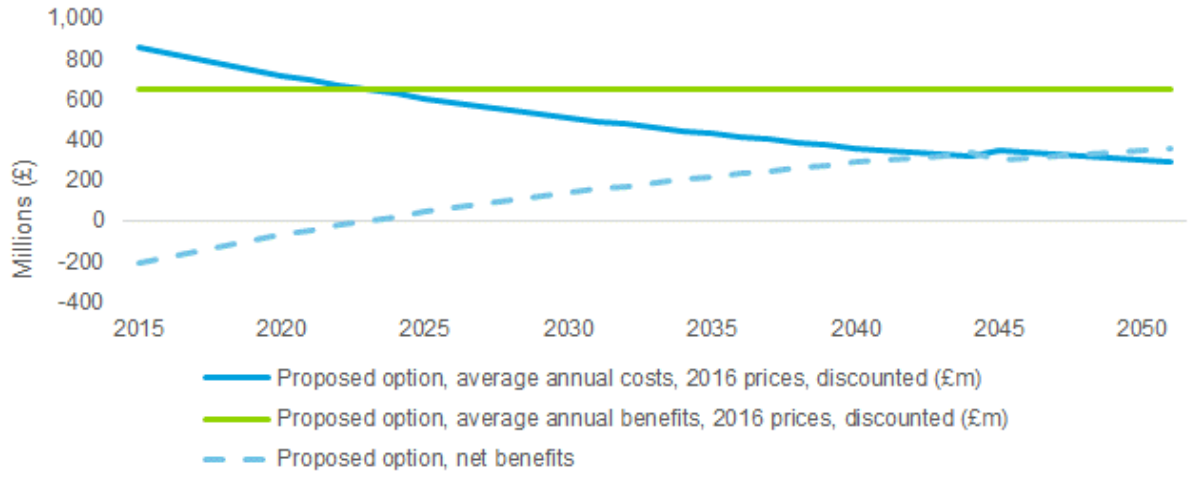
- Price base: costs and benefits were calculated in 2012 prices and have therefore been re-based to 2016 prices using a CPI data from the ONS
- Appraisal period: benefits and costs are forecasted over a 37 year period from 2015 to 2051 in the IA and this has remained the same in this analysis
- Discount rate: a discount rate of 3.5% has been applied for the first 30 years and 3% for the remaining seven years.

Using these underlying assumptions and the estimated costs and benefits provided in the IA for both the baseline and proposed option, the impact assessment is reconstructed on an annual basis over the appraisal period. Specifically, average annual non-discounted costs by sector were used to populate the annual time series, which was then discounted and re-based to 2016 prices. This step was completed for both the baseline and proposed option. The present value of benefits is presented as a single figure that has been discounted over the appraisal period, distributed over the 37 year appraisal period and rebased to 2016 prices. It is assumed that these benefits are distributed linearly over the time series.

In absolute terms, the reconstruction of the impact assessment for the 2015 RBMP update yields a total present value (PV) benefit of £24.1 billion and a PV cost of -£18.6 billion. The proposed option therefore delivers net benefits of £5.5 billion (2016 prices) over the period 2015-2051.

These benefits can be graphically represented on an annual basis over the appraisal period.

Figure 4 Proposed option benefit cost assessment, 2015-2051, £ millions



Source: Deloitte calculations

Figure 4 illustrates the annual distribution of costs and benefits, based on the assumptions that have been made and applying average annual costs and benefits across the time series. It is recognised that the actual distribution of costs and benefits may not mirror this exact profile, however the present value of benefits and costs, when summed over the time series, yields the same result.

