

# **Economic benefits of environmental science**

A study of the economic impacts of research funded  
by the Natural Environment Research Council

November 2006

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## 1 Foreword from the NERC Project Board

The Natural Environment Research Council (NERC) is committed to spending its share of the science budget, currently around £371 million per annum, as effectively and efficiently as possible. This includes ensuring that knowledge generated by NERC research is exploited for the benefit of the UK economy. This may be by informing government policy, improving procedures and practices, contributing to new products and services, or helping to improve the quality of life. The NERC Project Board note that the Office of Science and Innovation requires a step change in realising and demonstrating economic benefits from investment in the science base.

NERC already has excellent examples of where its research has had an economic impact. For example, through the Proudman Oceanographic Laboratory, NERC provides the data required to inform decisions on when to raise or lower the Thames barrier. The cost of getting this wrong would be £30 billion, without counting the loss of human lives.

However, the Board wanted to improve its overall understanding of NERC's specific contribution to the economy and to quantify this role in monetary terms if possible. This would help to build a stronger evidence-base on the impacts of NERC funding and help with decision-making in the future. In July 2005, NERC was therefore pleased to commission PricewaterhouseCoopers (PwC) to carry out a study of the economic impacts of NERC research. As this was a pilot project, and realising that the scale and diversity of NERC's research would prohibit analysing its entire portfolio, a case study approach was taken. It has focussed on ten illustrative areas of NERC funding including potential benefits from planned research.

PwC used an accepted methodology, known as evidence-based appraisal, which focuses on interviews with key stakeholders. A deliberately cautious approach was taken with regard to the economic modelling – with benefits being annualised over 25 years using a discount rate of 3.5% for all case studies. This conforms to HM Treasury appraisal standards and protocols as set out in the 'Green Book' on appraisal and evaluation in central government. A relatively modest and experimental study of this type was not expected to yield a robust gross financial estimate of the economic benefit of all NERC-funded research and the report based on PwC's work should be read in this context. Additionally, there has been no attempt to 'cherry-pick' only those case studies with a good story to tell.

The Board welcomes PwC's findings, which are couched in terms of strategic, wider and direct benefits. These provide further evidence that NERC has a positive impact on the UK economy and will inform future work on demonstrating and quantifying these impacts. While, NERC is happy to share its findings with stakeholders, it should be noted that this is an internal report which has not been tailored for an external audience.

The Board is grateful to all the stakeholders who have been involved in the Study. Particular gratitude is due to those who were interviewed by PwC and who provided valuable comments on both the findings and the process.

**NERC Economic Impacts Study Project Board (David Bloomer, Hazel Jeffery, Steven Wilson), May 2006**

## 2 Executive Summary

In May 2006, PricewaterhouseCoopers LLP (PwC) produced an economic impacts study for the Natural Environment Research Council (NERC), the UK's leading environmental research organisation. This pilot study examined the economic benefits of NERC's investment in the science base.

The study concluded that the economic contribution of NERC-funded research is considerable. There is a good strategic match between the outcomes of NERC-funded research and goals in the Government's 'Science and Innovation Investment Framework 2004-2014'. It is also possible to quantify examples of direct and wider benefits. While this study focused on UK benefits, it is clear that far greater impacts accrue globally.

Key recommendations:

- More systematic interaction between the NERC community and policy makers.
- Integration of economic impacts measurement as part of future programme/project set up.
- Focus on releasing benefits as well as measuring. There is a key role for 'technology translators' in disseminating knowledge as well as the well-recognised role of technology transfer expertise in realising commercialisation.

### The study

The Government's ten-year investment framework for science and innovation, 'Science and Innovation Investment Framework 2004-2014' highlights the economic case for supporting public investment in science. NERC wanted to improve its overall understanding of its specific contribution to the UK economy.

In view of the scale and diversity of NERC's research activities, the study focused on ten case studies, selected in conjunction with the Project Board, according to their relative maturity, science area, and size of funding. The case studies were chosen because they have already added, or are expected to add, scientific value, not because NERC anticipated them to produce high economic benefits. Consultation with key stakeholders in the science and end user communities around the different case studies offered an academically accepted source of primary research that has provided evidence of the impacts of NERC funded research.

The study developed a value chain for each case study, identifying a range of qualitative, strategic benefits, and wherever possible providing a quantitative benefits assessment. In projecting the economic benefits of NERC's investment in the science base, the authors consulted with the Office of Science and Innovation and HM Treasury and applied a methodology that is consistent with the HMT 'Green Book'<sup>1</sup>. The figures are thus independently and conservatively assessed. The authors have not extrapolated a gross financial estimate for NERC as this would be technically unsound. However, the overall figures indicate a considerable payback from NERC science, particularly given that the impact of the funding NERC provides for studentships and fellowships, apart from capacity building, was not included within the scope of the study.

The study's authors characterised benefits to the UK economy as:

- strategic qualitative benefits of use to policy makers and regulators, increasing the effectiveness of public services and policy making, and having a wider impact on society

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<sup>1</sup> HM Treasury (2003), Appraisal and Evaluation in Government, HMSO

- direct and quantifiable benefits improving efficiency and competitiveness in the public and private sectors
- wider benefits that have enabled better decision-making, and thereby delivered positive and quantifiable benefits to society as a whole.

## Strategic benefits

Stakeholders identified the strategic benefits arising from NERC research as:

- **UK reputation** – stakeholders judged that NERC-funded research and scientists have enabled the UK to have a first class reputation in many important fields of environmental science, notably climate change, ozone research and marine biotechnology.
- **Sustaining and improving the UK science base** – many of the case studies show that the research programmes have successfully attracted further funding into the UK science base. For example, the Rapid Climate Change Programme has attracted £1.72 million from European Partners and £3.93 million from the US.
- **Policy development and implementation** – evidence from stakeholder interviews indicates that NERC-funded research strengthens the evidence base for policy making by developing a clearer understanding of the short, medium and long term causes and implications of environmental change.
- **Networks, national and international collaboration** – stakeholders highlighted the role NERC provides in bringing together new national and international collaborative networks. Stakeholders identified this as a key benefit of programmes such as Urban Regeneration and the Environment (URGENT), the Terrestrial Initiative in Global Environmental Research (TIGER) and others.
- **Public engagement, awareness-raising and communication** – NERC-funded scientists at the British Antarctic Survey not only identified the hole in the ozone layer in the 1980s but they also had a central role in disseminating their findings and explaining their significance to the highest level of government, paving the way for international action through the Montreal Protocol.
- **Decision-making and empowerment** – evidence derived from studies demonstrates that NERC funded research and facilities can enable people and organisations to respond quickly to environmental issues.
- **Addressing market failure, encouraging innovation and showing leadership** – one of the roles of public funded research is to build a critical mass in key research areas that privately funded research bodies would not tackle.
- **Promoting competitiveness and scientific transfer** – several case studies indicated that NERC funded science and research promoted and supported technology and knowledge transfer.

## Direct and wider benefits

Stakeholders identified direct as well as wider benefits. Where stakeholders were not able to specify the extent of those benefits, the authors developed examples that indicate the potential benefits accruing from the research. The authors have projected the economic benefits in monetary (present value) terms over 25 years and using a discount value of 3.5 percent. (A monetary value expressed in present value terms represents the future stream of

benefits converted into equivalent values today that is in 2006). Examples of direct and wider benefits are given below while the table provides a more detailed summary.

**Direct benefits** include NERC's *Flood Estimation Handbook*, and its supporting software, which provides flood risk information on a post-code level throughout the UK. As an example, based on stakeholder evidence, the authors conservatively estimate that this handbook has saved the UK economy between £7 million and £34 million (present value), depending on the cost and number of hydrologists carrying out flood risk assessments, over 25 years.

Gritting and salting icy roads costs local authorities millions of pounds each year. Part of NERC's Urban Regeneration and the Environment Programme (URGENT), 'Route forecasting to optimise road de-icing', may directly benefit local authorities in the future by reducing unnecessary salting. Using stakeholder views and third party data, the authors predict that this project would help to achieve cost savings of the order of a present value of £20 million over 25 years.

**The study highlighted wider economic benefits** from NERC's investment in the science base by examining evidence used in policy makers' decisions, commercialising new techniques or publishing new knowledge. For example, based on stakeholder evidence, the work on de-icing roads in winter could contribute economic benefits in the region of £13 million to £29 million in present value terms, based on fewer deaths and casualties on British roads.

Another example is the subsidence data supplied by the British Geological Survey (BGS). This could contribute wider benefits to the UK economy by helping to reduce the insurance costs of subsidence. The authors estimated that a saving of 1-5% over these costs would provide an average present value in the range of £3 million to £11 million per annum (over 25 years that grosses up to £70 million to £270 million).

The study contained examples of benefits anticipated by research programme managers while others were more serendipitous. The Marine and Freshwater Microbial Biodiversity programme provided an exemplar of the key role of technology transfer expertise in realising commercialisation.

### **Acknowledgements**

During the course of this study, the authors interviewed some 70 stakeholders. PwC are grateful to all of them for their invaluable contribution to this report.

**NERC ECONOMIC IMPACTS STUDY 2006**  
**Summary table to show examples of projected economic benefits**  
**accruing from projects funded by NERC**

Case Study	NERC funding and period	Example benefit <sup>2</sup>
Flood Estimation Handbook (FEH)  See Case Study 8 for full details	While NERC did not fund the FEH directly, it did pay for its predecessor, the Flood Studies Report (FSR) on which the FEH was heavily reliant	£7m to £34m – cost savings in preparing flood risk assessments (direct benefit)
Urban Regeneration and the Environment (URGENT) – Route Forecasting to Optimise Road De-icing – Entice See Case Study 4 for full details	URGENT – £9.7m (1997-2003), which led to the Birmingham spin-out company, Entice – £270K to Entice	£20m – resource savings when salting roads (direct benefit)
URGENT  See Case Study 4 for full details	URGENT – £9.7m (1997- 2003)	£13m to £29m – based on improved road salting leading to fewer deaths and serious casualties (wider benefit)
Lowland Catchment Research (LOCAR)  See Case Study 7 for full details	£7.75m (2000-2006)	£2m to £9m – potential savings in monitoring Water Framework Directive implementation (direct benefit)
Global Nitrogen Enrichment (GANE)  See Case Study 3 for full details	£6m (1998-2006)	£7m to £48m – based on the potential for reducing nitrogen excess in the environment (wider benefit)
Geo-reports and Subsidence Information  See Case Study 9 for full details	Around £300k for 2004-2005	£70m to £270m – based on reducing insurance costs of subsidence (wider benefit)
Marine and Freshwater Microbial Biodiversity  See Case Study 5 for full details	£6.9m (2000-2005)	£224m to £1,122m – based on the UK gaining a 1–5%t share of the marine biotechnology products market (wider benefit)

<sup>2</sup> Figures represent a present value estimated over 25 years using a discount rate of 3.5%

# Part 1 – Methodology and findings

## 3 Introduction and project overview

### 3.1 Purpose

The Natural Environment Research Council (NERC) delivers independent research, survey, training and knowledge transfer in the environmental sciences<sup>3</sup>. It is one of the eight Research Councils that fund and manage scientific research and training in the UK. It has a budget of around £419 million per annum to fund scientific research in universities and at its own sites. £371 million of that budget comes through the Office of Science and Technology (OST). The remainder, around £48 million, comes from sources that include contract research, data sales and licence income.

NERC has the lead UK responsibility for developing, funding and delivering environmental sciences. NERC's mission is<sup>4</sup>:

“To gather and apply knowledge, create understanding and predict the behaviour of the natural environment and its resources, and communicate all aspects of our work.”

PricewaterhouseCoopers LLP (PwC) were engaged by NERC to undertake an appraisal of a selection of the key economic benefits (or 'value') generated by NERC's activities as a principal funding agent of environmental research throughout the UK. It is anticipated that the evidence based findings from this study will enable NERC to demonstrate better the impact on the UK economy of the science that it funds by linking research to demonstrable outcomes.

The case for public investment in the science base is made in the Government's Science & Innovation Investment Framework 2004-2014, which states:

“For the UK economy to succeed in generating growth through productivity and employment in the coming decade, it must invest more strongly than in the past in its knowledge base, and translate this knowledge more effectively into business and public service innovation.”

The purpose of this study is to understand more clearly the economic impact of NERC's investment in the science base and to identify within that the following types of economic benefits arising from NERC-funded research:

- strategic and policy benefits (e.g. increased effectiveness of public services and better policy making)
- direct benefits (e.g. productivity and efficiency gains)
- wider benefits (e.g. avoided costs of environmental damage)
- the primary focus of the project has been on NERC's longer-term, public funded strategic science rather than its contract research. NERC also has an important role in training new scientists and engineers, who perform academic research. However,

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<sup>3</sup> [www.nerc.ac.uk/about/work/mission.asp](http://www.nerc.ac.uk/about/work/mission.asp) accessed 20th November 2006

<sup>4</sup> NERC (2002) Science for a Sustainable Future 2002-2007

the impact of the funding NERC provides for studentships and fellowships, apart from capacity building, is not included within the scope of the study. The findings have been focussed at a UK, more than European or global, level. It is clear though that the work of NERC has important global benefits and it is recognised that these might usefully be the subject of future work. But even in the course of this study, important international benefits have been identified and detailed from the case studies that were investigated. For example, the benefits that are likely to accrue from the RAPID programme in understanding the prospects and consequences of RAPID climate change, or the contribution of research by the British Antarctic Survey on monitoring the ozone layer, which contributed to the Montreal Protocol.

NERC also makes a contribution to supporting **blue skies science**, which aims to achieve innovative research results and it is important to note that the case studies will nearly all have built on blue skies research. However, this creative sort of research can often lead to outcomes unimagined at the outset, and as such, it does not lend itself well to detailed study in a report of this sort.

## 3.2 Methodological approach

This report summarises the results of a social and economic benefit assessment conducted on case studies of NERC-funded research. Such assessments are commonly conducted, usually by public sector bodies and organisations, on a wide range of infrastructure projects, policies and programmes. The methodological framework of this, and indeed the majority of socio-economic assessments<sup>5</sup>, is prescriptive in nature, it is summarised below and described in detail in Annex A.

### 3.2.1 Key features of the approach

The approach sought to identify and quantify the full range of benefits arising from NERC-funded research. It is important to note that:

1. this study analyses the economic benefits of **discrete case studies** which are examples of NERC-funded research and does not seek to gross up benefits for NERC as a whole
2. the evidence that was gathered about the capacity of each case study to achieve economic benefits is based on **stakeholder views**, an accepted method of evidence collation, additionally third party sources have also been used to complement or validate stakeholder views
3. economic benefits, arising from case studies and which represent benefits arising for the entire UK economy, have been disaggregated as follows:
  - strategic benefits that are qualitative in nature and which arise to policy makers and regulators, increasing the effectiveness of public services and policy making, and having a wider societal impact
  - direct benefits that arise as quantifiable efficiency and competitiveness gains for public and private sector institutions

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<sup>5</sup> Examples of other assessments of similar nature are found in the Methodology Annex A

- wider benefits that arise as an outcome of research that might have facilitated better decision-making, and thereby delivered positive and quantifiable benefits to society as a whole.

**Figure A.1** in Annex A summarises the main components of the methodology.

### 3.2.2 Case study selection

In view of the scale and breadth of NERC's research activities this research was focused on ten illustrative case studies. The reasons for taking this approach were that there are a very large number of projects funded by NERC, and the time over which they are funded is correspondingly broad. It was therefore necessary to constrain the scope and duration of this study in a proportionate way.

The criteria for identifying the case studies included:

- science areas – based on NERC's scientific priorities: climate change, Earth's life-support systems, sustainable economies
- amount of funding – broken into three broad ranges of greater than £10 million, £2.5-10 million, and less than £2.5 million
- maturity – the relative completeness of the project (e.g. case studies include some that are just starting, while others were completed some time ago).

In identifying the potential case studies, a structured sample was developed, with key objectives being to:

1. select those which have either already added scientific value, or which are expected to, not with a view to those which have the most significant potential economic benefits
2. identify measurable outcomes in terms of benefit to economic competitiveness, public policy and services, and improved quality of life.

Data from within NERC on business activity, outputs and studies carried out within particular research sectors, were reviewed and advice taken on potential case studies from the NERC Economic Impact Study (EIS) project team, who in turn were advised by NERC Swindon Office and research and collaborative centres. Building on this advice and PwC's own research, and using criteria within an evaluation framework, a shortlist of potential case studies was identified. These potential case studies were presented to the EIS Project Board<sup>6</sup>. Following discussions with the Project Board, a further iteration of the list of case studies was circulated around the NERC research community with the opportunity to

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<sup>6</sup> The EIS Project Board members are Steven Wilson (Director of Science and Innovation), David Bloomer (Director Finance and Information Systems), Hazel Jeffery (Business Manager for Planning and Evaluation), supported initially by Stuart Pryde, and from September 2005 by Joanna Tudor (Team Leader – Business Performance Management) and Kirsty Adam (Planning and Performance Manager)

comment on the proposals and to suggest alternatives. The NERC Executive Board then agreed a final shortlist of ten case studies on 16<sup>th</sup> September 2005.

1. Terrestrial Initiative in Global Environmental Impact Research (TIGER) Programme
2. Rapid Climate Change (RAPID) Programme
3. Global Nitrogen Enrichment (GANE) Programme
4. Urban Regeneration and the Environment (URGENT) Programme
5. Marine and Freshwater Microbial Biodiversity (M&FMB) Programme
6. Environment and Human Health Programme
7. Lowland Catchment Research (LOCAR) Programme
8. The Flood Estimation Handbook (FEH)
9. Geo-reports and subsidence information
10. Discovery of a hole in the ozone layer and subsequent research

**Figure A.2** in Annex A includes the generic NERC's Value Chain graph that was used to analyse each case study. Each of the case studies was assessed against this value chain, and this is presented at the end of each case study chapter.

The implications of taking such an approach are that:

1. this study provides only an illustration of potential applications and benefits arising from the science that NERC invests in
2. as such the benefits identified in this report cannot be grossed-up to a 'whole of NERC' level, because the sample is not sufficiently representative; there are also likely to be issues of double counting between case studies, which PwC have not sought to resolve
3. the projected benefits are therefore purely indicative of those that will arise more generally from NERC's portfolio of funded research.

On this basis, the overall economic contribution made by NERC will be significantly greater than specified by this study.

### 3.2.3 Stakeholder consultation and validation

For each case study, the nature of the research was reviewed, together with its application and end use. Capturing and expressing the value associated with this end-use through stakeholder evidence was the primary focus of this study.

Two types of stakeholders were consulted through this study:

- scientists and academics that have been, or are being, funded by NERC or belong to organisations (e.g. research centres) funded by NERC and who have played key roles in developing the case studies
- users and/or beneficiaries of NERC-funded research who use the outputs of research through participating in dissemination activities and who usually have a role in transforming research into policy and practice that may achieve an economic impact.

It was noted throughout the course of this study that some of the stakeholders might be involved with a NERC-funded research programme in more than one way. For instance, key users of research outputs are sometimes invited to be part of steering committees or user dissemination networks. Their perspective would be used to enhance the direction and dissemination of NERC-funded research. This is to be expected, and it is not believed that this compromised end-users objectivity. It was consistently found that stakeholders provided their views regarding the benefits of NERC-funded research in an impartial way.

At the end of the consultation process, the case studies were validated with a selection of key stakeholders to ensure that the evidence gathered had been correctly interpreted and as such, that this analysis could be considered robust.

A list of stakeholders consulted is included within each case study section in Part 2 of this report. A full list of all stakeholders consulted throughout this study is included in Annex B.

#### 3.2.4 Core economic assumptions

In each case study, and where practical, the economic benefits have been projected in **monetary (present value) terms**. A monetary value expressed in present value terms represents the future stream of benefits converted into equivalent values today by discounting them using an appropriate discount rate. The key assumptions that were used in this process include:

- **a discount rate of 3.5% real**, which is used in the evaluation of the effectiveness of projects or programmes which receive public sector funding, for the purpose of expressing the present value of benefits generated by NERC expenditure
- the timeframe over which the Present Value of projected benefits are appraised is **25 years** (Terminal Values are not used to capture perpetual benefits)
- the appraisal of economic benefits is **net in relation to a counterfactual baseline** that assumes the non-existence of NERC-funded research in each case study
- all the figures cited are in **2006 prices**.

It is of importance to note that this is **not a cost-benefit analysis** but an economic benefit analysis; therefore PwC focused on the NERC-funded research contribution to the creation of net economic benefits in relation to a counterfactual baseline and not in relation to the costs of providing that contribution. Additionally, it is important to clarify that this study is **not a financial benefit-cost assessment** but an assessment of economic benefits.

Financial benefit-cost analysis is concerned with the costs or savings that a particular project or action may have in a particular entity, whereas the economic benefit assessment is concerned with benefits arising for the entire economy. In some cases, however, the economic benefit may be at least the financial benefit of an initiative given that impacts may just be in one entity within the entire economy.

**Figure A.3** in Annex A summarises the key steps of the assessment process. PwC has aimed to follow this process in each of the case studies analysed.

### 3.2.5 Risk and uncertainty

The central role afforded to stakeholder consultation and empirical evidence in determining the extent of projected benefits is consistent with the evidence-based approach to appraisal employed throughout this study. PwC has not made adjustments to the resulting benefit projections; rather reflected the views of stakeholders and the informed literature have been reflected.

We note that the HM Treasury Green Book<sup>7</sup> acknowledges that, in some circumstances, it could be prudent to consider the economic concept of 'optimism bias', which seeks to recognise a risk that stakeholders could be over-optimistic about the key parameters of a project. An adjustment for optimism bias in the course of this study has not been made. This is because:

- this study is an economic benefit assessment, not a cost benefit analysis and as such, the Green Book approach to optimism bias (generally one of stress testing cost variances to determine the point (or ratio), at which benefits exceed costs) is not appropriate
- this study seeks to present ranges, as opposed to definitive projections of benefits. Where ranges are presented, they reflect the views of stakeholders or other documented assumptions on the prospective boundaries of the benefit case and as such, include an implicit allowance for optimism bias on a case study-by-case study basis
- the presentation of the projected benefits in real terms, using a 3.5% discount rate, represents best practice in the appraisal of public projects and programmes. This discount rate itself is somewhat higher than prevailing long-term Government Index Linked Treasury bill rates and as such could be considered to represent a very long term real discount rate; incorporating a modest premium which internalises issues of risk and uncertainty around the potential under-delivery of benefits.

## 3.3 The UK science research context

### 3.3.1 UK science research context

The Government's ten-year investment framework for science and innovation, '[Science and Innovation Investment Framework 2004–2014](#)', announced in the 2004 Spending Review, highlighted the economic case for supporting public investment in science. Annex A of the investment framework summarises the economic evidence supporting public investment in the science base. It highlights the need to embed this science core within a broader well-functioning national innovation system, involving the investments and actions of many other public and private sectors. The framework outlines how the Government intends to build the UK science, research and innovation system over the next decade. Among its aspirations it highlights the need for:

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<sup>7</sup> HM Treasury (2003) 'Appraisal and evaluation in Central Government'

- a greater responsiveness of the research base to the needs of the economy and public services
- world-class research at the UK's strongest centres of excellence leading to innovation and acting as a magnet for private R&D companies
- a more responsive supply of science, engineering and technical skills to the economy.

The ten-year framework sets out a comprehensive performance management system that will be reported on regularly and tied in with the biennial spending review process. There is a need to supplement NERC's own metrics for inputs and outputs with information on longer-term outcomes and impacts, and to identify the overall impact of NERC's research on the UK economy.

Modern economies recognise the importance of a strong public science base to support improvements in welfare. The outputs achieved from the science base, which include new knowledge, skilled people, new methodologies, and new networks, have contributed to improvements in the things that matter to us, such as wealth, education, health, environment, and culture. They have also improved decision-making about the governance of these things, including better public policy. It is not simple to quantify the contribution of science to advances in these areas, but a wide range of economic studies over a long period have recorded a range of direct benefits to the economy as a whole and to firms individually<sup>8</sup>.

### 3.3.2 NERC investments

NERC's investments during the period 2002-2007 focus around five strategic priorities<sup>9</sup>:

- science – to prioritise and deliver world-class environmental sciences to understand the Earth system
- using knowledge – to use NERC-funded science to identify and provide sustainable solutions to environmental problems
- skilled people – to train and develop skilled individuals to meet national needs
- leadership – to provide effective national and international leadership for the environmental sciences and, to deliver these five priorities
- organisation – to ensure that NERC is a flexible, fit for purpose organisation, and to achieve excellence in service delivery and customer focus.

This report is expected to help NERC to understand more clearly the extent to which it is contributing to the economic effectiveness of the UK, and to the effectiveness of public services and policy. This in turn should enable NERC to assess the extent to which it helps fulfil the Government's objective for a greater responsiveness of the research base to the needs of the economy and public services, as set out in the Government's ['Science and Innovation Investment framework 2004–2014'](#).

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<sup>8</sup> DTI (2004) Science & innovation investment framework 2004-2014

<sup>9</sup> NERC (2002) Science for a Sustainable Future 2002-2007



## 4 Key findings – economic outcomes of research

### 4.1 Introduction

Each of the case studies that were reviewed as part of this study is detailed in full in sections 5 to 14. The case studies are illustrative of the range of NERC's work; they are not a fully representative sample of all the research that it funds. The purpose of this section is to pull out the key economic benefits that were identified in the fieldwork<sup>10</sup> and to give an overview of NERC's economic impact. From p.31 there is a table summarising the findings.

The key findings of the study are grouped together by benefit themes – strategic, wider and direct economic benefits, and as demonstrated below, each theme is evidenced from a selection of case studies.

This study concentrated on benefits to the UK, but that does not infer that the benefits are only appreciated in the UK, indeed, wider global benefits have been included in this study where it is relevant and sensible to do so. It should also be stressed that while the benefits of NERC funding to training and education were not within the scope of the study, one of the benefits arising from NERC-funded research is capacity building across the UK and internationally and this element is captured below.

### 4.2 Strategic and policy benefits

As described above, one of the main ways in which NERC-funded research can have an impact on the local, national and international economies is by supplying the evidence needed by policy makers or regulators, and by supplying methods used by policy implementers. NERC-funded research might not necessarily offer direct policy solutions but it contributes high quality research that is vital to the taking of better informed policy decisions.

Strategic benefits arise to policy makers and regulators that use NERC's data, information and advice to increase the effectiveness of public services and policy development, regulation and implementation. In this section, the strategic benefits that were identified by stakeholders have been categorised under broad headings that are mostly derived from the Government's Science and Innovation Investment Framework 2004-2014<sup>11</sup>.

#### 4.2.1 UK reputation

The Government's framework sets out a vision for UK science and the position of the UK as a centre for world-class research. Stakeholders commented that NERC-funded research and scientists have enabled the UK to have a first class reputation in many important fields of environmental science notably climate change, ozone research and marine biotechnology. The importance of reputation has been explored through two case studies, TIGER and the work carried out by the British Antarctic Survey (BAS) in monitoring the ozone layer, which enabled the UK Government to make significant contributions to international environmental policy. TIGER contributed the science behind the definition of what constitutes 'dangerous climate change' as set out in the United Nations Framework Convention on Climate Change

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<sup>10</sup> Around 80 interviews were carried out over a period of four months

<sup>11</sup> HM Treasury, Department for Education and Skills, Department for Trade and Industry (2004) Science and innovation investment framework 2004-2014

and the finding of the ozone hole by BAS scientists gave impetus and science base to the Montreal Protocol on Substances that Deplete the Ozone Layer<sup>12</sup>.

Evidence from stakeholders on a more recent case study, URGENT, indicates that NERC is continuing to support the UK's reputation for being innovative and undertaking ambitious science programmes. Stakeholders stated that URGENT showed **leadership** in Europe by tackling key urban environmental science questions (e.g. in the area of urban river management and air quality management). Stakeholders expressed the view that there was no comparable science programme in Europe and that furthermore, URGENT has established new repositories of urban environmental data, following rigorous protocols, and stakeholders have commented that this has awakened a lot of interest in Europe, with the result that further funding from the European Commission was levered in. The extra funding for research grants and development awards from the Commission and Research Councils totals £7.6 million.

#### 4.2.2 Sustaining and improving the UK science base

Many of the case studies have **levered further funding** into the UK science base and attracted funds for follow-on work. RAPID attracted €2.5 million (£1.72 million) from the European partners and \$7 million (£3.93 million) from the National Science Foundation (NSF) in the US. This was the first major joint programme between the NSF and NERC. PwC was told that the URGENT programme has generated a further £2.4 million of research grants from the Research Councils and £5.2 million in development awards from Research Councils, the British Council, the [EU LIFE Programme](#)<sup>13</sup>, [Framework Programme 6](#)<sup>14</sup> and [INTERREG](#)<sup>15</sup>. Notably, the URGENT programme appears to have facilitated both further funding of the science community that received direct URGENT funding and also funding of associated urban research in other universities and organizations, not all of which is yet quantified<sup>16</sup>.

Stakeholders judged that one of the ways that NERC has improved and is **improving the research capacity** of those institutions, universities and research centres that it funds is through bringing together different members of the scientific community to collaborate. Increased multidisciplinary working is one of the key challenges identified by the Government in enabling the UK science and innovation system to deliver its vision for UK science over the coming decade<sup>17</sup>. The Environment and Human Health programme is bringing together a network of multi-disciplinary scientists to define the research questions better with the result that, according to stakeholders, the scientific benefits of investment in research will be maximised. The Marine and Freshwater Microbial Biodiversity (M&FMB) programme is another case study where stakeholders felt that the programme has greatly enhanced the national scientific and research capability in the field of marine microbiology and molecular biology.

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<sup>12</sup> The Montreal Protocol stipulates that the production and consumption of compounds that deplete ozone in the stratosphere are to be phased out. The Protocol was signed in 1987 and as at September 2002 has been ratified by 183 countries

<sup>13</sup> LIFE, the Financial Instrument for the Environment is a significant part of the European Union's environmental policy. It co-finances projects in three areas: LIFE Nature, LIFE Environment, and LIFE Third Countries

<sup>14</sup> The 6<sup>th</sup> Framework Programme covers Community activities in the field of research, technological development and demonstration

<sup>15</sup> INTERREG III is a community initiative which aims to stimulate interregional cooperation in the EU between 2000-06

<sup>16</sup> Welch M. (2003) URGENT Added Value

<sup>17</sup> HM Treasury, Department for Education and Skills, Department for Trade and Industry (2004) op. cit. pp19-22

Evidence received from stakeholders indicates that NERC is not only improving the UK science base through maximising the knowledge output capacity but also it has a key role in contributing to the physical infrastructure and **establishing research facilities** for others to benefit from. LOCAR funding has been used to establish research facilities in three locations around England, which have been designed to achieve the best possible field conditions for innovative, cutting-edge multi-disciplinary research. Key parts of these LOCAR-funded research facilities will continue to be operational after the end of the programme providing a legacy to other institutions (including universities) that will take over ownership of this equipment, and already students not funded through LOCAR are benefiting from the facilities in their studies.

Stakeholders were clear about the contribution of NERC-funded research to **focusing research priorities**, given that there is limited funding available, the most pressing research needs should be addressed first. Both the RAPID and the Environment and Human Health programmes are going to help set out a clearer roadmap of what the key research areas are and should be which, according to stakeholders, will contribute to efficient and effective research.

The contribution by NERC-funded scientists to **increasing global understanding and developing the knowledge base** on global issues (e.g. on climate change) is also a benefit identified by stakeholders. The RAPID programme and the work done by BAS to observe the ozone hole were both case studies that demonstrated a contribution to the scientific knowledge base that can be used by scientists and policy makers around the world. Stakeholders commented that the scientists working for BAS and the RAPID programme are building up data and collecting evidence that is being and will be used by scientists around the world in fields that are of global significance.

#### 4.2.3 Policy development and implementation

In the Science and Innovation Investment Framework the Government identifies a challenge in ensuring that recently developed knowledge from the research base is available to analyse opportunities, and for risk avoidance for the UK and to enable the Government to make informed policy decisions on the basis of the best available evidence<sup>18</sup>. Although NERC-funded research is not driven by policy, it does investigate policy relevant issues. Its contribution to influencing policy development and implementation, along with tracking compliance with and impact of policy is significant, and stakeholders including the policy makers themselves evidenced this.

One of the potential contributions of NERC-funded research to policy stems from its provision of robust science that **strengthens the evidence base for policy making**. The provision of such information enables policy makers to develop and implement more effective and efficient policy. Within the case studies that PwC reviewed there were useful examples of how this is happening in practice. The RAPID programme is expected to supply the global climate research community with data, which will enable them to narrow the uncertainty around future predictions of climate change. It was anticipated that this input from RAPID will lay the foundations for, and be integrated into the process of cost-effective policy making and decision taking. Stakeholders expect that the RAPID outputs will impact on national and

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<sup>18</sup> HM Treasury, Department for Education and Skills, Department for Trade and Industry (2004) op.cit. pp.24

international climate policy through influencing UK climate change scenarios, and the 5<sup>th</sup> Intergovernmental Panel on Climate Change (IPCC) assessment report in 2012<sup>19</sup>.

A recent report<sup>20</sup> that benchmarked national environmental stewardship established the UK Government as fifth best in the world in tackling domestic and international environmental problems. Compliance with local, national, European and international environmental policies and regulations is important if the UK is to maintain and improve its reputation in the field of natural resource management. Often failure to comply with policy, for example, the EU Water Framework Directive, incurs fines for the offending Member State. Stakeholders held the view that NERC-funded research was significantly contributing to **enabling the UK to comply with a range of environmental policies**. For example, stakeholders judged that the LOCAR programme will provide the fundamental scientific background required for policy makers to make an informed decision on how to implement the EU Directives, such as the [Water Framework Directive](#)<sup>21</sup>, the [Nitrates Directive](#)<sup>22</sup> and the [Habitats Directive](#)<sup>23</sup>. The Flood Estimation Handbook (FEH) has also enabled the UK Government to deal effectively with flooding. Without the FEH, compliance with this aspect of the Water Framework directive would be much more difficult and expensive to achieve.

Another example provided from the case studies was the observations of the ozone layer carried out by BAS scientists contributing to **tracking the impact of international policies**, specifically the Montreal Protocol and its subsequent amendments. Stakeholders judged that BAS scientists play an essential role in enabling policy makers, the public, other scientists and stakeholders to follow the impact and effectiveness of the Montreal Protocol.

Stakeholders judged that another way that NERC-funded research had demonstrated its value was because it had led the Department of Trade and Industry (DTI) to widen its R&D agenda. Their view was that the innovation and findings arising from the M&FMB programme had influenced DTI policy makers and Ministers to the extent that, within the scope of its Technology Programme, the R&D call for proposals in the field of regenerative medicine was widened to encompass marine research. Stakeholders felt that this outcome is notable because it will open up further financial support for basic and applied research in the marine environment.

#### 4.2.4 Networks, national and international collaboration

Another theme that became apparent throughout the investigation of the case studies is the particular contribution that NERC funding and scientists make to bringing together scientists

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<sup>19</sup>The IPCC terms of reference are to: assess available information on the science, the impacts, and the economics of — and the options for mitigating and/or adapting to — climate change; and provide, on request, scientific/technical/socio-economic advice to the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change

<sup>20</sup> Pilot 2006 Environmental Performance Index: [http://www.yale.edu/epi/2006EPI\\_Report\\_Full.pdf](http://www.yale.edu/epi/2006EPI_Report_Full.pdf) and country profiles [http://www.yale.edu/epi/2006EPI\\_AppendixC.pdf](http://www.yale.edu/epi/2006EPI_AppendixC.pdf)

<sup>21</sup> Water Framework Directive 2000/60/EC: [http://europa.eu.int/comm/environment/water/water-framework/index\\_en.html](http://europa.eu.int/comm/environment/water/water-framework/index_en.html)

<sup>22</sup> Nitrates Directive 91/676/EEC: [http://europa.eu.int/comm/environment/water/water-nitrates/index\\_en.html](http://europa.eu.int/comm/environment/water/water-nitrates/index_en.html)

<sup>23</sup> Habitats Directive 92/43/EEC: [http://europa.eu.int/comm/environment/nature/nature\\_conservation/eu\\_nature\\_legislation/habitats\\_directive/index\\_en.htm](http://europa.eu.int/comm/environment/nature/nature_conservation/eu_nature_legislation/habitats_directive/index_en.htm)

and researchers, from around the UK and the rest of the world, to establish networks and collaborate within a national or international framework.

Stakeholders felt that the networks have a synergistic effect for those involved, bringing together scientists from multiple disciplines as with the TIGER programme but also enabling multidisciplinary science to take place, as exemplified by the Environment and Human Health programme. Stakeholders reported that TIGER achieved a better integration of biological and physical parts of terrestrial ecosystems because of the network of multi-disciplinary groups involved.

The RAPID programme, the first major joint programme between the National Science Foundation in the US and NERC, also includes partners from Norway and the Netherlands. Stakeholders judged that this programme is not only helping the Government to meet its stated aspirations to be global leader on issues such as climate change, but it is bringing other countries with it in the quest to understand the issues.

It was found that another programme that demonstrated what could be achieved through network development is the M&FMB programme, which stakeholders felt was instrumental in:

- bringing together a disparate marine and freshwater microbiology community
- building a critical mass to support a knowledge sharing network
- carrying out world-leading knowledge generation
- contributing to developing the UK marine biotechnology industry.

Even though science projects within the programme have finished, further funding (£250k) was supplied to support [BlueMicrobe](#)<sup>24</sup>, the knowledge transfer network which grew out of the programme, available on the internet. It aims to communicate with those in the public and private sector with an interest in research, development and commercial exploitation of aquatic microbiology and marine biotechnology. Stakeholders felt that the technology transfer co-ordinator had added value to the programme through promoting the science to the research and user community.

Similarly, URGENT brought together an urban science community of some 50 Principal Investigators (PIs) and some 50 postgraduates and postdoctoral fellows versed in urban science and its applications. It is expected that this group of researchers could take this science area to new heights in the future. Importantly they have the ability to embed the essential interdisciplinary and knowledge transfer skills developed in URGENT into future undergraduate teaching and postgraduate training, as well as into new research initiatives.

#### 4.2.5 Public engagement, awareness raising and communication

The Government's ambition, as set out in the Science and Innovation Investment Framework, is for greater public confidence and engagement in scientific research and its innovations. NERC-funded research, as evidenced by stakeholders, has the potential to make an important contribution to engaging with the public and raising the public's awareness of areas of scientific, environmental and social importance.

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<sup>24</sup> [www.bluemicrobe.com/home](http://www.bluemicrobe.com/home)

For example, BAS scientists<sup>25</sup>, following the discovery of the ozone hole, had a key role in engaging and communicating with the public and governments around the world about the issue of ozone layer damage. Stakeholders commented that the efforts of those BAS scientists contributed to an increased public awareness and understanding of the negative impact of human behaviour on the ozone layer and also helped gain wide spread acceptance by politicians, policy makers, public and press of the need for change in behaviour.

The Government's aim for greater public confidence and engagement in scientific research infers the need for scientists to communicate effectively with the public. The British Geological Survey (BGS) supplies geohazard reports known as 'GeoReports' to house buyers, developers and the insurance sector in particular. Stakeholders felt that these reports are a good example of knowledge transfer and how to communicate complex (geological) information to the public and commercial sectors. Stakeholders indicated that they could get the necessary information easily from BGS, that it is accurate and relevant to their needs. BGS GeoReports were used as a best practice example in DTI's Knowledge Transfer Partnerships report of October 2004<sup>26</sup>.

NERC-funded research scientists also need to communicate with those implicated by the findings of their research. Stakeholders highlighted that GANE provided a user-friendly and accessible explanation of nitrogen enrichment issues, which has been paramount in persuading relevant groups, such as farmers, of the various impacts that, for instance, their fertilizer usage may have.