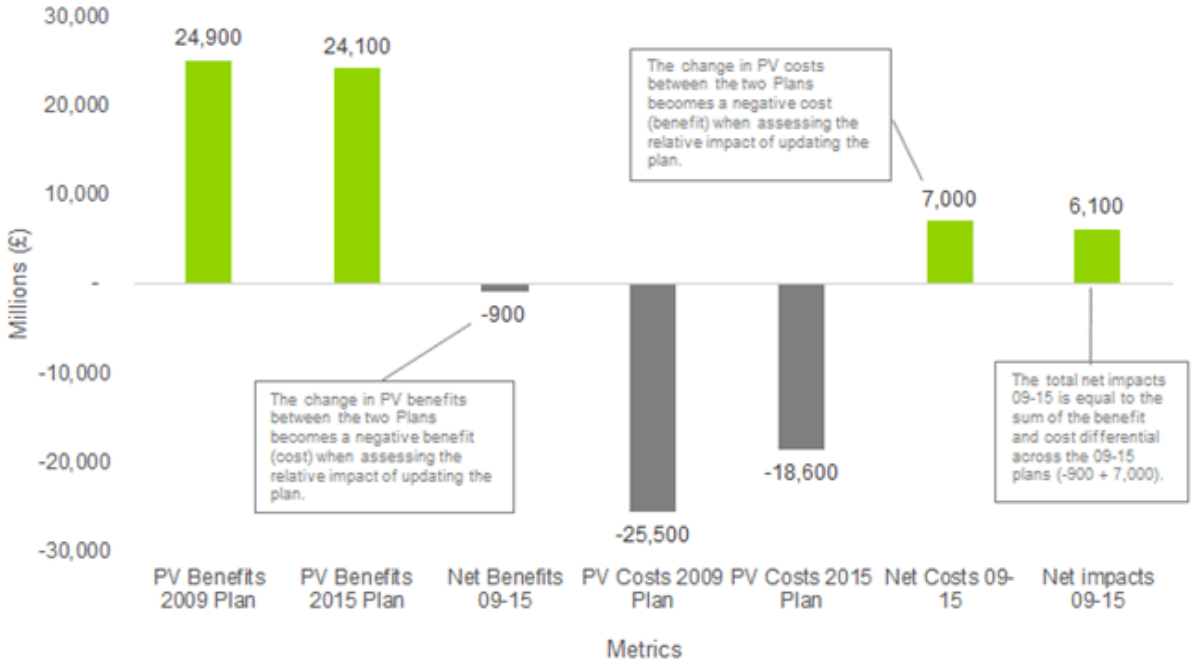
The reconstructed impact assessment can also assess the net benefits which are created by adopting the updated 2015 RBMP compared to the 2009 version which it proceeds.

In relative terms, the 2015 update to the RBMP yields a net change in PV costs of -£7.0 billion and a net change of PV benefits of -£856 million. A reduction of costs (a double negative) results in a net benefit. As a result, the relative net benefits supported as a result of the 2015 RBMP update compared to the 2009 version equates to a positive £6.1 billion.

The net benefits that are generated by updating the RBMP are therefore achieved through a reduction in the cost of compliance, which yields a relative benefit to the private sector compared to the previous plan. Although the PV of environmental benefits decline slightly in the proposed options, this decline is outweighed by an even greater reduction in cost.

The net benefits supported through the 2015 update can be visualised using a waterfall diagram as depicted below.

Figure 5 Relative net benefits supported by the 2015 update to the RBMP, £ Millions



Source: Deloitte calculations. Note that figures may not sum due to rounding. Columns in green are positive and represent benefits. Columns in grey are negative and represent costs.

As the diagram highlights the 2015 update provides a loss of benefit of -£0.9 billion, which is compensated by cost savings of £7.0 billion, yielding a positive net impact of £6.1 billion in relation to updating the 2015 RBMP from its 2009 version.

These results can be further interpreted by understanding to which sector these benefits are accruing and what the drivers of these benefits are. The benefits to these sectors come in the form of cost reduction, with the largest cost reductions flowing to the water companies. The drivers of cost reduction for each sector are the exclusion of schemes that have been assessed as likely to be disproportionately expensive[38]. Those schemes which are driving the cost reductions are outlined below according to the benefiting sector:

- Water industry: additional improvements to sewage treatment works to remove ammonia and phosphate as well as schemes that would reduce the quantity of water abstraction.

[38] Environment Agency (2015), Update to the river basin management plans for England's water environment.

- Industry, Services and infrastructure: schemes to ease fish passage and to improve private sewage treatment works.
- Rural land management: schemes to reduce diffuse rural pollution at source.
- Government: habitat improvements schemes and schemes to ease fish passage

4.3 Water quantity wider impacts assessment

4.3.1 Methodology and rationale

The contributions that NERC has made in the area of water quantity and abstraction was detailed in Chapter 2. Material contributions have been made both in relation to setting abstraction standards as well as in helping to inform the new reform for water abstraction regulation. Despite the valuable contributions of NERC science in these areas, there were a number of other organisations involved which built upon NERC's inputs and added value in their own right. In addition, the value chain of activities to which NERC science was an input is so extensive that through consultation it was concluded that a quantification of impacts, even if not apportioned to NERC, would not be feasible.

Instead, a qualitative case study analysis has been used. Specifically, consultations with Defra and the EA were undertaken in order to explore the various ways in which NERC science has been used and has added value to their operations. The findings from these consultations is presented in the case studies which follow.

4.3.2 Wider Impact Case Studies

A total of seven consultations were undertaken, which explore the various ways in which NERC may have created value for their organisation. Through these discussions, several non-quantifiable impacts were identified:

- Inspiring confidence and accuracy: the use of NERC science, over similar alternatives, has given Defra and the EA more confidence that their outputs are as robust and accurate as possible.
- Innovation and exploratory research: exploratory research has supported innovation and building up of the knowledge base in areas other research funders have not been able to support.

These are explored in more detail below, with specific examples highlighted by Defra and the EA cited.

Case Study 1: Inspiring confidence and accuracy

The Future Flows and Groundwater Levels project (referred to as 'Future Flows') was a joint-funded partnership project between NERC, the Environment Agency of England and Wales, Defra, UK Water Industry research, the Centre for Ecology and Hydrology, the British Geological Survey and Wallingford Hydrosolutions.

The Future Flows project focused on developing the most comprehensive understanding across space and time of how rising temperatures due to climate change will affect water availability in England, Wales and Scotland. Although there was extensive prior research on the impact of climate change on river flows, the geographic coverage of these studies was not exhaustive, nor were methodologies consistent enough to compare different locations. As such, the Future Flows project filled a specific gap in the research landscape by providing a comprehensive picture and eliminated the aforementioned constrains of the existing research base.

The Future Flows project developed two unique datasets for Great Britain:

- Future Flows Climate: a time series (1950-2098) consisting of 11 scenarios of precipitation and potential evapotranspiration for Great Britain

- Future Flows Hydrology: a time series (1951-2098) consisting of 11 scenarios of projected daily river flow and monthly groundwater levels for 282 rivers and 24 boreholes in Great Britain

These two datasets use the latest projections from the UK Climate Impact Programme, including the UKCP09 projections from the Met Office Hadley Centre. They have been made publically available and can be downloaded online free of charge.

1. Water Resource Planning Guidelines

Given that the Future Flows dataset is publically available, it has likely been used in a multitude of ways by a number of different people and organisations. However, detailed consultation was undertaken as part of this study with the Environment Agency to understand how Future Flows has been used to support their operations specifically in relation to water quantity.

Water companies in England and Wales have a statutory duty under the Water Industry Act 1991 to promote the efficient use of water by customers, further water conservation, and take account of the desirability of water conservation.[39] In order to fulfil this objective, the companies are required to prepare and maintain a water resources management plan (WRMP), which sets out how companies intend provide a secure supply of water for people and business in their area over a 25-year period, while protecting the environment.[40]

"NERC's involvement provided a high level of confidence in the science behind the data. This means that users know that any subsequent work is based on high quality, reliable analysis." – Environment Agency

In order to facilitate the drafting of the WRMPs, the Environment Agency (and other organisations[41]) has published the Water Resource Planning Guideline, which provides technical guidance and frameworks for water companies to follow when developing and presenting their WRMPs. The latest Guidelines were published in 2012 and the Environment Agency and partner organisations are currently preparing a new version, which will be published in in 2016.[42]

Consultation with the Environment Agency found that the Future Flows dataset was instrumental in preparing the 2016 update to the Water Resource Planning Guideline. As explained by the EA, in order for water companies to meet their statutory obligations with respect to water supply and conservation, they must know what the future supply of water is likely to be. The Future Flows data provided the basis for the technical information, which the water companies will use to plan for future supply sustainability.

Through consultation, the EA noted that the ability to use the Future Flows data created material value-add to the new guidance through the greater confidence and level of accuracy that it ensured. The EA noted that it is imperative that they ensure that decisions being made regarding the security of future water supply are based on the most accurate information available, which is Future Flows data. Although Future Flows are still estimates, they provide the greatest levels of confidence than any alternative data that could be used.

2. Reform of the Water Abstraction Regulation System

In addition to the EA, Defra has also used the Future Flows data to feed into the modelling they have undertaken in developing the proposed Reform of the Water Abstraction Regulation

[39] Defra (2012), Information for Water and Sewerage Undertakers and Regulators on Statutory Environmental and Drinking Water Provisions Applicable to the Water Sector in England. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69603/pb13829-statement-obligations.pdf
[40] Environment Agency (2016), Water resource management plans. Accessed at: https://www.gov.uk/guidance/balancing-water-resources
[41] Ofwat, Defra and the Welsh Government
[42] Note that the updated guidelines are co-produced by the Environment Agency, Defra, Welsh Government, Natural Resources Wales and Ofwat.