#### 4.2.6 Decision-making and empowerment

In its vision for science the Government aspires that 'through engagement, openness and dialogue, substantial and sustained progress will have been made towards building a society that is confident about the governance, regulation and use of science and technology'<sup>27</sup>. Evidence derived from several case studies demonstrates that NERC-funded science has the potential to enable people, whether in a personal or professional capacity, to be able to respond to key local, national or global issues affecting them, such as the risk of flooding, or the impact of climate change.

For example, BGS supplies subsidence data and related reports that enable homebuyers, as well as the insurance sector and developers, to make decisions based on the risk of subsidence in a particular area. Users of the subsidence information can decide whether or not they should build/buy a property/development in a particular location or what remedial action is required for an existing property/development to be made safe. Based on this vital information, stakeholders were able to demonstrate that users of such information are **empowered** to make better informed decisions, and this leads to avoiding future costs and preventing loss of investment through avoiding or mitigating a subsidence incident later. The increasingly localised information on risk of subsidence provided by BGS, which is currently provided at postcode and household level, meets the needs of the **information age**, which demands fast access to reliable and up-to-date information. Stakeholders also judged that

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<sup>25</sup> Joe Farman, Brian Gardiner and Jonathan Shanklin were the three BAS scientists who published a paper in 1985 the journal *Nature*, entitled 'Large losses of total ozone in Antarctica reveal seasonal ClOx/NOx interaction'. *Nature* 315: 207-10.

<sup>26</sup> DTI Knowledge Transfer and Public Sector Research Establishments  
[http://www.ost.gov.uk/enterprise/knowledge/KTP\\_CaseStudies.pdf](http://www.ost.gov.uk/enterprise/knowledge/KTP_CaseStudies.pdf)

<sup>27</sup> HM Treasury, Department for Education and Skills, Department for Trade and Industry (2004) op. cit. pp19

with the likely increase in erratic weather caused by climate change, the demand for accurate subsidence data is predicted to increase further.

URGENT is another programme which provided evidence of how NERC supports decision-making. According to the URGENT brochure, one of the key outputs of the programme is 'Decision support systems targeted to enable planners, industry and regulators to improve urban sustainability'. This is exemplified by the example of 'Sensing device and software system for optimising road de-icing' within the URGENT case study and supported by stakeholders. The software enables local authorities to decide when and where they should salt the roads as part of their winter maintenance programme. The technology also enables a user to work out how much salt should be laid down thereby ensuring an effective governance of human and financial resources.

The 'Flood Estimation Handbook', according to stakeholders, also supports good governance by helping to identify flood risk areas where development should be prevented and avoid potential costs to the UK economy. The Handbook also contributes to a reduction in the costs of flooding (e.g., damaged commercial or private property and impacts on human life) by improving the accuracy of flood scheme design for areas which are vulnerable to flooding, and therefore reducing the likelihood of flooding in these areas.

#### 4.2.7 Addressing market failure, encouraging innovation and showing leadership

One of the roles of publicly-funded science, as discussed in the Science and Innovation Investment Framework, is to build critical mass in key research areas which cannot be left to the market. Stakeholders identified that the Marine and Freshwater Microbial Biodiversity (M&FMB) programme has done that. It was their view that the programme revealed the wealth of aquatic microbial biodiversity, particularly in the marine environment, built scientific knowledge and networks in this field, and demonstrated the potential for biotechnological exploitation. Indeed, the market failure to explore the marine environment meant that until the M&FMB programme, most UK bio-prospecting for biotech applications occurred on land not in the sea. Stakeholders felt that without the programme, the deep sea would not be seen as a resource for bio-prospecting.

In establishing the M&FMB programme, NERC has shown **leadership** to support scientists and researchers to explore a field that was previously little understood. It has supported scientists to **innovate** and harness the potential of the marine and freshwater environment as a resource for biotechnological applications, to innovate and to explore new markets based on these applications. Whether the research or current potential applications supported by the programme are taken to market or not, stakeholders thought it certain that over the next 25 years, there will be successful marine and freshwater applications reaching the market, for example, in the field of pharmaceuticals, skin care products and anti-fouling.

#### 4.2.8 Promoting competitiveness and scientific transfer

The Science and Innovation Investment Framework sets out that "through knowledge transfer and capacity building activities the UK will be making significant contributions to sustainable development and stabilisation of a world in which issues of poverty, education, water provision, population and global warming are tackled". Several case studies suggested that NERC-funded science and research has promoted and supported UK economic competitiveness, and scientific technology transfer and product spin-outs with wider associated societal benefits.

The M&FMB programme supported scientists to innovate and to look at novel organisms to produce novel products. As a result, there are potentially new products that could reach the market over the next 25 years, for example, antibiotics, anti-malarial drugs, anti-fouling products, and naturally derived sunscreens and skin care products.

Additionally, URGENT, through its contribution to the realisation of the Sustainable Management of Urban Rivers and Floodplains (SMURF) project is facilitating the transfer of scientific knowledge to other parts of parts of Europe, particularly by proving tools to involve the public in the rehabilitation of urban rivers. This is an important objective of the EU Water Framework Directive.

### 4.3 Wider and direct economic benefits

This section includes findings of the wider and direct economic benefits that could, according to stakeholders interviewed, be linked to NERC-funded research.

Throughout this study stakeholder views that suggest that NERC-funded research can contribute to the achievement of relevant direct as well as wider economic benefits in the UK have been gathered. As is typical in studies of this sort, only in some instances, however, have stakeholders felt able to estimate and justify the extent to which they believe that NERC-funded research can contribute towards improvements in policy or practice, which ultimately could deliver an economic benefit.

As with the strategic benefits identified above, the case studies in sections 5 to 14 contain a detailed overview of PwC's economic analysis and this section provides a summary of the main findings on wider and direct benefits arising from each of the case studies assessed.

For some of the case studies, and for reasons that are described in detail in the case study sections, stakeholders have not been able to estimate and/or justify the extent to which NERC-funded research contributes to the accrual of wider and direct benefits. For these cases, **illustrative benefit examples** have been provided. These examples are not aimed at assuming the impact of a case study but just to provide an indication of the potential impact on the issue addressed by the case study. Therefore, when illustrative benefit examples are presented, the same assumption has been used for an illustrative level of impact over a given baseline related to the case study.

Projected benefits, either illustrative or informed by stakeholder views, are presented in two ways: a present value and an average annual present value. A monetary value expressed in **present value** terms represents the future stream of benefits over a 25-year period, converted into equivalent values today by discounting them using a 3.5% discount rate (as explained in section 3.2.4.). Note that in some cases, the expected benefits from a case study arise only for a number of years (e.g., 10 years from 2010 to 2020) within the 25-year period. The **annual average present value** takes the present value figure and divides it by 25 years. These figures are therefore comparable across the different case studies.

#### 4.3.1 Wider benefits

According to stakeholders consulted and the subsequent analysis, the main areas of wider economic benefits to which case studies could be linked to include:

- The **Rapid Climate Change programme (RAPID)** has the potential to achieve wider economic benefits in the future by providing research evidence that will reduce uncertainty around climate change, and inform climate change related policy and business decisions in the UK and internationally. Research evidence from RAPID therefore has the potential to reduce the detrimental consequences of a potential MOC collapse/rapid climate. Third party data has been used to estimate that the potential economic impacts of MOC collapse are likely to exceed £40 billion annually or approximately 0.1% of projected gross world product in 2100.
- The **Global Nitrogen Enrichment Programme (GANE)** has the potential to help achieve wider policy benefits in the future by providing policy makers with evidence to take informed decisions to tackle excess nitrogen emissions through better policy design and implementation. Third party data has been used for an illustrative projection, which suggests that a reduction of 1-5% on the costs of enrichment due to Nitrogen would provide a saving in the range of £7 million to £50 million in present value terms, or an average present value of £0.3 million to £1.9 million per annum.
- The **Urban Regeneration and the Environment Programme (URGENT)** through one of its projects “Route forecasting to optimise road de-icing” has the potential to achieve wider policy benefits by providing local authorities with a technology to improve decision-making on when and where roads need to be salted. Stakeholders have suggested that this technology should help to increase the accuracy of road salting during winter that may result in a number of reduced accidents. Using stakeholder views and third party data, it has been projected that this project funded under the URGENT programme may help to avoid fatality and casualty costs linked to accidents due to icy roads in the order of £13 million to £29 million in present value terms, or an average present value of £0.5 million to £1 million per annum.
- The **Marine and Freshwater Microbial Biodiversity (M&FMB) Programme** may have the potential to contribute to realising wider benefits for the UK economy by increasing the market share of the UK in the marine biotechnology products market through a series of potential spin-offs that commercialise products in this market. Stakeholders acknowledge that benefits will be realised in the long term (i.e., up to 25 years from now). However, as an illustrative example, if the UK were to achieve a 1-5% share of this market by 2021, it would project a present value in the range of £224 million to £1,122 million, or an average present value in the range of £9 million to £44 million per annum.
- The **Flood Estimation Handbook (FEH)** has the potential to achieve wider benefits for the UK economy by helping to improve the accuracy of the design of flood management schemes. As an illustrative example, if the current costs of flooding were to increase (or avoided costs decrease) in a range of 1-5% this would equate to a range of £12 million to £45 million of additional costs per year, with a present value in the range of £197 million to £746 million, or an average present value in the range of £8 million to £30 million per annum.

- The **discovery of the hole in the ozone layer and subsequent research** has achieved wider benefits for the UK economy by helping to reduce the number of skin cancer cases in the UK through supporting the definition of the Montreal Protocol. Using assumptions from third party sources, it has been projected that in the absence of the Montreal protocol, the cost of skin cancer for the UK would provide a present value saving of around £836 million. Only a portion of the benefits projected to the Montreal Protocol could potentially be allocated to BAS work and stakeholders did not feel able to provide views of the extent to which BAS work supported the Montreal Protocol. However, for the purposes of illustration, a 1-5% portion of the savings allocated to the Montreal Protocol equates to around £8 million to £42 million in present value terms, or an average present value of £0.3 million to £1.7 million per annum.
- The **subsidence data supplied by the British Geological Survey (BGS)** has the potential to achieve wider benefits for the UK economy by helping to avoid and/or reduce the insurance costs of subsidence. If it is assumed that the subsidence insurance claims will continue to grow at a rate of 2.3% per year between 2004 and 2030, a saving of 1 -5% over this baseline (could be considered as avoided cost) would provide a present value in the range of £70 million to £270 million, or an average present value in the range of £3 million to £11 million per annum.

#### 4.3.2 Direct benefits

According to stakeholders consulted and the subsequent analysis, the direct economic benefits arising from the case studies include:

- The **Rapid Climate Change programme (RAPID)** should contribute to achieving direct economic benefits through the development of stationary MOC monitoring stations that enable the monitoring of MOC, which would otherwise have been logistically impossible and financially prohibitive. According to views and data supplied by stakeholders, it is projected that RAPID could provide cost savings in the range of £32 million to £36 million in present value terms, or £1.3 million to £1.4 million in average annual present value terms.
- The **Lowland Catchment Research (LOCAR)** should contribute direct economic benefits to the UK economy by providing data and evidence that reduces the costs/increases the efficiency in the monitoring the Water Framework Directive (WFD) implementation. As a matter of illustration, a reduction of 1-5% on the costs of monitoring and implementing the WFD after 2015 would provide present value savings in the range of £2 million to £9 million or an average present value in the range of £73K to £365K per annum.
- The **Flood Estimation Handbook (FEH)** may contribute to achieving direct benefits for the UK economy by providing a standard approach used by the vast majority of hydrologists and engineers in the UK which allows for estimating flood size and frequency across the UK, and by providing a software package (WINFAP-FEH) that allows users to execute routine calculations faster than before the FEH was introduced. The present value for these savings for a 25-year period would

potentially be within a range of £7 million to £34 million, or an average present value in the range of £0.3 million to £1.3 million per annum.

- The **Urban Regeneration and the Environment Programme (URGENT)** through one of its projects 'Route forecasting to optimise road de-icing' has the potential to achieve direct benefits in the future by providing local authorities with a technology to improve decision-making on when and where roads need to be salted. Stakeholders have suggested that this technology should help to increase the accuracy of road salting during winter that will result in cost savings to local authorities. Using stakeholder views and third party data, it has been projected that this would help to achieve cost savings of the order of a present value of £20 million, or an average present value of £0.8 million per annum.

#### 4.4 Summary table: projected economic benefits of NERC-funded research

The following table outlines the projected economic benefits of the case studies that have been examined during the course of this project. Information on the level and period of funding of the case studies, and a brief description of each has been included. Summary information of the economic benefits that have been identified is also provided.

All monetary values are expressed in present value (PV) terms, which represents the future stream of benefits converted into equivalent values today (i.e., in 2006) by discounting them using a **discount rate of 3.5% real**, which is used in the evaluation of the effectiveness of projects or programmes which receive public sector funding. The timeframe over which the present value of projected benefits is appraised is **25 years**. The average annual present value is therefore the PV distributed over that 25-year period.

More comprehensive information on the benefits summarised below can be found in the individual case studies.

## NERC ECONOMIC IMPACTS STUDY

### Summary table to show examples of projected economic benefits from the ten case studies

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
<p>Case Study 1 <b>Terrestrial Initiative in Global Environmental Impact Research (TIGER) Programme</b></p> <p>This programme studied global environmental changes at the land surface. It addressed the processes, impacts and feedbacks of climate change on land.</p> <p>£20m (1992-1997)</p> <p>See page 38 for full case study</p>	<ul style="list-style-type: none"> <li>▪ Strengthened UK reputation at international level</li> <li>▪ Network development and international collaboration</li> <li>▪ Policy development – national policy – UK position on climate change and international climate policy – Inter-governmental panel on climate change</li> <li>▪ Long-term outcomes – Dynamic Global Vegetation Models were precursors of models used today</li> </ul>	-*	-

<sup>28</sup> **Strategic benefits** are qualitative in nature and arise to policy makers and regulators, increasing the effectiveness of public services and policy making, and having a wider societal impact. **Direct benefits** arise as quantifiable efficiency and competitiveness gains for public and private sector institutions. **Wider benefits** arise as an outcome of research that might have facilitated better decision-making, and thereby delivered positive and quantifiable benefits to society as a whole

\* Cells marked ‘ – ‘ have been left intentionally blank

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
<p><b>Case Study 2</b> <b>Rapid Climate Change (RAPID) Programme</b></p> <p>This programme is expected to make a major contribution to understanding and quantifying the likelihood and magnitude of rapid climate change in the near future in Western Europe. It will provide, for the first time, continuous observations of the Atlantic Ocean circulation, which is responsible for Europe's temperate climate.</p> <p>£20m (2001-2008)</p> <p>See page 45 for full case study</p>	<ul style="list-style-type: none"> <li>International collaboration</li> <li>Setting research priorities on rapid climate change</li> <li>Raising public awareness – key paper led to 70 articles in general press in Nov 05</li> </ul>	<p><b>Stakeholder views</b></p> <p>'Savings' due to more efficient monitoring of the MOC<sup>29</sup> through new technology</p> <p>PV: £32m to £36m</p> <p>Average annual PV: £1.3m to £1.4m</p>	-
<p><b>Case Study 3</b> <b>Global Nitrogen Enrichment (GANE) Programme</b></p> <p>The programme focused on the transformation and pathways of reactive nitrogen from land to sea, the fluxes of reactive nitrogen at landscape and global scales, and the impacts of reactive nitrogen on the global terrestrial carbon sink.</p>	<ul style="list-style-type: none"> <li>Evidence to back up policy making relating to tackling excess nitrogen emissions</li> <li>Increased awareness of the impacts of excess nitrogen – focused attention at UK and European level</li> </ul>	-	<p><b>Illustrative benefit</b></p> <p>Tackling excess nitrogen emissions. Third party data has been used for an illustrative projection which suggests that, if policy changes as a result of GANE, led to a reduction of between 1% and 5% in the costs of enrichment resulting from nitrogen emissions, savings would be:</p>

<sup>29</sup> Meridional overturning circulation, see RAPID case study, page 45, for details

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
£6m (1998-2006)  See page 55 for full case study			PV: £7m to £48m Annual average PV: £0.3m to £1.9m
Case Study 4 <b>Urban Regeneration and the Environment (URGENT) Programme</b>  This programme was established to integrate urban ecological and environmental research across the geological, terrestrial, freshwater and atmospheric sciences.  £9.7m (1997-2003)  See page 65 for full case study	<ul style="list-style-type: none"> <li>Scientific leadership through follow up funding</li> <li>Development of a scientific network and capabilities</li> <li>Informed policy making and implementation through, for example, strong links with ODPM and Birmingham City Council</li> </ul>	<b>Stakeholder views</b> Potential resource savings to UK LAs through development of more efficient technology for salting of roads (Benefit arises from the 'Route forecasting to optimise road de-icing' project funded by NERC-URGENT)  PV: £20m Average annual PV: £0.8m	<b>Stakeholder views</b> Potential savings to UK due to avoided deaths and serious casualties as a result of improved salting of roads. (Benefit arises from the 'Route forecasting to optimise road de-icing' project funded by NERC-URGENT)  PV: £13m to £29m Average annual PV: £0.5m to £1m
Case Study 5 <b>Marine and Freshwater Microbial Biodiversity (M&amp;FMB) Programme</b>  This programme aimed to increase knowledge of marine and freshwater biodiversity and to understand the nature and stability of these systems  £6.9m (2000-2005)	<ul style="list-style-type: none"> <li>Network and knowledge development – bringing together the scientific community, building critical mass, world leading knowledge generation and knowledge transfer</li> <li>Development of UK marine biotechnology industry</li> </ul>	<b>Stakeholders views</b> Efficiency gains were described by stakeholders. Technology developed through M&FMB can increase the efficiency of drug companies in identifying and developing new drugs. However, stakeholders felt unable to put a value on these efficiencies.	<b>Illustrative benefit</b> Potential UK marine biotechnology products market share. Assumes UK achieves 1% to 5% market share of the marine biotechnology products by 2021  PV: £224m to £1,122m Average annual PV: £9m to £44m

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
See page 84 for full case study	<ul style="list-style-type: none"> <li>Addressing market failure</li> <li>Commercial innovation</li> </ul>		
<p>Case Study 6 <b>Environment and Human Health Programme</b></p> <p>This is a new programme being developed by NERC and other partner organisations to address how society can best manage the natural and built environment to improve human health.</p> <p>£2.4m (2006-not defined)</p> <p>See page 92 for full case study</p>	<p><b>Potential Benefits</b></p> <ul style="list-style-type: none"> <li>Provision of research focus – increase understanding, define questions and choose appropriate research avenue</li> <li>Development of a multi-disciplinary scientific network by bringing medical and environment scientists together</li> <li>Building links between science and policy</li> <li>Better informed policy decisions UK scientific leadership in an emerging area</li> </ul>	Programme at a very early stage – direct benefits not yet quantifiable	Programme at a very early stage – wider benefits not yet quantifiable. An example of a potential long-term benefit is in contributing to the avoidance of healthcare costs. For example,; asthma treatment currently costs NHS £850m/yr.
<p>Case Study 7 <b>Lowland Catchment Research (LOCAR) Programme</b></p> <p>This programme is researching the on-going processes controlling the movement of groundwater and the factors</p>	<ul style="list-style-type: none"> <li>Support of policy (e.g. in implementation of EU Directives such as the Water Framework; Nitrates; and Habitats Directives)</li> <li>Establishments of Scientific</li> </ul>	<p><b>Illustrative benefit:</b></p> <p>Monitoring of implementation of the Water Framework Directive. Assumes LOCAR contributes to a reduction of 1% to 5% in the costs of monitoring and implementing the</p>	-