System.[43] Specifically, the Future Flows data was used in the hydrological model, which then fed into an agent-based model developed by Defra to test how actors will react within different constraints of the new regulation. Defra noted that if this data was not available, they would likely have found an alternative which would have allowed them to develop the proposed regulation. However, any alternative would have been perceived as less credible, likely causing the proposal to command less confidence and authority.

Case Study 2: The Value of Innovation and Exploratory Research

Consultation with the Environment Agency and Defra also found that NERC is seen as adding value to their operations through the innovation and 'blue sky' exploratory research it supports in relation to water quantity. The organisations highlighted that NERC's business model accommodates a greater degree of uncertainty (or risk) when embarking on a new research project, particularly when a practical or policy application has yet to be identified. Supporting research that has a risk of failure supports innovation and is seen by Defra and the EA as generating value and adding to the overall research base even if results are inconclusive or unsuccessful.

Specific examples of where NERC has added value through supporting innovative and blue-sky research are highlighted below.

1. UK Droughts & Water Scarcity Programme:

The period April 2010 – March 2012 was the driest period on the 128 year record for the Thames catchment.[44] This period of drought put the water supply of the Thames catchment (which includes London) at risk and highlighted vulnerability of the water supply to extreme weather conditions. As the EA noted, historically there has been minimal funding dedicated to drought research in the UK, due in part to its perceived relative importance compared to other research areas. However, shortly after the 2010-12 drought, NERC launched the UK Droughts & Water Scarcity Programme, bringing drought research to the forefront of the research agenda.

> "Without NERC, it is unlikely that another organisation could have brought together so many people to work on this type of applied research" – Environment Agency

This is a five-year interdisciplinary, £12m+ NERC programme in collaboration with ESRC, EPSRC, BBSRC and AHRC. Beginning in 2013 and currently ongoing, the programme aims to support improved decision making in relation to droughts and water scarcity. To date it has funded four specific UK-focused projects.[45]

From the perspective of the EA, this programme has already created significant value through the fact that it has quickly brought together 40-50 scientists who are now focused on drought research who previously or otherwise would not be. Although it is difficult to know which components of this research will or will not be adopted into policy, the EA noted that it has acted as a catalyst to create research momentum in an important area. This cohort of 40-50 drought specialists are now more likely to apply for further funding from other organisations to continue drought research and continue building the research base in this area. The EA noted that without NERC, no one could

[43] Defra (2015), Future Water Resources Management: Reform of the Water Abstraction Regulation System – Impact Assessment. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/492418/abstraction-reform-ia.pdf

[44] Thames Water (2015), Final Water Resource management Plan 2015-2014. Accessed at: http://www.thameswater.co.uk/tw/common/downloads/wrmp/WRMP14_Section_1.pdf

[45] (1) Historic Droughts: understanding past drought episodes to develop improved tolls for the future, (2) IMPETUS: improving predictions of drought to inform user decisions, (3) MaRIUS: managing the risks, impacts and uncertainties of drought and water scarcity, and (4) DRY: drought risk and you

have brought together such a cohort of scientists dedicated to this type of exploratory drought research.

2. Changing Water Cycle Programme

In 2011 Lavers et al. published a ground-breaking study which established the link between winter floods in Britain and the presence of atmospheric rivers.[46] Atmospheric Rivers (ARs) are narrow ribbons across the earth's surface along which a large flux of moisture is transported from the subtropics to the mid-latitudes. Given the large amount of water vapour that ARs transport, they can lead to heavy precipitation when they hit land. Prior to this research, the majority of research had focused on the link between ARs and major flooding and snowfall in the western United States.

Lavers et al. proved that ARs occurred simultaneously with the 10 largest winter flood events since 1970 in a range of British river basins, suggesting that ARs are persistently critical in explaining extremely winter flooding in the UK.[47] This research was funded by NERC under the Changing Water Cycle programme, HyDef project.

This project created value in several ways. Firstly, the European Centre for Medium-Range Weather Forecasts (ECMWF) has recognised that identification of ARs is more accurate than the previously used precipitation forecasts in predicting flooding. As such, the ECMWF's Early Warning system for flooding is based on ARs.[48] In addition, the EA highlighted that this research led to a direct transfer of knowledge within the UK, since it allowed for a UK-specific research base to be established in relation to ARs.

It was noted that the geographic relevance is of particular importance for environmental science research, where the most accurate research must be geographically focused on the area or country in question. Since international research was based on areas in the United States with geographic characteristics much different than the UK, these findings could not be easily translated and applied here. The EA noted that if NERC had not funded this exploratory type of research, it would most likely have been funded via the EU, which would have broadened its geographic scope and weakened its relevance and application to the UK.

3. Soil Moisture Network

The CEH's Soil Moisture Network (COSMOS-UK[49]) is studying how soil moisture varies across the country with soil type, climate and vegetation. The EA noted that this ongoing project is innovating in the area of hydro-meteorological modelling and if successful, could be a practice adopted by the EA and possibly others. While the EA is willing to innovate and continue to improve their modelling and measuring techniques, it was noted that a project such as this, which does not guarantee an outcome which can be immediately implemented by the Agency, is challenging for them to undertake.

> "Our research and development needs to have a high chance of success. On the other hand, NERC can fund the blue-sky exploratory research that, if successful, can lead to step changes in the way we do things." – Environment Agency

As such, the EA sees value in this project regardless of the outcome: if the techniques developed can be adopted by the EA, then they will benefit from the innovation without having to have

[46] Lavers, D. A., R. P. Allan, E. F. Wood, G. Villarini, D. J. Brayshaw, and A. J. Wade (2011), Winter floods in Britain are connected to atmospheric rivers, Geophys. Res. Lett., 38, L23803, doi:10.1029/ 2011GL049783. http://www.met.reading.ac.uk/~sgs02rpa/PAPERS/Lavers11GRL.pdf
[47] Ibid.
[48] European Centre for Medium-Range Weather Forecasts (2014), Increasing the limits of predictability of floods by using NWP ensemble forecasts. Accessed at: http://www.ecmwf.int/sites/default/files/elibrary/2014/13759-increasing-limits-predictability-floods-using-nwp-ensemble-forecasts.pdf
[49] This project is funded by NERC as part of the RCUK Capital Investment Strategy.

assumed the risk. If the techniques cannot be adopted, they still see value in knowing what doesn't work and being one step closer to identifying what will.

4. Land Use, Climate Change and Water Availability

This study, co-funded by Defra, CEH and BGS, responded to an earlier study which identified knowledge gaps in the understanding of how land use and management could affect water availability under conditions of climate change. The research, undertaken by Cranfield University, CEH and BGS with support by the EA, included a modelling exercise to understand how water moves through soil to calculate how much water is either evaporated, runs off or leaves the soil at its base.[50]

Through consultation Defra explained that although this study has yet to be linked to any specific changes to policy or regulation, it is possible that it will feed into the 25 year Environmental Plan currently under preparation. In addition, Defra noted that the study has already had added value through raising awareness of key issues amongst the stakeholder group it will look to engage with as it prepares the Environmental Plan. In this sense, the research has served to open up a new area of thought and has facilitated an informal knowledge exchange which will support Defra's future endeavours. While it is likely that an organisation alternative to BGS or CEH could have delivered elements of this study (such as the rapid evidence review), BGS and CEH had already developed the skills required to undertake the modelling, suggesting that this value add is attributable to NERC.

5. Knowledge Transfer Fellowships

Knowledge transfer fellowships are provided for a six to twelve month period to post-doctorates. These fellowships are part or fully funded by NERC and provide a temporary post in the Environment Agency for those with a PhD in environmental science. Consultation with the EA indicated that these fellowships provide significant value to the Agency in several ways: first, they provide an opportunity for practical, on the job training which allows students from academia to understand how the Agency functions and how their skills can practically be applied. This is an important process in facilitating the transfer of both knowledge as well as skills for the UK's leading research base into practical application for environmental policy and regulation. The value that these specialists can bring to the EA through their expertise in particular areas of environmental science is significant, and these fellowships have been recognised as a critical step in facilitating the transfer of both knowledge, skills and manpower from academia into industry.

The case studies above have highlighted specific examples where NERC science has provided value add to Government agencies, as well as supporting the UK research base and innovation. The consultations have confirmed that in all cases, the alternative to NERC science (the counterfactual) would not have delivered an outcome of the same quality, accuracy and confidence. It is important to note that these case studies represent a limited selection of views from the departments and therefore cannot be interpreted as representative. Nevertheless, they do suggest that NERC's contribution to generating these wider impacts is indeed material.