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
<p>affecting the interactions between surface water and ground water.</p> <p>£7.75m (2000-20006)</p> <p>See Page 100 for full case study</p>	<p>networks, collaborations and capabilities</p>	<p>WFD after 2015</p> <p>PV: £2m to £9m</p> <p>Average annual PV: £73K to £365K</p>	
<p><b>Case Study 8</b> <b>The Flood Estimation Handbook (FEH)</b></p> <p>The FEH provides a better way of estimating flood frequency and includes computer software and extensive data sets to help apply the procedures. The handbook is designed to help reduce flood frequency and, while NERC did not fund the FEH directly, it did pay for its predecessor, the Flood Studies Report (FSR) on which the FEH was heavily reliant.</p> <p>See page 107 for full case study</p>	<ul style="list-style-type: none"> <li>▪ Support of policy to protect people and property implementation (DEFRA, EA)</li> <li>▪ Aids design of appropriate flood defences and protection structures for reducing risk of flood damage</li> </ul>	<p><b>Stakeholder views</b></p> <p>Savings in preparation of flood risk assessments</p> <p>PV: £7m to £34m</p> <p>Average annual PV: £0.3m to £1.3m</p>	<p><b>Illustrative benefit</b></p> <p>Avoidance of costs of flooding. Assumes the current costs of flooding would increase (or savings would decrease) by between 1% and 5% if it were not for the FEH</p> <p>PV: £197m to £746m</p> <p>Average annual PV: £8m to £30m</p>
<p><b>Case Study 9</b> <b>Geo-reports and subsidence information</b></p> <p>The British Geological Survey provides information on the likelihood of natural ground instability, enabling any potential investor in a house, development or piece of land to make</p>	<ul style="list-style-type: none"> <li>▪ Enhanced decision-making and empowerment of the public in general, mortgage companies, insurers and developers, as well as planning authorities</li> </ul>	-	<p><b>Illustrative example</b></p> <p>Insurance costs of subsidence. Assumes that BGS data results in a saving of 1% to 5% in the cost of UK subsidence insurance claims</p>

Case Study (Title, brief description, amount and period of funding)	EXAMPLES OF ECONOMIC BENEFITS <sup>28</sup>		
	Key Strategic Benefits	Direct Benefits	Wider Benefits
		Benefits expressed in present value (PV) terms over 25 years using a discount rate of 3.5%. Projections are based on stakeholder views or, where unobtainable, are illustrative examples. Full analyses are provided in the case studies.	
<p>informed decisions, about the risk of future subsidence events and associated costs.</p> <p>Around £300K for 2004/2005 (NERC has been the parent body for BGS since 1965)</p> <p>See page 117 for full case study</p>	<ul style="list-style-type: none"> <li>▪ Easy and fast access to relevant information</li> <li>▪ Lack of alternative data of comparable quality</li> </ul>		<p>PV: £70m to £270m Average PV: £3m to £11m</p>
<p><b>Case Study 10</b> <b>Discovery of hole in ozone layer and subsequent research</b></p> <p>British Antarctic Survey (BAS) scientists discovered the hole in the ozone layer in 1985. Their discovery, based on long-term observations of data, led to an appreciation that human activity was having a significant and negative impact on the global environment. They provided a crucial part of the evidence for a ban on chlorofluorocarbons (CFCs) and gave impetus to the implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer</p> <p>£40m (1985 – ongoing)</p> <p>See page 125 for full case study</p>	<ul style="list-style-type: none"> <li>▪ High quality science – major contribution to ozone research</li> <li>▪ Enhanced UK position – contribution to international policy making level such as the Montreal Protocol</li> <li>▪ Raising awareness of human induced environmental damage and its impacts</li> </ul>	-	<p><b>Third party source/illustration</b> Reducing costs of skin cancer cases. Assumes BAS work results in 1-5% of the UK savings projected for the Montreal Protocol</p> <p>PV: £8m to £42m Average annual PV: £0.3 to £1.7m</p>

## 4.5 Conclusions and recommendations

Ten case studies is a small sample from which to identify the range of economic benefits accruing from the science that NERC funds but it is clear from PwC's work that the economic contribution of research funded by NERC is considerable. While this study focused on benefits at a UK level, it was apparent that the impacts of research occur at many geographical and organisational levels.

NERC's research tackles global environmental problems, and therefore generates global economic benefits. By way of context it is useful to understand that, according to Munich Re (one of the world's largest re-insurers), economic losses from natural disasters in the 1990s totalled over US\$608 billion, greater than losses over the four previous decades combined<sup>30</sup>.

The benefits from the case studies that were examined are quantifiable in some cases, and in others, there is an identifiable qualitative benefit case. Even from the small number of case studies examined it is clear that NERC-funded research makes a substantial contribution to the UK economy even though the methodology used in this study does not lend itself to producing a credible aggregated benefits case. From the sample reviewed, it is also evident that there is a good strategic match between the outcomes of NERC funded research and the Government's 'Science and Innovation Investment Framework 2004-2014'. This match is something that was identified once the fieldwork was complete rather than something that PwC sought to prove from the outset.

In some cases the economic impacts identified in this study had been anticipated by science managers, in others the benefits were more serendipitous. Impacts for directed programmes were unsurprisingly more predictable. For others, such as the case of the ozone observations, the economic benefits were quite unexpected, and indeed could not have been anticipated.

The **integration of economic impacts measurement** as part of future programme/project setup is recommended. There may be value in carrying out, at the outset of directed programmes in particular, an ex ante evaluation to identify the potential economic benefits that might arise from the pursuit of the research. This would not drive the research, but it would ensure that potential benefits are not only identified early on but also that appropriate planning can be put in place to release them, recognising the:

- key role of 'technology translators' in disseminating knowledge
- role of technology transfer expertise in realising commercialisation.

With regard to dealings with the private sector, it was found that the Marine and Freshwater Microbial Biodiversity programme provided an exemplar of the **key role of technology transfer expertise in realising commercialisation**.

It was also apparent that while there are some strong existing links between NERC and government departments and regulatory bodies, there was a need identified during research by several policy makers for NERC to **systematize the interaction between policy makers and the NERC research community**. Links exist but could be improved with a number of central government departments: the Department for the Environment Food and Rural Affairs, the Department for Communities and Local Government (formerly the Office of the Deputy Prime Minister), the Department for Trade and Industry (DTI), and HM Treasury.

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<sup>30</sup> <http://www.dfid.gov.uk/news/files/disaster-risk-reduction-faqs.asp> accessed 22/11/06

## Part 2 – Case Studies

## 5 CASE STUDY 1 – Terrestrial Initiative in Global Environmental Impact Research

### 5.1 Case study description

#### Summary

TIGER, which aimed to understand the dynamics between climate and land, positioned the UK as a global leader in the field of terrestrial carbon dynamics and produced outputs that are still used today and are embedded in international climate change policy.

**Start date:** 1992    **End date:** 1997

It should be noted that the thinking behind TIGER started four years earlier. According to the former Chairman of Tiger, in 1988, discussions started on 'doing something about climate change' and active planning for TIGER took place from 1988-91, so that funding could start in 1992.

#### Funding

Over £20 million was provided for the TIGER project. Stakeholders commented that in their view NERC showed foresight and commitment in allocating such a large sum of money in an area of novel research.

#### Background

In order to meet the requirements of the [United Nations Framework Convention on Climate Change](#) (UNFCCC)<sup>31</sup>, it was important to understand how ecosystems respond to global environmental change. The TIGER programme was set up for several strategic reasons as well as to address a number of scientific issues.

The strategic reasons why TIGER was established were:

- to develop a field of terrestrial research in the wider field of global climate change
- to build a research community in this area, which at the time was fragmented
- to develop a semi-managed style of strategic science which gave more flexibility to scientists to allow them to decide how to achieve the programme objectives, whilst keeping them closely focussed on the objectives.

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<sup>31</sup> The [United Nations Framework Convention on Climate Change](#) (UNFCCC) aimed at reducing emissions of greenhouse gases in order to combat global warming.

The TIGER programme was set up also to address a number of scientific questions surrounding the effects that global environmental change will have on ecosystems and, in particular, the effects of global warming. Concrete examples of the questions TIGER was set up to address included:

- Will native species be lost and alien species invade?
- Which species will be lost and gained, where and how quickly?
- What are the relationships between the structure and functioning of ecosystems? Can they be used to predict how global change will affect Britain's biodiversity and whether our ecosystems will continue to provide us with clean air, fresh water, food and aesthetically pleasing surroundings?
- How much carbon dioxide can be absorbed from the atmosphere by terrestrial ecosystems?
- Would completely new ecosystems appear?
- What is the effect of carbon dioxide and the minor greenhouse gases?

## Objectives

TIGER aims were:

- to investigate physical and biological processes through which the land surface influences climate
- to predict the overall effects of climate change on the natural environment
- to understand the feedbacks from the land they may accelerate or slow climate change
- assist climate prediction by improving the way processes at the land surface are represented in General Circulation Models - computer models that simulate past, current and future climate
- investigate how climate change interacts with other environmental changes including pollution, increased ultraviolet radiation, formation of deserts and reduction in biological diversity
- develop new techniques for field measurements and long-term monitoring of the environment
- establish a monitoring network for the UK to test predictions and to detect change
- design field and laboratory experiments that stimulate future environmental conditions
- explore the applications of molecular biological methods to global environmental problems.

To summarise, TIGER studied the processes, impacts and feedbacks of climate change on land, and how changes in land use alter ecosystems. Feedbacks from the land surface may act either as accelerators or brakes to climate change.

## Key Research Outputs<sup>32</sup>

The TIGER programme took a targeted, directed and community approach to achieving its research objectives outlined above. Some of this research involved manipulating physical environmental conditions in order to simulate possible ecosystems of future climates.

The programme's main outputs were in the form of scientific discoveries and a better understanding of the interactions between the natural environment and climate change. The

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<sup>32</sup> NERC Policy and Communications Division (1996). *The Scope of Tiger*, Swindon.

results were of significant use in improving scientific understanding of past and current climate and processes for climate change impact models. Some key results, insights and advances from TIGER's research are given below.

- Discovery of the large scale on which carbon is being accumulated by forests.
- The carbon store in peat is vulnerable to climate change, though results from TIGER suggest that losses due to warming would be at least partly offset by greater input from plants, due to rising CO<sub>2</sub>.
- Methane emissions from wetlands can be predicted more accurately thanks to new knowledge about the way vegetation helps methane to escape from peat into the atmosphere.
- Intensively managed pasture produces far more nitrous oxide than previously suspected.
- Further insight into the finding that most plants respond to an increase in CO<sub>2</sub> by growing faster, but this 'fertilisation' effect varies in strength and duration.
- Demonstration of the strength of feedbacks from the land surface to the climate, highlighting the need for their inclusion in the General Circulation Models (GCMs).
- A computer model developed during TIGER improved representation of land surface feedbacks by allowing for the lag between climate change and redistribution of vegetation.
- TIGER provided up-to-date descriptions of the land surface from little-studied, remote localities such as semi-arid regions, to be used in GCMs.
- Some general rules were established for predicting which plants and groups will benefit from environmental change and which will lose out, helping to foresee the changing face of the landscape.
- TIGER has produced new methods for predicting how species may spread
- In a variety of TIGER studies, drought consistently emerged as an important driver of ecological change, and its effect can be greater than that of predicted rises in temperature or CO<sub>2</sub>.

A number of tools were also developed.

- The establishment of a UK network of sites for monitoring change.
- Applications of remote sensing (from satellites and aircraft), for example, to map the rate of evaporation and the distribution of vegetation.
- Assembly of global data sets and development of models for predicting future global changes to carbon cycling in soils and vegetation.
- Establishment of an atmospheric observatory to study how methane is oxidised in the atmosphere.
- Laser-based methods for measuring emissions of gases even in very low concentrations.
- A reliable methodology for validating total national emissions of methane and nitrous oxide from natural and industrial sources.
- Pioneering application of molecular biology to reveal unsuspected biodiversity among bacteria that produce and consume methane.
- Methods for simulating future environments in the open air, including manipulation of temperature, water supply, carbon dioxide concentration and ultraviolet-B radiation.

Three key outputs of the TIGER project (as seen by one senior external interviewee) were:

1. better understanding of terrestrial carbon dynamics, including impacts of elevated CO<sub>2</sub> on carbon uptake and the dynamic response of heterotrophic respiration to increasing temperature
2. development of Dynamic Global Vegetation Models (DGVMs), which simulate both the physiology and structural dynamics of the land surface in a changing climate and can be linked to a GCM
3. a better understanding of the role of biodiversity in ecosystem functioning.

## **Dissemination and users**

The outputs from TIGER were disseminated to the scientific community through publication of scientific papers, finale workshops, conferences, and to the wider public through public meetings, the website and an ongoing exhibition at the Natural History Museum. Presentation meetings were also held for industry, the media and politicians, with the aim of increasing awareness of the issues and impacts.

Over 500 papers were published in refereed journals, and four special issues within the following journals were published: Plant and Soil, Atmospheric Environment, Hydrology and Earth System Sciences, and Functional Ecology.

Stakeholders indicated that scientists and researchers are still producing papers that are linked to, or originated in, TIGER work.

## **5.2 Methodology**

Key stakeholders (six from the scientific community and two end users) were interviewed to understand their informed opinion of the economic impact of the TIGER programme.

## **5.3 Findings**

### **5.3.1 Strategic and policy benefits**

Stakeholders saw the TIGER programme as exceptional for its time. It had a great impact both nationally and internationally. TIGER led the way in the early 1990s in carrying out research in global change science, an area where there was widespread interest but little practical experience. Four key areas of strategic and policy benefits were identified.

#### ***UK reputation***

As TIGER was based in the UK, its success had implications for the UK science community as a whole. According to stakeholders, the project was perceived internationally as an innovative, cutting edge project, addressing all the major issues concerning global change and terrestrial ecosystems. It was therefore a boost to the image and reputation of UK global change science.

In addition to drawing on international discussions to identify priority research areas, the TIGER programme also heavily influenced the international debate by having a strong

representation of the UK research community at the discussions. Many of the major themes of TIGER are still critical international research areas today.

### ***Network development and international collaboration***

Stakeholders judged that TIGER played a vital role in establishing the international effort focussed on the issue of biodiversity, which is today a major theme of the [DIVERSITAS<sup>33</sup>](#) programme.

Another outcome of the TIGER programme identified by stakeholders was that it showed how a large number of individual research groups from multiple disciplines could be brought together to tackle large and complex global change questions in a collaborative way. A better integration of biological and physical parts of terrestrial ecosystems was possible with the multi-disciplinary groups.

According to stakeholders, the design of the programme has also been viewed as a model for large co-ordinated projects that simultaneously need to address important national objectives, and make major and direct contribution to international research.

### ***Policy development***

Stakeholders identified that TIGER had a direct impact on national policy through feeding into the UK position on climate change and indirectly to international policy through feeding in to the Inter-Governmental Panel on Climate Change, which draws on UK national evidence and programmes.

John Gummer, the Environment Secretary of State at the time, spoke at the TIGER end of programme event for policy makers and other users. He commended the significance of TIGER, saying that it was important: "Not just that we are being better informed and wiser than we have been before, but because the policy of Britain and the policy of Europe and the policy of the world has been affected directly and dramatically by TIGER." See <http://www.nwl.ac.uk/tiger/tigereye/JGummer.htm>

It was also the stakeholders' view that TIGER provided the critical underpinning for more current scientific research that is having an impact on international climate and energy policy.

For example:

- TIGER fed into the debate on what constitutes 'dangerous climate change'. Article 2 of the UNFCCC states that the basis for the Convention is to stabilize greenhouse gases at a level where they will no longer cause dangerous interference with the climate system. The work of TIGER on the terrestrial carbon cycle, the lesser greenhouse gases, and its support of the development of Dynamic Global Vegetation Models (DGVMs) are 'direct antecedents' to the research that is now enabling us to simulate much more accurately the carbon dynamics over the past century

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<sup>33</sup> DIVERSITAS is an international programme of biodiversity science: <http://www.diversitas-international.org/>

- TIGER has contributed significantly to research into 'sink saturation'. Research has shown that the current strong terrestrial carbon sink is likely to weaken and perhaps turn into a source later this century. This discovery implies that the atmospheric CO<sub>2</sub> concentration may well surge later this century, leading to stronger warming and more severe climate change than currently anticipated. There are therefore direct implications of this discovery on international policy, for example in deciding the rate and level of emission reductions required to avoid dangerous climate change.

TIGER staff and researchers were aware that the programme would have implications for other economic systems, such as agriculture and forestry. The first programme on agriculture, forestry and soils within the International Geosphere-Biosphere Programme was spun off from TIGER, with Bernard Tinker (Chair of TIGER) as the first leader and several TIGER scientists supporting aspects of it.

### ***Long-term outcomes - scientific knowledge***

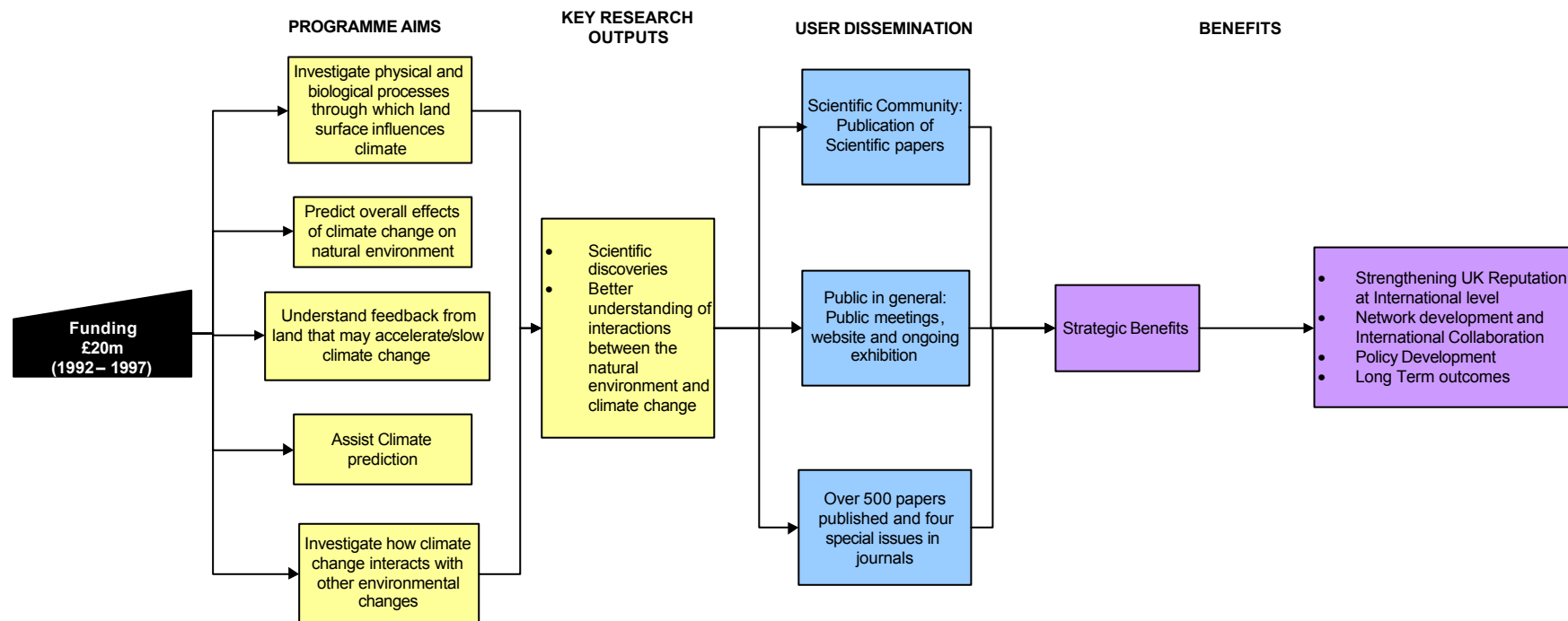
Despite it having finished in 1997, evidence from the research indicates that the outcomes of the TIGER programme are still being used by the science community today and can still be seen as making important contributions to the evolving major fields of global change science. While the DGVMs and models for soil carbon dynamics are much more sophisticated today than during the TIGER programme, TIGER drove the important first step in producing these crucial models. Its results have been used in many types of climate change and impact models both in the UK and internationally to help provide better forecasts of processes.

### **5.3.2 Wider and direct benefits**

As mentioned above, stakeholders identified that TIGER had an impact on national and international climate change policy by providing a better understanding of terrestrial carbon dynamics particularly in the definition of dangerous climate change. Stakeholders have not felt able, or indeed that it was appropriate, to suggest that TIGER has or will be able to accrue wider or direct economic impacts, or to specify the extent to which they believe that TIGER research outputs may contribute towards improvements in policy or practice, which ultimately could deliver an economic benefit.

An illustrative example has not been provided in the case of TIGER as no appropriate counterfactual baseline was identified.

## TIGER's Value Chain



## 6 CASE STUDY 2 – Rapid Climate Change

### 6.1 Case study description

#### Summary

The Rapid Climate Change Programme (RAPID) is expected to make a major contribution to understanding and quantifying the likelihood and magnitude of rapid climate change in the near future in Western Europe. A large part of the programme will be, for the first time, to provide continuous observations of the Atlantic Ocean circulation, which is responsible for Europe's temperate climate. These observations are initially for four years, with funding being sought to obtain a decade of data. The pilot scheme with instruments stretched between Africa and the United States could pave the way for a permanent monitoring system. The RAPID programme is expected to act as an early warning system of changes in the Atlantic Ocean's circulation. RAPID has the potential to reduce or limit the detrimental effects of a potential collapse of the circulation leading to rapid climate change. According to stakeholders, RAPID outputs will contribute to reducing the uncertainty in climate change models, particularly for models looking at climate change in Europe. It is therefore anticipated that the programme will lay the foundations for, and be integrated into, the process of cost effective policy making and decision taking.

#### Rapid Climate Change (RAPID) programme

**Start date:** 2001    **End date:** 2008

#### Funding

NERC has provided the RAPID programme with £20 million, over the seven-year period.

#### Background

Our planet has experienced climate extremes throughout its history, from hot tropical conditions to ice ages. Scientists believe that these changes in climate take place over many thousands to millions of years. However, our planet has also experienced large changes in climate over one to two decades. It is possible therefore that these rapid climate changes could happen in our lifetime.

The oceans affect climate in the UK, because ocean currents transport heat from the warmer tropics towards the Arctic. The ocean heats the weather systems crossing the Atlantic towards the British Isles, and helps maintain the mild climate. Changes this ocean circulation – variously known as meridional overturning circulation (MOC) or thermohaline circulation (THC) – is predicted to affect the UK climate.

There is a need for a better understanding of the processes involved in heat transport in the oceans, the interactions between the atmosphere and the oceans and past rapid climate

change events, in order to predict future changes in climate and weather patterns more accurately. The RAPID programme will help fill some of the gaps in our current understanding of rapid climate change.

Climate change has been a key focus of the UK Government for some years now; it recently featured strongly in the agenda of the EU and G8 for which the UK held joint presidency in 2005. The concern though has been focused on steady changes in climate over a century. However, growing evidence suggests that increases in global temperatures may lead to more rapid and irreversible shifts in the climate system<sup>34</sup>. With the emphasis on rapid climate change increasing, the need for sound scientific research to feed into informed public policy becomes ever greater.

## Objectives

The specific objectives of the programme<sup>35</sup> are listed below.

1. To establish a pre-operational prototype system to continuously observe the strength and structure of the Atlantic meridional overturning circulation (MOC).
2. To support long-term direct observations of water, heat, salt, and ice transports at critical locations in the northern North Atlantic, to quantify the atmospheric and other (e.g. river run-off, ice sheet discharge) forcing of these transports, and to perform process studies of ocean mixing at northern high latitudes.
3. To construct well-calibrated and time-resolved palaeo data records of past climate change, including error estimates, with a particular emphasis on the quantification of the timing and magnitude of rapid change at annual to centennial time-scales.
4. To develop and use high-resolution physical models to synthesise observational data.
5. To apply a hierarchy of modelling approaches to understand the processes that connect changes in ocean convection and its atmospheric forcing to the large-scale transports relevant to the modulation of climate.
6. To understand, using model experimentation and data (palaeo and present day), the atmosphere's response to large changes in Atlantic northward heat transport, in particular, changes in storm tracks, storm frequency, storm strengths, and energy and moisture transports.
7. To use both instrumental and palaeo data (see 1-3) for the quantitative testing of models' abilities to reproduce climate variability and rapid changes on annual to centennial time-scales. To explore the extent to which these data can provide direct information about the THC and other possible rapid changes in the climate system and their impact.
8. To quantify the probability and magnitude of potential future rapid climate change, and the uncertainties in these estimates.

## Key research outputs

Research communities from the following fields are involved in the research:

- physical and tracer oceanography
- meteorology
- palaeoceanography
- sea ice research

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<sup>34</sup> POST (2005) Rapid Climate Change, Post Note No. 245, London

<sup>35</sup> RAPID Science Plan <http://www.noc.soton.ac.uk/rapid/sci/Scienceplan.php>

- atmosphere, ocean, cryosphere and climate modelling.

**Models and observation data** are being generated by research communities collaborating in the RAPID programme, via the following activities:

- reconstructing past changes using palaeo data
- assessing the effects of change on the atmosphere, ocean circulation, ice sheets and land
- testing and improving local and global scale models, using palaeo and present day observations

The RAPID Data Centre (RDC) manages the output of data monitoring and models from the RAPID programme. The RDC is comprised of two NERC designated data centres, the British Atmospheric Data Centre (BADC) and the British Oceanographic Data Centre (BODC).

### Dissemination and users

In line with standard practice for ongoing research programmes, access to data is currently initially restricted to RAPID participants and is only available to other parties with explicit written permission, or after two years (as laid out in the RAPID data policy). The Hadley Centre, DEFRA, the Tyndall Centre and UK Climate Impacts Programme (UK CIP) are all likely to use of RAPID outputs (e.g. data, model simulations/predictions, probabilistic assessments of rapid change). The aim of the data produced is that they will constitute a key NERC resource and that they will have significant scientific and policy impact long after the formal end of the programme. Annual meetings are being held to bring together the RAPID community to discuss progress and disseminate results.

Scientific papers are being and will be produced for the research community, and already the paper by Harry Bryden et al.<sup>36</sup> on 'Slowing of the Atlantic Meridional Overturning Circulation at 25°N' has been widely discussed and attracted the attention of the global media in November 2005.

A public website<sup>37</sup> has been established to provide information to those outside the RAPID community, and information will be produced by the knowledge transfer co-ordinator for use by non-specialists. Findings from the programme have been covered by the Science Museum on their website, (<http://www.sciencemuseum.org.uk/antenna/currentslowdown/>).

At the end of the programme, a finale will be held to which both scientists and stakeholders will be invited to attend. One option under consideration is to hold this finale event in conjunction with an exhibition at the Science Museum (this remains to be confirmed).

## 6.2 Methodology

Key stakeholders (two from the scientific community and four end users) were interviewed to understand their informed opinion of the economic impact of the RAPID research.

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<sup>36</sup> Bryden, H. L., Longworth, H. R., Cunningham, S. A. (2005) Slowing of the Atlantic meridional overturning circulation at 25° N, *Nature*, 438, pp. 655-657

<sup>37</sup> <http://rapid.nerc.ac.uk/>

## 6.3 Findings

### 6.3.1 Strategic and policy benefits

RAPID plays a unique role in monitoring the Atlantic meridional overturning circulation (MOC), as no-one else is attempting to collect continuous observations of the total MOC. Over the last 50 years, only four direct observations were taken of the MOC at 25°N (a fifth 'one-off' observation was taken as part of RAPID using traditional hydrographic measurements from a ship). This is insufficient if scientists are to identify trends of what is happening to the MOC to be able to generate predictions of what will happen to it in the future, and to assess the impact of its collapse. The latitude of around 26°N is the most suitable for monitoring and understanding changes in the basin wide Atlantic MOC (observations have been and are being made at other locations in the North Atlantic, but allow for less clear interpretations of possible changes).

Stakeholders unanimously believed that the most important benefits of the current RAPID programme to policy development and quality of life would arise only if the measurements of the MOC, a major part of the RAPID programme, continued for the long-term future. However, stakeholders also agreed that the current RAPID programme would still have a substantial impact on various areas during its initial phase as discussed below.

#### ***International collaboration***

RAPID has established international collaboration between Norway, the Netherlands and the UK resulting in a joint announcement of opportunity for proposals with a total of €4 million of funding being made available (€2.5 million from the European partners). Further collaboration has occurred with the National Science Foundation (NSF) in the US, who contributed an additional \$7 million towards developing the MOC monitoring system as part of a joint NERC-NSF evaluation of UK and US proposals. In addition, the National Oceanic & Atmospheric Administration (NOAA) in the US is contributing to the programme 'in kind' through monitoring of the Florida Strait using underwater cables and ship-based observations. This joint programme is the first of its kind between the US NSF and NERC.

#### ***Setting research priorities***

Stakeholders assessed that the observations and findings from the current RAPID programme (RAPID 1) could help set out a clearer roadmap of what the key rapid climate change research areas are and should be, and could contribute to improvements of climate models. It is expected that RAPID 1 will increase understanding on how the MOC system works but decision-makers would not be able to comment on the probability of MOC collapse for some time yet, stakeholders suggested 15 to 20 years. However, a major uncertainty in making such a probabilistic statement depends on knowing the variability of the MOC, and a decade of observations will allow that to be quantified, for the first time.

#### ***Raising public awareness***

The Bryden et al. paper, which included data collected as part of the RAPID programme, has raised the possibility of rapid climate change in the public's eye. In November 2005, it was covered in at least 70 articles and news bulletins, including the [BBC](#), New Scientist, [CNN](#)

[International](#) and the Sydney Morning Herald (Australia), and major national UK papers (Times, Telegraph, [Guardian](#), Independent, Daily Mail). Coverage of issues was enhanced by use of a DVD, which was produced by NERC in late 2005 featuring the research being undertaken in the Atlantic.

### ***Long-term benefits over the next 25 years***

RAPID is likely to continue until 2014, and therefore stakeholders were asked about the benefits of continuing the MOC measurements to 2014 and the benefits of this over the next 25 years.

Stakeholders held the view that the data and models generated under the RAPID programme will underpin future climate prediction work and will be used in risk and impact assessments by analysts, policy makers and businesses. On this basis, stakeholders also explained that RAPID could impact on national and international climate policy through influencing UK climate change scenarios, and the fifth Intergovernmental Panel on Climate Change (IPCC) assessment report in 2012<sup>38</sup>.

The monitoring of the MOC by RAPID could provide a background of data against which climate models can be checked and tested. There are several climate change modelling centres around the world, and they are all giving very different answers with respect to whether climate change can cause MOC collapse and if so, when this could take place. RAPID could help the global climate research community distinguish the better models and thereby narrow the uncertainty around future predictions of climate change.

Stakeholders therefore felt that RAPID, through continuous observations over at least a decade, had the potential to provide an improved assessment of the likelihood of the collapse of the MOC, what the impacts of that might be and an indication of when it might happen.

The RAPID MOC observations could act as an early warning system of MOC collapse and therefore lay the foundations for, and be integrated into the process of cost effective policy making and decision-taking. Stakeholders judged that RAPID data and models are pieces of the jigsaw that informs the policy debate around the likelihood of rapid climate change in Europe. At the time of discussion, stakeholders felt that MOC collapse is a 'low probability – high impact' event. The economic cost would depend on the likelihood of collapse and its timing, both of which are uncertain, which reinforces the need for long-term monitoring of the MOC to reduce the uncertainty.

The Bryden et al. findings<sup>39</sup> indicate a 30% decrease in the MOC. These findings are greater than would be expected from the models over a period of 12 years and have emphasised the need to gather long-term measurements to establish whether this decrease in the MOC is just a blip or a trend. The measurements also serve as a test for the quality of the model

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<sup>38</sup> The IPCC terms of reference are to:

- Assess available information on the science, the impacts, and the economics of—and the options for mitigating and/or adapting to—climate change
- Provide, on request, scientific/technical/socio-economic advice to the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC)

The IPCC assessment reports attempt to answer questions such as:

- Has the Earth's climate changed as a result of human activities?
- In what ways is climate projected to change in the future?

<sup>39</sup> Bryden et al. op. cit.

predictions. Stakeholders emphasised the importance of long-term observations so that decision-makers can interpret the output of RAPID and do not respond to anomalies in data, which might suggest that MOC collapse is imminent when in fact the results are not significant when seen in the context of historical trends (for which, until now, data did not exist).

It can therefore be concluded that RAPID has an economic benefit through reducing uncertainty over the right course of action. The scale of this economic benefit is discussed below in the section on wider and direct benefits.

It is expected that businesses could also be future beneficiaries of the more statistically accurate risk statements that RAPID will produce, and the early warning system for rapid climate change. For example, those in the energy and agricultural sectors, and insurance companies would all be able to build their long-term business plans around, and in response to, any likelihood and impact of MOC collapse.

However, if RAPID is to act as an effective early warning system of rapid climate change, then its outputs need to be sensibly interpreted by the scientists and initial data users (e.g. the Hadley Centre), policy makers and other actors with responsibilities to react to any potential MOC collapse (e.g. the energy sector). They must be connected with the information outputs, understand the implications and be able to act or respond to RAPID. Otherwise an early warning system does not guarantee better policy making, effective business planning and, indirectly, quality of life. This area is being addressed by RAPID through its knowledge transfer activities.

In conclusion, the full policy and quality of life benefits will only arise if the observation system continues to monitor the MOC. A decade of data would allow, for the first time, the variability of the MOC to be established as a baseline against which changes can be assessed. Stakeholders had the view that at least 25 years worth of data would be needed to monitor trends effectively, and that continuous monitoring is required.

### **6.3.2 Wider and direct benefits**

#### **6.3.2.1 Wider benefits**

##### Potential areas of economic impact

According to stakeholders, RAPID outputs will contribute to reducing the uncertainty in climate change models, particularly for models looking at climate change in Europe. In particular, there is still great uncertainty around the likelihood of MOC collapse and what the impacts would be in Europe. RAPID will contribute to predicting the impacts of rapid climate change and therefore to defining the appropriate policy and business approach or response to any potential likelihood of MOC collapse.

An example of how RAPID might help business decision-making is included below:

**Example of potential for using RAPID outputs to plan business:**

Energy providers will need to respond to the outputs of RAPID, even though currently MOC collapse has a low probability of occurring, the collapse, should it occur, will have a high impact. One scenario of the impact of MOC collapse is colder winters<sup>40</sup> in Northern Europe, and this has implications for energy consumption in winter (e.g. more central heating required in households). Energy providers would need to use the interpretations of RAPID findings and its input to models to decide if MOC collapse would require more power stations to service colder winters, and these need several years lead in time before they can be built. RAPID will enable energy providers to plan for the likelihood of MOC collapse and respond more effectively to the impacts of rapid climate change, should it occur. In the face of MOC collapse and rapid climate change, and without RAPID, Northern Europe could be exposed to energy shortages.

Therefore RAPID provides research evidence that reduces the uncertainty and informs climate change related policy and business decisions in the UK and internationally. This may be able to help reduce the detrimental effects of MOC collapse/rapid climate change on human health and economic activity.

Extent of impacts

Stakeholders were interviewed in the course of this study to identify the extent to which they believed that RAPID will contribute towards improvements in policy or practice, which ultimately could deliver an economic benefit. In this case, the extent to which RAPID reduced/limited detrimental effects of rapid climate change on human health and economic activity.

By accessing third party sources, and as a matter of context only, Keller et al (2000)<sup>41</sup> estimates that the potential economic impacts of MOC collapse are likely to exceed £40 billion annually, or approximately 0.1% of projected gross world product in 2100.

Stakeholders emphasised that although there may be some contribution from RAPID, it is not possible to quantify to what extent it helps to achieve current or future wider economic benefits. The main reasons given for this include:

- the programme is still not finished and will be till 2008, therefore the outputs of the programme still need to be developed
- the likelihood of the MOC collapse is low and therefore it is also highly uncertain if and when benefits may accrue
- benefits realisation also depends on the interpretation of RAPID outputs by other groups, such as the Hadley Centre and the Tyndall Centre, who will interpret the RAPID data and inform possible policy responses.

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<sup>40</sup> <http://www.guardian.co.uk/science/story/0,3605,1654803,00.html> and Dr Tim Osborn, Climatic Research Unit of the University of East Anglia

<sup>41</sup> Keller, K., Tan, K., Morel, F. M. M. and Bradford, D. F. (2000) Preserving the ocean circulation: implications for climate policy. *Climatic Change*, 47, 17-43

### 6.3.2.2 Direct benefits

#### Potential areas of economic impact

Stakeholders held the view that the RAPID monitoring stations are a very cost effective way of monitoring the MOC. Over the last 50 years, the previous five (1957, 1981, 1992, 1998, 2004) direct observations of the MOC used ships which are more expensive to operate than RAPID monitoring stations, as follows.

#### Extent of impacts

The RAPID programme has led to the development of a solution to the problem of how to obtain accurate data on the MOC that enables a level of monitoring activity to take place that would otherwise have been logistically impossible and financially prohibitive.

According to the RAPID Science Co-ordinator (all figures in 2006 prices):

- the RAPID arrays in the Atlantic cost around £1.6 million to £2.1 million annually to run and maintain. These arrays are expected to be in place during the period for which funding is guaranteed (2005-2014)
- if each measurement were to be completed using a ship, that would take about 30 days, and would cost £0.53 million per transect. To have been able to monitor the MOC continuously would have required 12 measurements per year, at a cost of £6.3 million per year [12\*£0.53m].

For purposes of estimating potential direct benefits of RAPID, PwC has taken these assumptions from stakeholders. However, it is relevant to note that some of these may be conservative as stakeholders also mentioned that:

- measurements using a ship are just for one latitude (26°N) and further measurements would need to be taken across the Deep Western Boundary at several locations
- in practice the actual costs of using a ship would be much higher as a ship would need to be dedicated to the task, with several groups of scientists and crew so people would not need to be continuously at sea. This also assumes that the ship, crew and scientists would be readily available, which in practice they are not.

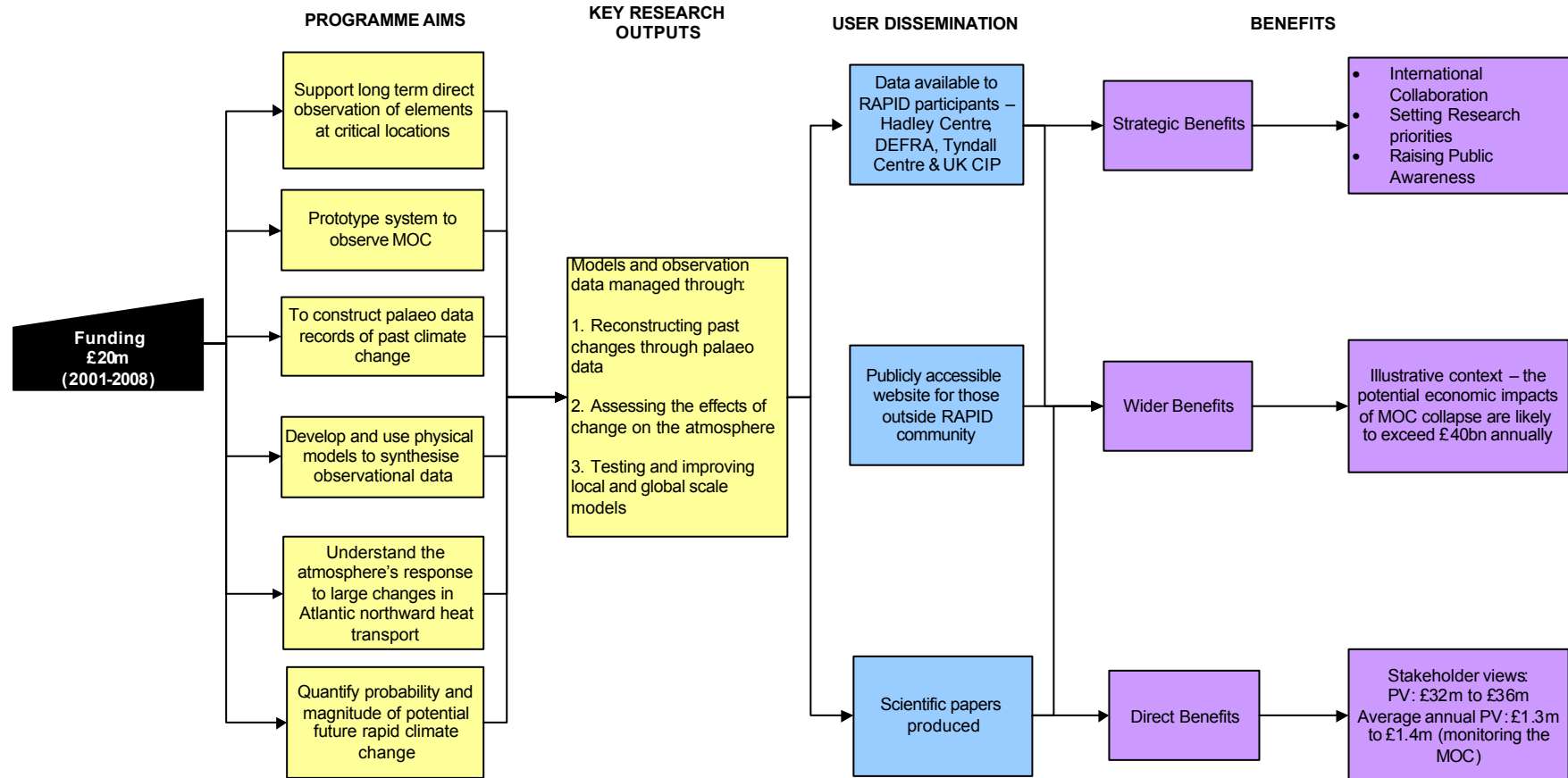
#### Projection of benefits

- The counterfactual baseline (in a world without the RAPID arrays) would be £6m/year if the RAPID programme was to use ships to monitor the MOC continuously over a year.
- During a year, the usage of arrays could reduce costs of monitoring the MOC in the range of £4.2 million to £4.7 million per year [£6.3m– £1.6m to £6.3 - £2.1].
- It's assumed, as suggested above, that the arrays are in place during the period for which funding is guaranteed starting from this year (2006-2014) then over that nine-year period.