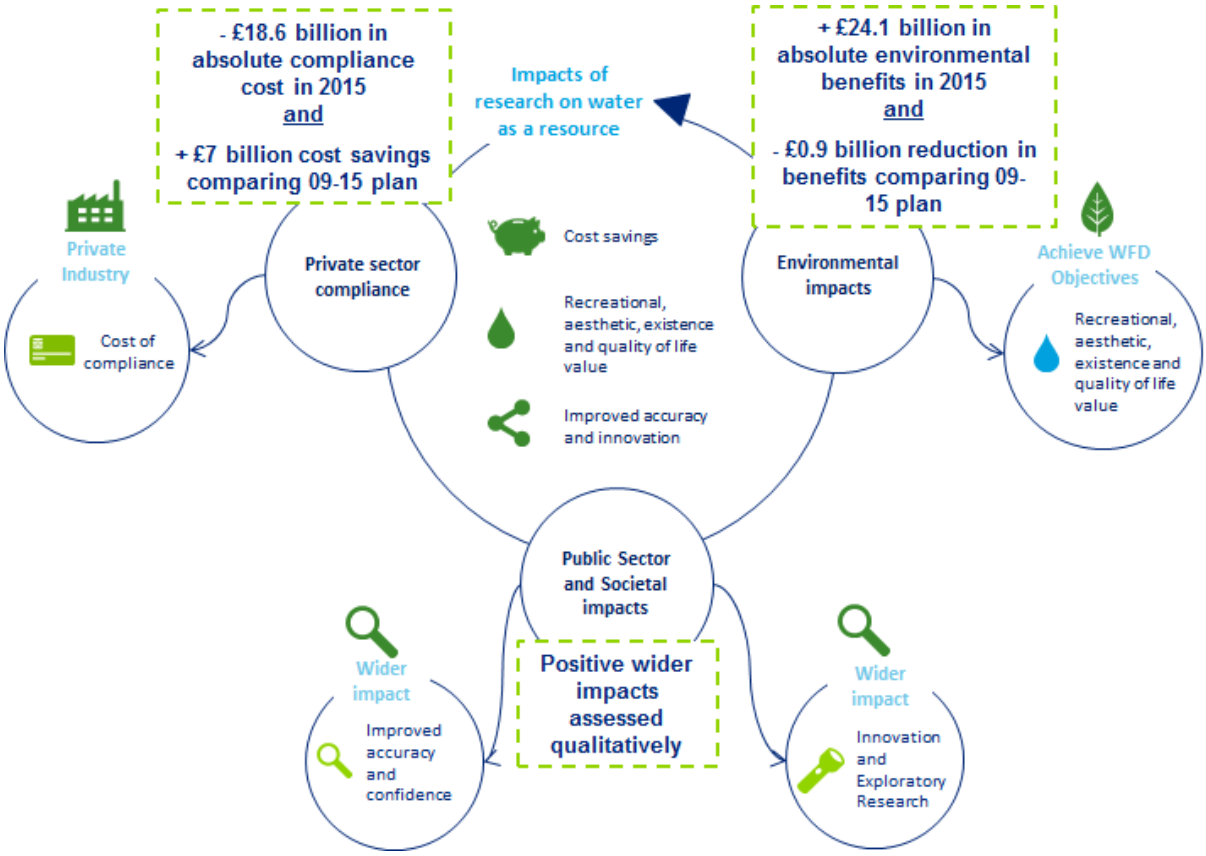
4.4 Summary of water quality and water quantity impacts

The preceding sections have assessed the contribution that NERC science has had in the areas of both water quality and water quantity. As highlighted in Figure 6, water quality impacts have been assessed in both their absolute terms (as supported through the 2015 RBMP) as well as in relative terms (comparing the net impacts of the 2009 and 2015 RBMP). Both the RBMP itself and its updates have provided substantial environmental and economic impacts.

[50] Defra (2014), Land use, climate change and water availability – Phase 2: Summary Report. Accessed at: http://randd.defra.gov.uk/Document.aspx?Document=12335_LUC,CCandWaterAvailabilityP2SummaryReport.pdf.

NERC science has also supported water abstraction standards, regulation and improved understanding, which have been assessed qualitatively through interviews with NERC science users, namely the Environment Agency and Defra.

Figure 6 Impact assessment framework containing absolute and relative impacts



Source: Deloitte

Deloitte.

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