- It's assumed that the monitoring costs stay constant (in 2006 prices) for the nine-year period.

Given these assumptions, direct benefits from RAPID could provide a present value in the range of £32 million to £36 million, or an average annual present value of £1.3 million to £1.4 million. The effect of this would have been that without RAPID the vessel borne monitoring was most unlikely to have occurred.

# RAPID's Value Chain



## 7 CASE STUDY 3 - Global Nitrogen Enrichment

### 7.1 Case study description

#### Summary

The Global Nitrogen Enrichment thematic programme (GANE) funded by NERC addressed the accumulation of nitrogen. The programme focused on the transformation and pathways of reactive nitrogen from land to sea, the fluxes of reactive nitrogen at landscape and global scales and the impacts of reactive nitrogen on the global terrestrial carbon sink.

GANE has the potential to achieve wider policy benefits in the future by providing policy makers with evidence to make informed decisions about how to tackle excess nitrogen emissions through policy design and implementation. The area of wider benefits where GANE may have its greatest impact is on reducing detrimental effects of nitrogen excess on human health and economic activity.

**Start date:** 1998/89

**End date:** 2005/06

#### Funding

GANE is a £7.1 million Thematic Programme funded by NERC (£6 million), with additional contributions from MAFF (£750k) and the Scottish Executive Environment and Rural Affairs Department (SERAD) (£400k).

#### Background

It has only recently become widely appreciated that fossil fuel burning, fertilizer production, legume growing, livestock farming and biomass burning are now releasing more reactive nitrogen into the global environment than pre-industrial processes. Whereas the global carbon cycle is being perturbed by less than 10%, the global reactive nitrogen cycle is being perturbed by over 90%. Furthermore, world energy and food demands make it inevitable that this nitrogen release will continue to increase proportionately much faster than the release of carbon. Consequently, reactive nitrogen is accumulating in the biosphere, oceans and atmosphere and is having powerful interlinked effects – while some of these might be positive (e.g. faster forest growth) others are negative (e.g. eutrophication of watercourses).

Research on nitrogen enrichment is important because<sup>42</sup>:

- the UK population are releasing 'reactive' nitrogen into the UK and global environment at an unprecedented rate

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<sup>42</sup> GANE's website <http://gane.ceh.ac.uk/>

- most regions of the UK have elevated levels of nitrogen due to fertilizer use, animal production and burning fossil fuels
- nitrogen oxides in the air generate ozone, both are harmful to human health
- nitrates and ammonium can reduce biodiversity
- nitrates and ammonium acidify soil and water, and they contribute to corrosion of building materials and statues
- nitrates pollute lakes, estuaries and the coastal marine environment
- global nitrogen enrichment is playing a part in changing the Earth's climate.

### Objectives

GANE addresses the UK interest in nitrogen accumulation, tackling some of the fundamental, modelling and scaling problems from UK and global perspectives. Issues have been identified which are unresolved and are of concern to the users of NERC science.

The programme covered three themes<sup>43</sup>:

- Transformation and pathways of reactive nitrogen from land to sea, focusing on organic nitrogen and the gaseous dissipation of nitrogen in rivers and coastal areas
- Fluxes of reactive nitrogen at landscape and global scales, developing models of sources and sinks within landscapes/catchments and of the continental-scale spread of nitrogen, measuring nitrogen deposition in remote areas and reassessing global soil emissions of NO and N<sub>2</sub>O
- Impacts of reactive nitrogen on the global terrestrial carbon sink, UK N-sensitive semi-natural and Arctic ecosystems, and UK shelf sea ecosystems

### Key research outputs

GANE examined the effects of nitrogen enrichment on biodiversity, soil processes, water quality, and greenhouse gas emissions. The research involved over 130 scientists working in multi-disciplinary teams from many institutions, in the UK and abroad. GANE supported 34 research grants and 29 PhD studentships (all now completed).

GANE results have helped to:

- identify the environmental damage nitrogen pollution causes in the UK
- estimate the effects of nitrogen enrichment on biodiversity
- determine the potential for mitigation and recovery of certain ecosystems
- fulfil international obligations relating to the control of pollutants and emissions of the greenhouse gas nitrous oxide.

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<sup>43</sup> GANE's website <http://gane.ceh.ac.uk/>

It is worth noting that, as stakeholders have mentioned, GANE is part of a wide range of research projects around this issue. Therefore, research achievements in the area are usually of a cooperative nature rather than isolated to just one programme.

### **Dissemination and users**

GANE was a directed programme in terms of its overall research focus; however, the majority of projects implemented were responsive in nature, within the objectives of GANE. The Steering Committee were responsive in terms of what research could be supported and funding was largely based on science excellence rather than providing too strong a steer in terms of the direction of the programme.

An extensive number of publications of research papers from the GANE programme have been published to date and are listed on the GANE programme website. A special issue of *Water, Air & Soil Pollution: Focus* [volume 4 No.6 2004] was produced by the programme, consisting of 30 papers. Copies of this volume were distributed to interested policy-makers both in the UK and overseas.

Additionally, pamphlets, presentations and direct conversations between scientists and other stakeholders have been used to disseminate the outputs of the programme.

An event was held in London on 16 February 2005 to showcase the results of the GANE programme. GANE results were expected to be applicable to a range of fields and the event was intended for a wide audience, including those in central and local government, conservation agencies, biological research, agriculture and industry. The event was attended by over 150 delegates with representative from English Nature, DEFRA, Scottish Natural Heritage, Environment Agency, Scottish Executive Rural Affairs Department, Scottish Environment Protection Agency, Countryside Council for Wales (CCW), Forest Research, Joint Nature Conservation Committee, NGOs (including the RSPB, Plantlife and the Soil Association), industry, farming organisations and local government.

The finale event brochure 'Global Nitrogen Enrichment – Too much of a good thing?' contained accessible summaries of 16 key programme findings.

GANE scientists input into the UN/ECE Critical Loads meeting in Berne, November 2002. Eleven GANE scientists attended the meeting, including six that were invited by the organisers and three who were sponsored by GANE. Policy makers and regulators used the outcome of this meeting across Europe.

## **7.2 Methodology**

Stakeholders (three from the scientific community and two end users, and one other) were interviewed to understand their informed opinion of the economic impact of the GANE programme.

## 7.3 Findings

### 7.3.1 Strategic and policy benefits

#### ***Evidence to back up policy making and implementation***

The UK has major interests in the issue of excess reactive nitrogen at national and global levels. This interest encompasses policies on land, air and shelf sea pollution, land use, river and coastal zone management, farming practices, waste and sewage disposal, conservation of habitats and biodiversity, and climate change, among others.

These interests have been recognized in the nitrogen related research completed or in progress on, for example, nitrate leaching, air pollution and critical loads, funded by NERC, the BBSRC, government departments, the EU, Environment Agency, conservation agencies and others.

According to stakeholders, GANE has helped to build a clear understanding of the issues that arise out of the excessive release of reactive nitrogen. It has helped to build a clear case for why nitrogen emissions should be reduced and how effects of emissions could be mitigated. In this way, it has provided policy makers with evidence to make informed decisions about how to tackle excess nitrogen emissions through policy design and implementation. GANE has not sought to suggest how emissions might be reduced.

Additionally, stakeholders comment that around five projects had direct application as supplying advice to policy makers and regulators, among them DEFRA/MAFF, English Nature, the Scottish Executive, CCW, and the Environment Agency.

In this way, and together with other sources of related research, GANE outputs have been used by the UK Government to take better decisions in terms of policy development and implementation and, in particular, in setting emission limits at a national, regional and international level. In particular, GANE has provided useful evidence important to a wide range of policy problems and issues, including<sup>44</sup>:

- ammonia emissions
- the effect of nitrogen deposition on wildlife habitats
- nitrate loss from agriculture
- nitrogen in marine ecosystems
- the implementation of the Water Framework Directive
- nitrous oxide emissions
- carbon sequestration
- sustainable development

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<sup>44</sup> Costigan P (2005) GANE - A stakeholder perspective (presentation at the GANE Finale event)

- implementing the Kyoto Protocol.

### ***Increasing awareness about the impacts of excess nitrogen***

Given that GANE did not establish projects directly commissioned by government departments to answer specific policy questions, but rather it established responsive projects within the area of nitrogen enrichment, it might have been perceived as a less relevant programme for policy makers. However, stakeholders have stated that GANE was crucial in positioning excess of nitrogen as a strategic problem and focused people's attention on the issue at a UK and European level. They mentioned GANE provided crucial evidence that motivated further directed research projects and conservation investments funded by Government.

At a local level, GANE outputs have helped to create greater awareness of the problems that excess of nitrogen presents to communities. Stakeholders suggested that GANE provided a user friendly and accessible explanation of nitrogen enrichment issues, and that this has been of paramount importance in persuading relevant groups, notably farmers, of the various impacts that fertilizer usage may have.

Similarly, GANE has equipped the Joint Nature Conservation Committee (JNCC) with data and arguments to advise Government on the appropriate course of action in dealing with the conservation of biodiversity.

Overall, from the point of view of some stakeholders, GANE has brought a set of research strands together and provided a reference point for nitrogen research.

### **7.3.2 Wider and direct benefits**

Stakeholders have indicated that GANE contributed to achieving wider economic benefits rather than direct benefits.

#### **7.3.2.1 Wider benefits**

##### Potential areas of economic impact

According to stakeholders, although GANE was not intended to reduce nitrogen emissions, it had the effect of providing policy makers with the evidence to make informed decisions on tackling excess nitrogen emissions. Stakeholders acknowledge that it is policy design and implementation, rather than research, that is the mechanism by which nitrogen emissions may be constrained and thereby reduce their impact on the national and international economy. Equally successful policy needs to be based on scientific evidence.

The table below provides a summary of PwC's understanding of the application of GANE to the nitrogen policy agenda, and illustrates the principal mechanisms through which it might deliver benefits.

##### Extent of impacts

Although stakeholders acknowledge the value of GANE and believe that it has been a very worthwhile investment, none of the stakeholders were able to provide views of the potential

quantifiable impacts of GANE research outputs. Stakeholders believe that is difficult to isolate the impacts of GANE on policy for the following reasons:

- some of the policies that GANE has informed are still not in implementation (e.g. Water Framework Directive) or do not relate only to nitrogen enrichment (e.g. Kyoto Protocol)
- other research programmes or projects have been inspired or built on GANE, including specific research programmes funded to deliver answers to very specific policy related questions. Overall new knowledge from diverse research sources have been blended together, for instance by DEFRA, to inform policy making.

Nevertheless, stakeholders estimated that NERC funding for GANE (£6 million) was a notable contribution to the sum total of nitrogen related research that occurred during GANE's main period of activity. Additionally, GANE's contribution was complementary to other related research and, in some cases, has motivated further research. It therefore had a considerable impact overall.

To identify the likely impact of GANE third party sources were reviewed, and these indicate the following:

- Pretty (2005)<sup>45</sup> mentions that studies have estimated the costs of eutrophication, one of the impacts of excess nitrogen, to be of the order of £50 million to £70 million (social damage), £4-5.5 million (ecological damage) and £4 million (policy response) per annum. The cost of enrichment due to nitrogen has been estimated to be of the order of £57 million to £80 million per annum for the UK economy. The types of costs that can be expected from excess nitrogen include:
  1. *Social damage costs*
    - Reduced value of waterside dwellings and water bodies
    - Drinking water treatment costs
    - Clean up costs of waterways
    - Reduced value of non-polluted atmosphere
    - Reduced recreational and amenity value
    - Losses to tourist and aquaculture industries
    - Health costs to humans, livestock and pets
  2. *Ecological damage costs*
    - Negative effects on biota
  3. *Policy response costs*
    - Compliance control costs
    - Direct costs for monitoring

Additionally, some benefits such as increased value of fisheries, fertilisation effect on farmland and improved sources of food for wild birds and shell fish can also arise as a result of nitrogen excess. The following box illustrates in more detail the ways in which excess nitrogen can cause social, environmental and economic damage.

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<sup>45</sup> Pretty et al. in Ag Syst (2000); J Env Policy Manage (2001); Env Sci Tech (2003); Food Policy (2005) suggested by Pretty J (2005) An Assessment of The Costs of Nitrogen Enrichment (presentation delivered at the GANE Finale event)

### Impacts of excess of reactive nitrogen

Excessive reactive nitrogen can adversely affect the UK environment and its economy. Below are some of the micro and macro impacts:

- **Leaching into groundwater, lakes, rivers and coastal waters:** if soils become nitrogen saturated or acidified, nitrogen can leach into waterways, causing acidification of the water. This leaching removes important nutrients from the soil, reducing its fertility. It also pollutes groundwater and can cause an excessive growth of plant life in water, leading to oxygen depletion (eutrophication). Lack of dissolved oxygen in water has led to significant fish kills in the Baltic Sea, Black Sea and Chesapeake Bay.
- **Acidification of soil:** deposited nitrogen acidifies the soil, bringing about changes in its chemistry, altering the amounts of other available nutrients and increasing the amount of toxic aluminium, which is often toxic to the development of plants.
- **Bryophytes (mosses and liverworts) and lichens are particularly sensitive to nitrogen levels.** These mosses play a vital part of the upland community in that they are the most important peat forming plants. Britain also possesses one of the highest levels of diversity of this taxonomic group of plants and therefore it is felt important that these plants are protected.
- **Nitrates and ammonium can reduce biodiversity:** experiments show that in areas of high nitrate concentrations, a few species of plant dominate, whereas in areas with lower concentrations of nitrates, many more species of plant can be found. For example, in large areas of Northern Europe, high levels of nitrogen deposition has resulted in conversion of heathlands rich in biodiversity into grasslands containing relatively few species.
- High levels of ozone at low altitude is the number one pollutant affecting plants in Europe - it **reduces crop yield** and also affects the plants in other, more subtle ways.
- **Costly purification systems** have had to be introduced in the US, where nitrogen levels in the water have risen ten-fold since the beginning of last century.
- Global nitrogen enrichment is playing a part in **changing the Earth's climate** – global nitrogen enrichment is affecting the rate of increase of all major greenhouse gases (CO<sub>2</sub> - by altering the terrestrial and ocean carbon sinks, CH<sub>4</sub> and O<sub>3</sub> - by altering the oxidizing capacity of the atmosphere, and N<sub>2</sub>O directly). Nitrous oxide is estimated to contribute 6% of climatic forcing. N<sub>2</sub>O remains in the atmosphere for over 100 years (it is not readily deposited back into the ground like NO<sub>x</sub> or ammonia) and has a global warming potential over 200 times greater than that of CO<sub>2</sub>. Nitrogen enrichment of the soils and waterways results in increased levels of N<sub>2</sub>O in the atmosphere.
- **Ozone (generated at low altitudes by reactions with nitrates and sunlight) and nitrates are damaging to human health:** they irritate the airways of the lungs and worsen the conditions of people who have heart and lung disease.
- Nitrous oxide in the upper stratosphere contributes to the **thinning of the ozone layer;** nitrous oxide gets converted to nitric oxide and this acts as a catalyst in the reactions in which bromide and chloride radicals destroy ozone. There have also been suggestions that greenhouse gases (such as N<sub>2</sub>O) affect the thinning of the ozone layer. The theory is

that because warming increases particle formation at the poles and because ozone destruction takes place on the surfaces of crystals, this increase in surface area speeds up the rate of ozone destruction.

- A report by the Economics for the Environment Consultancy (EFTEC)<sup>46</sup> estimates that the welfare impacts to society from depreciation on inland (or surface) waters due to excess nitrogen are around £50 million per year<sup>47</sup>. Similarly, this study estimates the share of disamenity to be attributed to agricultural pollution for poor quality in bathing waters is of £3 million per year<sup>48</sup>.
- UNEP (2000)<sup>49</sup> mentions that current trends suggest that the problems with nitrogen enrichment are likely to worsen due to the increase in fertiliser use and the continuing boom in fossil-fuel dependent transportation. The level of nitrous oxide (N<sub>2</sub>O) in the atmosphere has increased by 8% since the industrial revolution and it is currently increasing by 0.2-0.3% per year. Human activities have doubled the amount of nitrogen available for uptake by plants, as the principle form of anthropogenic nitrogen is inorganic nitrogen fertilizer (60%). The consumption of this soared between the 1950s and 1980s but consumption is now either stable or decreasing. However, consumption is still increasing in developing countries.

#### Projection of benefits

The wider benefits arising as a result of GANE research outputs usage in policy making will not be modelled due to the lack of stakeholder views about the extent to which GANE can contribute to reduce the effects of nitrogen excess.

However, as an illustration, it is assumed that:

- research knowledge takes five years from the end of completion of the programme to impact on policy making<sup>50</sup> and probably another five years for policy change to impact on the economy
- the cost of enrichment due to nitrogen has been estimated to be of the order of £57 million to £80 million per annum for the UK economy
- as per UNEP (2005) mentioned above, the level of nitrogen and the impacts associated to it increase by 0.2% per year.

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<sup>46</sup> EFTEC (2004) Framework for environmental accounts for agriculture. London.

<http://statistics.defra.gov.uk/esg/reports/envacc/finalrep.pdf>

<sup>47</sup> This calculation is the result of applying a willingness to pay (WTP) estimate to all rivers of £5,900/km of river to the number of river kilometres in the UK (12,951km), multiplied by the percentage of nitrogen entering surface waters from an agricultural source (i.e. £50 m/y =£5,900/km/y x 12,951km x 0.7).

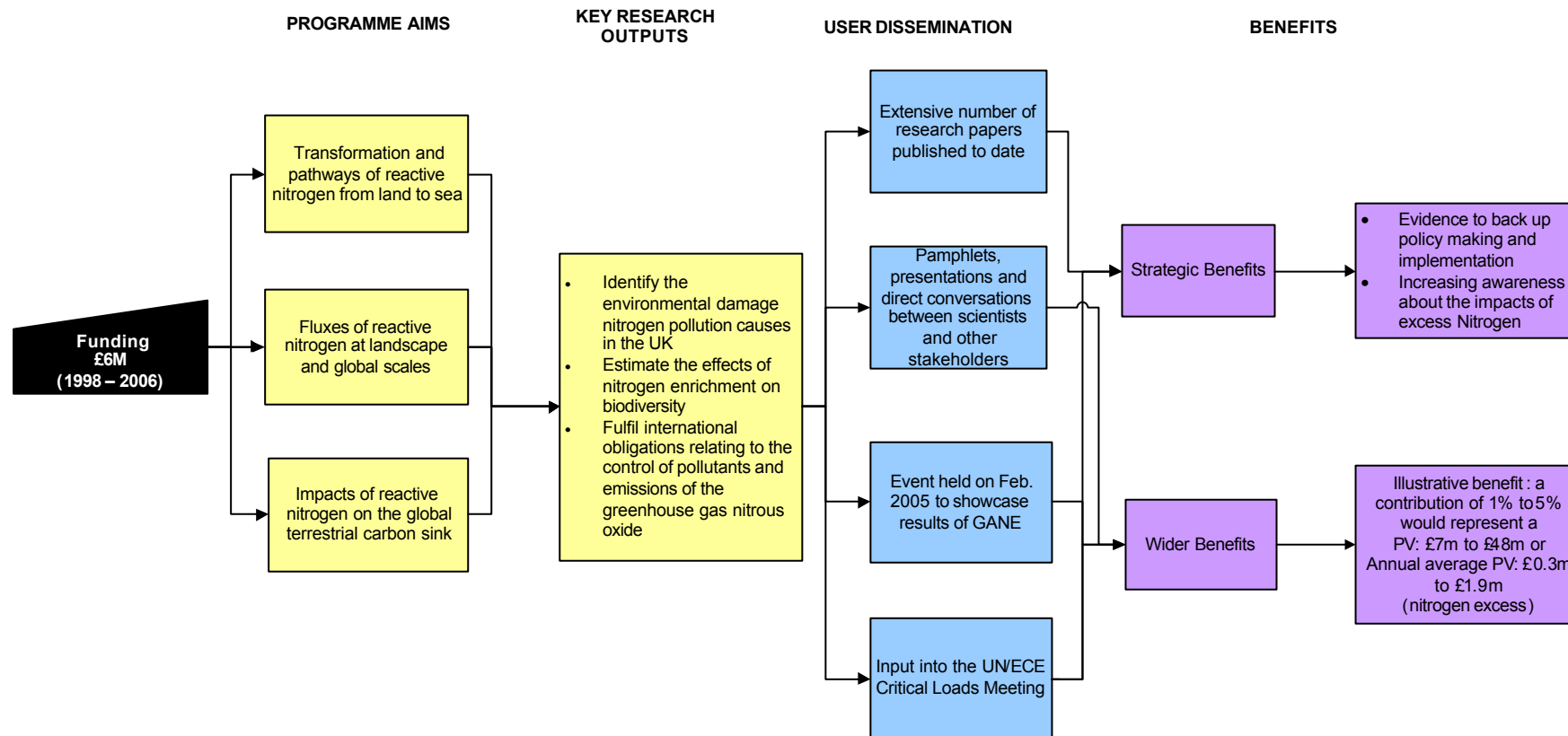
<sup>48</sup> (=£61.8 million/year estimated WTP for avoiding stomach upsets associated with bathing in faecally contaminated bathing water in British beaches x 5% of faecal pathogens to bathing waters is accounted for by agriculture).

<sup>49</sup> UNEP (2000) Geo2000 <http://www.unep.org/geo2000/pressrel/life.htm>

<sup>50</sup> Generic assumption implied by policy makers interviewed for other case studies.

If policy change, as a result of GANE, were to cause a reduction in the cost of enrichment due to nitrogen of 1% (of £57 million) to 5% (of £80 million) during the appraisal period, then a saving in the range of £7 million to £48 million in present value terms, or an average present value of £0.3 million to £1.9 million per annum, would arise.

# GANE's Value Chain



## 8 CASE STUDY 4 – Urban Regeneration and the Environment

### 8.1 Case study description

#### Summary

The Urban Regeneration and the Environment (URGENT) programme was established to integrate urban ecological and environmental research across the geological, terrestrial, freshwater and atmospheric sciences. The programme has worked in partnership with city authorities, industry and regulatory bodies.

The programme aim was to determine the magnitude of urban environmental problems and risks, to understand the underlying patterns and processes that affect them, and to produce effective strategies for control and management that will be accessible to users both in the UK and abroad.

Some of the major outcomes of URGENT have been the creation of new scientific networks, its leadership role in Europe in relation to developing urban environment science, and the provision of a series of follow up funding grants for its scientists, among others.

**Start date:** 1997    **End date:** 2003

#### Funding

NERC funding was £9.7m<sup>51</sup>.

#### Background

There were a number of key drivers behind the URGENT programme<sup>52</sup>.

- Over 90% of the population of the UK live in conurbations covering 10% of its land area and that a higher percentage of the world's six billion people tend to live in cities.
- Many urban centres in the developed world have experienced over 150 years of industrialisation and rapid urbanisation, leaving a legacy of contamination and dereliction.
- This presents risks to the health of urban inhabitants and ecosystems, inhibits safe and cost-effective redevelopment and diminishes the quality of life.
- The challenge is to clean up the legacy of the past and institute a sustainable development regime which will avoid repetition of past mistakes and reshape the structure and use of the urban environment.

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<sup>51</sup> URGENT website: <http://urgent.nerc.ac.uk/about.htm>

<sup>52</sup> URGENT website: <http://urgent.nerc.ac.uk/about.htm>

URGENT was the product of a wide range of scientists recognising that these issues relating to the urban environment required specific treatment.

### Project overview and objectives

URGENT was a programme of thematic research that was established to integrate urban ecological and environmental research across the geological, terrestrial, freshwater and atmospheric sciences and that has worked in partnership with city authorities, industry and regulatory bodies.

The projects aim was to determine the magnitude of urban environmental problems and risks, to understand the underlying patterns and processes that affect them, and to produce effective strategies for control and management, which will be accessible to users both in the UK and abroad.

The programme included more than 40 projects in four key areas - air, water, soil and ecology, which were managed by engineers and scientists. It focused on a small number of case study or demonstrator urban conurbations in the UK so as to capitalise upon opportunities to integrate science across different environmental media, but it has also developed generic models and solutions which can be applied more widely in the UK and internationally.

### Key research outputs

The table below summarises the key research outputs of URGENT as reported by NERC/URGENT:

Key research outputs of projects funded by URGENT's research grants <sup>53</sup>	Key technologies developed through URGENT's research grants
<ul style="list-style-type: none"> <li>▪ User-friendly software packages that can predict concentrations of atmospheric pollutants and their dispersal.</li> <li>▪ More knowledge of how climate varies within particular conurbations and the development of efficient and more cost effective ice prevention methods on urban roads.</li> <li>▪ New techniques to help remediate brownfield sites.</li> <li>▪ Improved methods and techniques to monitor and restore urban rivers.</li> <li>▪ The use of tree cover to help reduce atmospheric pollutants in urban areas.</li> </ul>	<p>Technologies that help to:</p> <ul style="list-style-type: none"> <li>▪ monitor roads and predict when they need salting in winter</li> <li>▪ monitor microscopic airborne particles and model airborne pollutants in cities</li> <li>▪ predict numbers of bacteria in coastal waters</li> <li>▪ give urban planners a web-based system that identifies and predicts environmental impacts</li> </ul>

<sup>53</sup> URGENT website: <http://urgent.nerc.ac.uk/about.htm>

<ul style="list-style-type: none"> <li>▪ New ways to help improve biodiversity in urban domestic gardens.</li> <li>▪ The production of an integrated database and environmental information systems that makes the results available to all.</li> <li>▪ Decision support systems targeted to enable planners, industry and regulators to improve urban sustainability.</li> </ul>	<p>impacts</p> <ul style="list-style-type: none"> <li>▪ detect abandoned mineshafts and mine waste</li> <li>new image software</li> </ul>
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These research outputs have helped and in most cases continue to help to:

- protect archaeological remains in construction sites
- monitor and assess contamination of soils and urban rivers
- rehabilitate waterways and river valleys polluted by industrial and domestic waste
- protect urban groundwater
- predict and improve air quality
- identify plants that can tolerate air pollution
- improve tree survival in heavily polluted soils
- increase biodiversity in gardens
- measure urban land uses from remote and GIS information
- understand how plants and animals use corridors of open land in towns and cities.

#### Dissemination and users

URGENT included a wide range of projects that produced new scientific knowledge around the priority areas for the programme. Many of these outputs have been published in scientific, academic journals or as books (e.g. 'Urban Rivers: Our Inheritance and Future' by Principal Investigator, Geoff Petts, see section 8.5.1.).

According to stakeholders consulted:

- around 16 URGENT projects were disseminated through enabling technologies and partnerships with users (e.g. Sensing device and software system for optimising road de-icing by Entice Technology, Environmental Information System for planners (EISP) or the Imaging technique to detect abandoned mine-workings and landfill in urban areas)
- another 30 URGENT projects had an impact on policy making - mainly at a local level but also nationally and internationally (e.g. the development of a model to assess the effect of pollutants on urban air quality)
- around 25-30% of URGENT's research activity took place in the West Midlands and more than 10 URGENT projects had a direct impact on Birmingham City Council (BCC) policy making.

Overall, the programme aimed to build links between decision-makers and users concerned with the reclamation, reshaping and management of the urban environment. For instance, stakeholders have mentioned that each project had designated 'users' who followed the research closely and had a direct interest in the findings. URGENT users included local and national statutory authorities, industry, the Environment Agency, the Office of the Deputy

Prime Minister (ODPM), English Nature, the Wild Life Trust, funders of urban redevelopment and private individuals.

In 1999, Mike Welch was appointed as national facilitator to follow-up the opportunities identified by the Network User Group / Exploitation Committee by engaging the user community and the research workers in the application of the results from the URGENT programme. The national facilitator aimed mainly to interpret research findings to make them accessible to different audiences and to find the best ways of engaging with potential users.

## 8.2 Methodology

Key stakeholders (four from the scientific community and two end users) were interviewed to understand their informed opinion of the economic impact of the URGENT Programme.

## 8.3 Findings

### 8.3.1 Strategic and policy benefits

According to stakeholders, URGENT has been able to create important scientific networks, and provided leadership in Europe in relation to urban environmental science. It has led to a series of follow-up funding grants for its scientists, and generated a range of benefits that may be attributed to specific projects within the programme.

#### ***Scientific leadership through follow up funding***

The URGENT programme has facilitated both further funding of the science community that received direct URGENT funding and also funding of associated urban research in other universities and organizations. Not all of this has yet been quantified but for instance, according to a report by Mike Welch written in 2003, URGENT:

- has generated a further £2.4 million of research grants from the Research Councils and £5.2 million in development awards from Research Councils, the British Council, the EU LIFE Programme, Sixth Framework Programme (FP6) and INTERREG<sup>54</sup>
- Principal Investigators (PIs) have also been commissioned by other organizations, such as the Office of the Deputy Prime Minister, English Nature, the Environment Agency, the water companies and the waste industry, to implement and develop URGENT research by undertaking short and longer term projects amounting to nearly £3 million
- there are a number of research proposals based on URGENT in the pipeline awaiting review, which could account for a further £1-2 million.

EPSRC's *Towards a Sustainable Urban Environment* (SUE) programme provides the current research council focus for interdisciplinary urban environmental research. Some of the learning from URGENT and also research team members (for example, at the University of Birmingham) are now engaged on research under this programme. Importantly in the case of

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<sup>54</sup> INTERREG III is a Community initiative, which aims to stimulate interregional cooperation in the EU between 2000 and 2006. It is financed under the European Regional Development Fund (ERDF).

Birmingham, SUE funding is continuing the demonstrator theme (in this case in the Eastside redevelopment area of the City) linking ecological sciences with infrastructure engineering and economic redevelopment skills. URGENT interdisciplinary skills and networks provided a direct basis for SUE.

Stakeholders argue that follow-up funding is a way of measuring the fact that other organisations give value to the research outputs and scientific expertise (not least interdisciplinary working and knowledge transfer skills) facilitated by NERC through URGENT. Scientific leadership and attracted funding can also represent a relevant source of investment to the scientific and academic communities in the UK. Additionally, the fact European funding has been allocated to follow up projects from URGENT demonstrates, to a large extent, that URGENT is playing a leading role, at least in some key areas, in terms of urban environment scientific research across Europe.

According to the experience of some stakeholders, there is no other comparable science programme in Europe and only slightly similar in the US. There is evidence that the work from URGENT is enabling discussions in Europe around different topics of the urban environment (e.g. the European Commission's Urban Themes).

### ***Scientific network and capabilities***

Stakeholders consulted suggest that as a result of URGENT, a group of well-integrated researchers working in the urban environment has been developed. This group includes an urban science community of some 50 Principal Investigators (PIs) and some 50 postgraduates and postdoctoral fellows versed in urban science and its applications. It is expected that this group of researchers could develop this science area substantially in the future. Importantly they have the ability to embed the essential interdisciplinary and knowledge transfer skills developed in URGENT into future undergraduate teaching and postgraduate training as well as into new research initiatives.

Finally, PwC was also told that, as well as a researcher community, there is also a better prepared user community that now has a much clearer appreciation of how university research works. There is evidence that the programme facilitated the development of new networks across industry, government and the research community.

### ***Policy benefits***

As mentioned above, several URGENT projects have made policy contributions. In particular, research outputs have been used as evidence to inform policy making and implementation across central and local government across the country. Some examples are:

#### Example 1: Supporting the Office of the Deputy Prime Minister (ODPM)

ODPM had particular interest in projects dealing with: urban water cycles, contaminated land and water assessments, ground inventories (e.g. imaging technique to detect abandoned mine-workings and landfill in urban areas), urban biodiversity, classification of urban areas and urban air pollution.

URGENT put together a series of repositories of urban environmental data, following rigorous protocols, to be used for a whole set of different purposes in the future.

The outputs of URGENT projects have been used in the preparation of Planning Policy Statements (PPS) including PPS23, which addresses contamination, and PPS25, which deals with flooding. These benefits also extend to local authorities who are important potential beneficiaries of URGENT's outputs through their responsibility for development planning.

Additionally, it is understood by stakeholders that there will be a timelag before some of the strategic and policy benefits of URGENT are felt. URGENT can be expected to contribute to every aspect of the Government's Sustainable Communities agenda.

#### Example 2: Working with the Birmingham City Council (BCC)

The BCC had strong interactions with URGENT and demonstrated a wide interest in its science. It supplied additional funding to projects such as EPSRC's SUE, SMURF<sup>55</sup> and DGT<sup>56</sup>, all of which had direct applications for the Birmingham City Council. As an example, SMURF was implemented on the River Tame in Birmingham (for more details refer to SMURF's project assessment in section 1.5) and other strands of URGENT-funded research served as evidence for local environmental policy formulation for the city of Birmingham. Additionally, stakeholders suggested that various URGENT projects have impacted the upgrade and re-development of Birmingham east side.

Overall URGENT work has demonstrated its contribution to better environmental practices in urban areas. URGENT could potentially enable important improvements in the quality of urban environments and of human life in such environment (e.g. managing pollution). However, it is also recognised that the future of URGENT's benefits are highly dependant on improvements in the way that outputs are communicated and disseminated not only to key policy makers but also to the wider population.

#### **8.3.2 Wider and direct benefits**

There are a number of wider economic gains to be realised from the URGENT research, for example:

- fewer accidents and less ill-health, for example, from improved control of urban air pollution, by means including the more effective use of tree planting
- better development of local areas, for example, as a result of SMURF, the use of the URGENT/ODPM Environmental Information System, and practical initiatives, such as enabling trees to grow on contaminated land
- reductions in time and cost of determining local land contamination by the use of DGT, which is a novel technique that simulates the up-take of metal pollutants by plants and of particular interest to local authorities and others affected by the contaminated land regime
- currently unquantified benefits arising from the use of URGENT findings by local planners, the Wildlife Trusts and others.

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<sup>55</sup> Sustainable Management of Urban Rivers and Floodplains

<sup>56</sup> Methods to investigate uptake of metals by plants at contaminated-land-sites, using diffusive gradients in thin-films (DGT) probes

Due to the wide range of projects covered by URGENT, it is not practical to apply the same methodology to assess the impacts of each and every funded project. It was agreed that two projects should be assessed in detail for direct economic benefits.

The next two sections include an assessment of two of the projects funded by NERC.

## 8.4 Project Assessment: Route Forecasting to Optimise Road De-icing

### 8.4.1 Introduction

**Start date: 1997    End date: 2001**

#### **Funding**

NERC URGENT initially provided £130,000 to a research group at the University of Birmingham. This funding enabled the group to finish designing an innovative technology that allows more efficient de-icing of roads. This initial sum was followed by another £140,000 from the NERC Small Business Research Initiative (SBRI) which enabled the researchers to commercialise the technology they had developed through ENTICE Technology Limited. In summary, NERC funding helped the developer of the technology to develop it in a shorter period of time, perform appropriate testing and commercialise the technology.

Some of the background research that led to the development of the technology was not funded by NERC, however, according to the developer, it would not have been possible to disseminate the technology without NERC funding.

In this study 100% of any economic benefits arising from this project was allocated to NERC.

#### **Background**

Research in this area has been relevant because the accuracy of temperature forecasts for the surface of the road network was not as detailed as it needed to be to optimise road safety. There were also inefficiencies in the way in which the UK's roads were maintained during the winter. For example, in Birmingham where there is more than 1,000km of road, only one road forecast centre was being used to decide whether or not to treat 26 salting routes in the City<sup>57</sup>.

As the road temperature varies depending on the altitude, degree of exposure to sunlight and the fact that the UK has a very marginal climate, there can be great variation between different roads within the same geographical area. Weather forecasting is significantly more accurate now than it was 20 years ago. There is therefore a need to incorporate this increased accuracy into the decision-making process for when and where to salt the roads. With recent improvements in technology and better monitoring systems, it became clear that a more precise method of prediction was possible.

Finally, this is an area where important efficiency savings could be achieved. As much as US\$10 billion is spent every year on the winter maintenance of roads around the world. As a

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<sup>57</sup> BBC News (2004) Hi-tech device to beat icy roads 03/03/2004 [Online] Available at [http://news.bbc.co.uk/1/hi/england/west\\_midlands/3527713.stm](http://news.bbc.co.uk/1/hi/england/west_midlands/3527713.stm) [Accessed 23rd December 2005]

result, in many countries around the world, public expenditure on the winter maintenance of roads is under scrutiny<sup>58</sup>.

## Objectives

The wider objective of the research was to contribute to an improvement in safety of the UK's roads. More specifically, this meant increasing the number of forecast points on the road network (e.g. every 50m) and thereby providing more accurate weather predictions.

## Key research outputs

The key output of focus here is a technology that enables improved weather forecasts for the road surface across a route network.

The IceMiser energy balance model uses survey data along with information from the weather forecasts to predict road surface temperatures and conditions at thousands of sites around a network. These predictions take account of the dominant role of sky view factor and other geographic, meteorological and road construction variables to improve accuracy<sup>59</sup>.

## Dissemination and users

Entice technology was founded in 2002 as a spin-out company from the University of Birmingham<sup>60</sup>. The company was established as a means of disseminating the research to users in an easy-to-use format.

The route information is generated by Entice Technology from the IceMiser energy balance model and is displayed in a Geographical Information System (GIS)<sup>61</sup>. The GIS maps are made available to customers via password protected web pages. The display software uses Open Source tools. A simple traffic light system gives suggested actions per route on a night-by-night basis. It indicates which routes should be treated (highlighted red), those to watch (highlighted yellow) and those roads that are not likely to need treating (green).

Local authorities can use the systems sold by Entice Technology in order to decide when and where they should salt the roads as part of their winter maintenance programme. The technology also enables a user to work out how much salt should be laid down. According to stakeholders, the new technology is also currently being evaluated against the forecasts produced by more traditional methods. The technology is being used permanently or as a trial in Devon, Neath - Port Talbot, South Gloucester and Hampshire. The Scottish Executive is also using it on the Moray and Connect A30/A35.

The local authority is a beneficiary as the improved forecasts mean they are better able to estimate when, where and how much salt should be laid. The general public will also benefit if better choices are made with respect to gritting as appropriate gritting improves road safety.

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<sup>58</sup> Thornes J.E. (2006) A Benefit/Cost Review of the Use of XRWIS for the Winter Maintenance of Roads in the UK

<sup>59</sup> Entice Technology (2005) Route Forecast [Online] Available at:

[http://www.enticetechnology.com/road/road\\_weather/routeforecast.html](http://www.enticetechnology.com/road/road_weather/routeforecast.html) [Accessed 23rd December 2005]

<sup>60</sup> Entice Technology (2005) [Online] Available at <http://www.enticetechnology.com/> [Accessed 23<sup>rd</sup> December 2005]

<sup>61</sup> Entice Technology (2005) Route Forecast [Online] Available at:

[http://www.enticetechnology.com/road/road\\_weather/routeforecast.html](http://www.enticetechnology.com/road/road_weather/routeforecast.html) [Accessed 23rd December 2005]

As a result of this technology, the main users (i.e. local authorities) should find the decision-making process for whether or not to salt roads on a particular night is made much simpler, thanks to the advice provided through the traffic light coding of the roads. From the data provided via the GIS maps, users should also be able to calculate the amount of salt required on different stretches of the road network.

#### 8.4.2 Consultees

Three end user stakeholders were interviewed to understand their informed opinion of the economic impact of the research into the efficient salting of icy roads.

#### 8.4.3 Wider and direct benefits

##### Potential areas of economic impact

According to Thornes (2005)<sup>62</sup>, the economic and safety benefits of road salting including XRWIS (Route Forecasting to Optimise Road De-icing) in the UK are of the order of £3,224 million (2006 prices) per year in the UK. These benefits are made of reduced traffic accidents (£800 million), reduced traffic delays (£2,100 million), emergency response (£300 million) and fuel efficiency (£24 million). The costs of winter maintenance come up to £265 million including vehicle corrosion (£125 million), Bridge/road corrosion (£5 million), street furniture corrosion (£2 million), water contamination (£1 million), vegetable and soil damage (£2 million) and the cost of salt spreading (£130 million). Therefore the benefit/cost ratio with the use of XRWIS could be 12 to 1 as opposed to 8 to 1<sup>63</sup> for the use of salt alone. It is suggested that although winter maintenance in the UK is already providing excellent value for money it could be even more cost effective and more environmentally friendly with the use of XRWIS.

Stakeholders expect that most local authorities would be using the technology in 5-10 years time. They have also estimated that if half of all local authorities started using the new technology, the potential winter maintenance savings would be as great as £13 million (reducing the winter maintenance bill from local authorities in 10%)<sup>64</sup>.

Through conversations with stakeholders, two main areas of potential benefits linked to the 'Route Forecasting to Optimise Road De-icing' technology have been identified.

- Direct benefits – by increasing the accuracy of when and where salt needs to be used for winter maintenance, this technology could help to reduce the overall use of salt and provide efficiency savings to local authorities.
- Wider benefits – by increasing the accuracy of when and where salt needs to be used for winter maintenance, this technology could help to reduce the likelihood of accidents due to icy roads.

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<sup>62</sup> Thornes JE (2006) A Benefit / Cost Review of the use of XRWIS for the winter maintenance of Roads in the UK (unpublished)

<sup>63</sup> The ratio of 8 to 1 comes from a previous publication by the same author

<sup>64</sup> Welch M (2003) URGENT Added Value

These two benefit areas are covered in the next sections.

### Direct benefits

One of the most relevant impacts of the device and software for optimising road de-icing is the potential for the UK Government to make considerable savings by using this technology.

One user of the technology in a local authority reported that a short study had been undertaken in Devon County Council comparing the number of times the road network was treated with grit and the number of times the road temperature dropped below zero. This study estimated that an extra £150,000 (2004 prices) was being spent a year as a result of treating the roads when they did not need to be treated. The road network in Devon spans 12,000km, whereas the road network in the UK is estimated at 370,000km<sup>65</sup>. The potential savings per year for the whole of the UK could therefore proportionally total £4.9 million (2006 prices), if the process by which the decision as to whether or not the roads should be salted is made more accurate and all local authorities decided to use the technology.

Assuming that 50% of all local authorities implement the technology by 2016 (in ten years from now), this work could project present value direct benefits of the order of £20 million or an average present value of £0.8 million per annum.

### Wider benefits

It is difficult to identify trends for accidents on icy roads. The number of casualties resulting from accidents on icy roads is linked to the weather and dependent on the severity of the winter conditions. If a winter is particularly severe, the number of casualties on roads could be high, even if the process by which roads are salted becomes more efficient. Therefore, it does not necessarily make sense to look at 'trends' in accidents on icy roads.

Very little data exists on the causes of accidents on icy roads. However, the following table shows data for casualties that occurred on icy roads in the UK between 1995 and 1997<sup>66</sup>.

#### **Reported accidents on snowy or icy roads in the UK**

Severity	Year of accident		
	1995	1996	1997
<i>Casualties on snowy or icy road surface</i>			
Fatal	77	87	43
Serious	1,206	1,363	612
Slight	7,323	9,654	4,414
Total	8,606	11,104	5,069

<sup>65</sup> Wikipedia (2005) Transport in the United Kingdom [Online] Available at:

[http://en.wikipedia.org/wiki/Transportation\\_in\\_the\\_United\\_Kingdom](http://en.wikipedia.org/wiki/Transportation_in_the_United_Kingdom) [Accessed 23rd December 2005]

<sup>66</sup> UK Parliament (1999) House of Commons Hansard Written Answers for 24 Feb 1999 (pt2) [Online] Available at:

<http://www.parliament.the-stationery-office.co.uk/pa/cm199899/cmhansrd/vo990224/text/90224w02.htm> [Accessed 23rd December 2005]

Stakeholders predicted that, with the technology, the accuracy of forecast would be improved by 2%. As the accuracy of these type of systems is already very high (approximately 89%) small percentage improvements could be very significant in reducing the number of accidents and their impacts on human life and human health.

It has been acknowledged by stakeholders that the increased accuracy provided by this technology is crucial to reduce the impacts of icy roads in human life and human health though preventing some accidents to happen. Stakeholders have assured that the de-icing roads technologies are already helping to save human lives while saving money.

1. Only about 30% of main roads are salted but these carry about 80% of the traffic. Some accidents therefore on untreated roads. Accident statistics for the last 20 years are available on the web. Damage only accidents are not listed in the table but are very significant (probably ten times the number of minor accidents).
2. Savings of the ENTICE system are not only due to accidents there are also savings to the environment (reduced salting) and reduced delays and enabling emergency services to continue operating.
3. Savings will start to accrue straight away as the number of systems increases.

To estimate the potential contribution of the 'sensing device and software system for optimising road de-icing by ENTICE technology the following has been assumed:

- as the choice of whether or not to grit the roads is entirely dependent upon the weather forecast, PwC assumed that the 2% improvement in the forecast through the usage of the technology is translated to efficiency improvements in road gritting and accident reduction of the same proportion
- a value of £1.4 million (2006 value at 2006 prices) as the economic cost of a human life in the UK, this is based on the Valuation Conventions for UNITE estimates of the economic cost of a lost human life in the UK at €1.5 million in 1998 prices (approximately £1 million)<sup>67</sup>
- a value of £167,000 (2006 value at 2006 prices) as the average cost of a seriously injured road casualty in the UK, this is based on a report by the Scottish Executive<sup>68</sup>
- the numbers of accidents on icy roads in winter are to stay constant between 1997 and 2030, a range between 43 to 87 fatalities and of 612 to 1,363 serious casualties (as per the table above) was assumed throughout the period of analysis due to the lack of clarity in terms of trends (as explained above)
- savings from the implementation of the ENTICE technology will start to accrue in ten years time from now (i.e. by 2016) and that by this date 50% of the local authorities across the UK are using this technology, as suggested by stakeholders.

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<sup>67</sup> UNITE (2001) Valuation Conventions for UNITE [Online] Available at:  
[http://www.its.leeds.ac.uk/projects/unite/downloads/D5\\_Annex3.pdf](http://www.its.leeds.ac.uk/projects/unite/downloads/D5_Annex3.pdf) [Accessed 22nd December 2005]

<sup>68</sup> Scottish Executive (2002) Road Accidents Scotland 2002 [Online] Available at  
<http://www.scotland.gov.uk/library5/transport/ras02-23.asp> [Accessed 23rd December 2005]

Given these assumptions for a 25-year period starting in 2005 and with a discount rate of 3.5%:

- the yearly savings that could potentially be attributed to ENTICE technology for reduction in fatalities would be of around £0.6 million to £1.2 million per annum [ $£1.4m * 2% * 43$  (or 87) \* 50%]
- the yearly savings that could potentially be attributed to ENTICE technology for reduction in casualties would be of around £1 million to £2.3 per annum [ $£167,000 * 2% * 612$  (or 1363) \* 50%]
- the present value of these impacts would be in the range of £13 million to £29 million
- the average present value of these impacts would be in the range of £0.5 million to £1 million per year.

## 8.5 Project Assessment: Sustainable Management of Urban Rivers and Floodplains (SMURF)

### 8.5.1 Introduction

This section focuses on the impacts of URGENT funded projects that led to the delivery of the SMURF project. SMURF was not a directly funded project<sup>69</sup>; however, SMURF could not have been envisaged without the funding that NERC provided to two URGENT projects led by Principal Investigators at the University of Birmingham. Therefore, this project assessment focuses on the strategic, policy and economic benefits of a set of URGENT funded projects, taking the implementation of the SMURF project as the main benefit.

URGENT focused on the sustainable management of the urban environment. Water was one of the main focus areas of URGENT and various projects carried out research on urban rivers. Three particular projects that presented crucial background for SMURF were:

- the development of a 'Hydroecological classification of urban rivers' by Dr. Angela Davenport, University of Birmingham and Prof. Angela Gurnell, University of Birmingham and Kings College, London
- rehabilitation of urban rivers: modelling the ecological risks of urban river sediments lead by Prof. Geoff Petts, University of Birmingham. This project in particular, produced a series of scientific papers and also led to the publication of a general book written for stakeholders and the public called 'Urban Rivers: Our Inheritance and Future' a joint initiative of the Environment Agency, SEPA, SNIFFER, Entec and the University of Birmingham with more than 150 copies distributed during the SMURF project alone
- modelling river corridors: the scientific basis for rehabilitation of rivers – lead Dr John West.

Stakeholders have explained that the expertise developed by URGENT led to the support of EU-LIFE and other partners, in the implementation of urban river restoration methodologies – SMURF.

The overall aim of SMURF was to demonstrate how the principles of urban river basin management planning could be applied to highly modified and degraded catchments<sup>70</sup>. It included physical works community participation activities based on methodologies developed through URGENT projects.

Importantly, according to stakeholders consulted:

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<sup>69</sup> The SMURF project had a total budget of approximately £1.9 million. The project was supported by an E.U. LIFE-Environment grant of £700k as well as contributions of project partners: Environment Agency, Birmingham City Council, Seven Trent Water, HR Wallingford, Staatliches Umweltamt Herten, University of Birmingham and King's College London. Stakeholders have acknowledged, however, that the Environment Agency contributed financially the most

<sup>70</sup> <http://www.smurf-project.info/index.html>

- URGENT funding helped to underpin the science, produce the research outputs (e.g. Urban Rivers book) and to develop the restoration methodologies used in SMURF
- URGENT brought a interdisciplinary team together which allowed the urban river restoration research outputs in a common language and facilitated the network of contacts for the implementation of SMURF
- without URGENT none of this would have happened because the interdisciplinary community was lacking funding to get started.

SMURF was based on a section of the River Tame in the West Midlands. The River Tame being a typical example of an urban river – polluted, heavily modified by culverting, straightening, re-routing and with concrete banks and few natural features. Additionally, the Tame offered some interesting characteristics of urban rivers that made it an appropriate example to apply methodologies developed during URGENT, this included<sup>71</sup>:

- the river was in a poor ecological state
- the river system was inaccessible over much of its length and is of poor amenity value to the local community
- fly tipping of domestic and commercial waste into the river environment was common
- beneath Birmingham, groundwater was rising, bringing with it contaminants that have previously remained in the ground
- wildlife habitat in the river and at the bankside had been badly damaged
- during storms pollution flushes into the river, causing a loss of oxygen and killing fish
- there were also increasing development pressures on bank-side locations, which will need to be managed in a sustainable way for both the community and river ecology.

Overall SMURF aimed to transform through a demonstration project a degraded river environment into something more natural with an enhanced ecosystem that people could enjoy.

### 8.5.2 Consultees

Key stakeholders (two from the scientific community and one end user) were interviewed to understand their informed opinion of the economic impact of the SMURF project.

### 8.5.3 Findings

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<sup>71</sup> <http://www.smurf-project.info/index.html>

### **Strategic and policy benefits**

One of the main strategic benefits of URGENT has been to fund science projects that attract interest that materialises in new funding and new projects. These projects may take scientific outputs to a next stage of research (i.e. new science) or take scientific outputs to implementation that may bring direct benefits to the community.

In essence, as stakeholders have suggested, projects like SMURF are part of the vision that URGENT had about the application of its research outputs. Stakeholders have provided evidence that it was only due to URGENT's people, science and partnerships that SMURF was possible. SMURF itself has already achieved some relevant benefits and are expected to achieve benefits in the future. According to stakeholders consulted, these benefits include:

#### **Increased awareness of the local communities in protecting and benefiting from the river basin**

Members of the local community were asked to become involved in the development of a vision for the River Tame by sharing their views of what constitutes an attractive urban river available for them to enjoy (e.g. meandering flow, trees, no culverts, no concrete channels, accessible, etc.) Additionally members of the public, including school children, participated in activities to improve the ecology and amenities of the river (e.g. planting trees). Awareness was therefore developed and knowledge improved about how environmental issues can affect quality of life and awareness raised around the value of engaging in river and local environmental conservation and enhancement. This project helped to develop the understanding of the linkage between water in an urban environment and the quality of people's life. It is anticipated that the improved connection that the local community should have with their local environment, combined with an enhanced urban river environment, will increase civic pride and the satisfaction of the community with their locality and engender and ongoing level of participation in the management of their local area.

#### **Establishment of ecological objectives for the river system and a transferable Sustainable Indicators set**

Key indicators coming from URGENT's science to monitor the hydroecological quality of the river were implemented and tested during SMURF. URGENT identified that the qualities of urban rivers were very different from rural rivers and that special indicators were needed to classify the physical quality of an urban river. This was of particular importance to identify first what quality meant for an urban river and then what would need to be improved before then being able to monitor the desired improvements.

#### **Develop a detailed land-use planning model to help with future redevelopment in the floodplain and protect the community from future impacts of climate change**

SMURF helped to model the effects that land use changes on the river basin could have on the river. This means that land use planners would be able to get information about the river and assess both the impact that developments could have on it, as well as the potential impacts that the river could have on the built environment (e.g. through increased flooding due to climate change).

#### **Networks and partnerships**

A key characteristic of the URGENT-funded projects that set a background to SMURF was the development of inter-disciplinary networks of experts working together for a purpose. URGENT managed to pull together local politicians (e.g. from the Birmingham City Council - BCC), policy makers and implementers (e.g. Environment Agency), utilities engineers (e.g. Severn Trent Water), landscape architects, land use planners and ecological and hydrological scientists to discuss the restoration of urban rivers. These partnerships helped to:

- develop a 'common language' about urban river management and restoration, that could be used across disciplines but also to communicate with members of the public
- develop a solid partnership that facilitated the implementation of SMURF (e.g. without an initial partnership with the BCC, SMURF would not have had a chance of being implemented as it was

Stakeholders believe that the ability to put together the application for SMURF reflected the relationships developed through URGENT with the BCC, the Environment Agency and Severn Trent as the idea originated in one of the URGENT User Group meetings.

### **Local, national and international policy contributions**

The SMURF project has been investigating how implementing sustainable land-use planning and water management techniques could tackle the problems associated with urban rivers. The work produced by the project is of high relevance for policy makers and implementors particularly of the EU Water Framework Directive (WFD) which focuses on the sustainable management of river basins. The WFD addresses, among other issues, the importance of public participation in river basin planning. Additionally, the WFD has identified that diffuse pollution from the urban environments is a key issue in river quality. The research done under URGENT and the implementation done by SMURF represents a real-life example of what this could look like in the future. The methods developed by the SMURF project have the potential to be used as a model for work on similar rivers throughout the UK and the European Community. During the time that SMURF was ongoing there were two international conferences (attended by over 220 delegates including scientists, postgraduate students, policy makers and public participation consultants) that provided an immediate mechanism for disseminating knowledge and experience.

The public participation facilitated by URGENT and SMURF on the demonstration project on the River Tame have also very clearly had an impact on local policy making. In particular, the projects have demonstrated that public authorities (i.e. BCC and the EA) are ready to work to achieve the vision that the community have for the local river as a step forward in achieving a local implementation of the WFD.

### **Wider and direct benefits**

SMURF was only recently implemented in the River Tame (e.g. some large trees were just planted in November 2005). There are plans to measure the extent to which the local vision, developed by local community members at the outset, has been achieved. Additionally, future observations will take place to review how the physical and ecological qualities of the urban river have changed. It is expected that this will take place within the next two years.

However, so far, there is useful anecdotal evidence of the improvements of the amenity, ecology and sustainability within the river catchment (the demonstrator site was within the Perry Hall Playing Fields) that SMURF has achieved on the River Tame:

- the river's alignment was remodelled to slow the flow, helping to create improved habitats for wildlife and opportunities for recreation
- plants and trees were planted
- benches have been installed
- better planning practices around the river are in place.

Overall, the visual impacts of the river surroundings, as well as the recreational opportunities associated to the river, have improved. According to stakeholders involved in the restoration process, more people are visiting the river and making use of its amenities. People use the river facilities to sit down and relax, enjoy the views and carry out various leisure activities (e.g. walk the dog). Around 100 people participated in a tree planting day, considered by stakeholders to have been one of the largest recent public activities seen on the River Tame urban bank.

Therefore, it is considered by stakeholders that URGENT/SMURF is achieving and/or will achieve important socio-economic benefits by:

- firstly, improving the access of the local population to a physically and ecologically enhanced urban river providing various services (e.g. better sights of the urban river, space for sport and leisure, etc.) at the River Tame
- secondly, providing the methods to achieve similar improvements in many rivers across the UK and Europe which supports the implementation of the WFD

Overall, stakeholders believe that this project can improve the quality of life of the surrounding communities in the River Tame and in many other rivers where similar methods are implemented. These improvements could potentially accrue economic benefits at a UK and/or European level in areas such as:

- avoided costs due to, for instance, potential improvements in health of local populations, reduced risk of flooding or improved water quality in areas where URGENT/SMURF methods are applied
- efficiency savings due to having a tested set of methods that can be used/customised widely across urban rivers across the UK and Europe to enhance and improve the implementation of policies such as the WFD.

Many research studies demonstrate that tax payers see a value in river restoration activities and are willing to pay to receive the benefits of such restoration. Some research studies also quantify the value that people give to restoration through economic methods such as Willingness to Pay (WTP). These estimations can be considered a valuation of the economic benefits of river restoration. For instance:

- Loomis et al (2000)<sup>72</sup> indicates that households would pay an average of \$21 per month or \$252 annually in their water bill for the additional ecosystem services along a 45-mile section of the Platte River, the 5 ecosystems being dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. (2000 prices)
- Georgiou et al (2000)<sup>73</sup>, estimated the associated willingness to pay of house-holds for improving the quality of the River Tame, according to 3 different scenarios<sup>74</sup>, measured as the increase in council tax level per house hold per year associated with a large improvement on water quality is valued at an increase of £30 in council tax per house hold per year. A medium improvement is valued at an increase in council tax of £15 per household per year and a small improvement is valued at an increase of £5 in council tax per household per year (2000 prices).

Although these are just examples, they provide an indication of the importance of river restoration to local people. By calculating the total amounts of tax that people would be willing to pay for the restoration of rivers across Europe, the scale of benefits that might be achieved if projects like SMURF were implemented in a large number of rivers across Europe could be considerable.

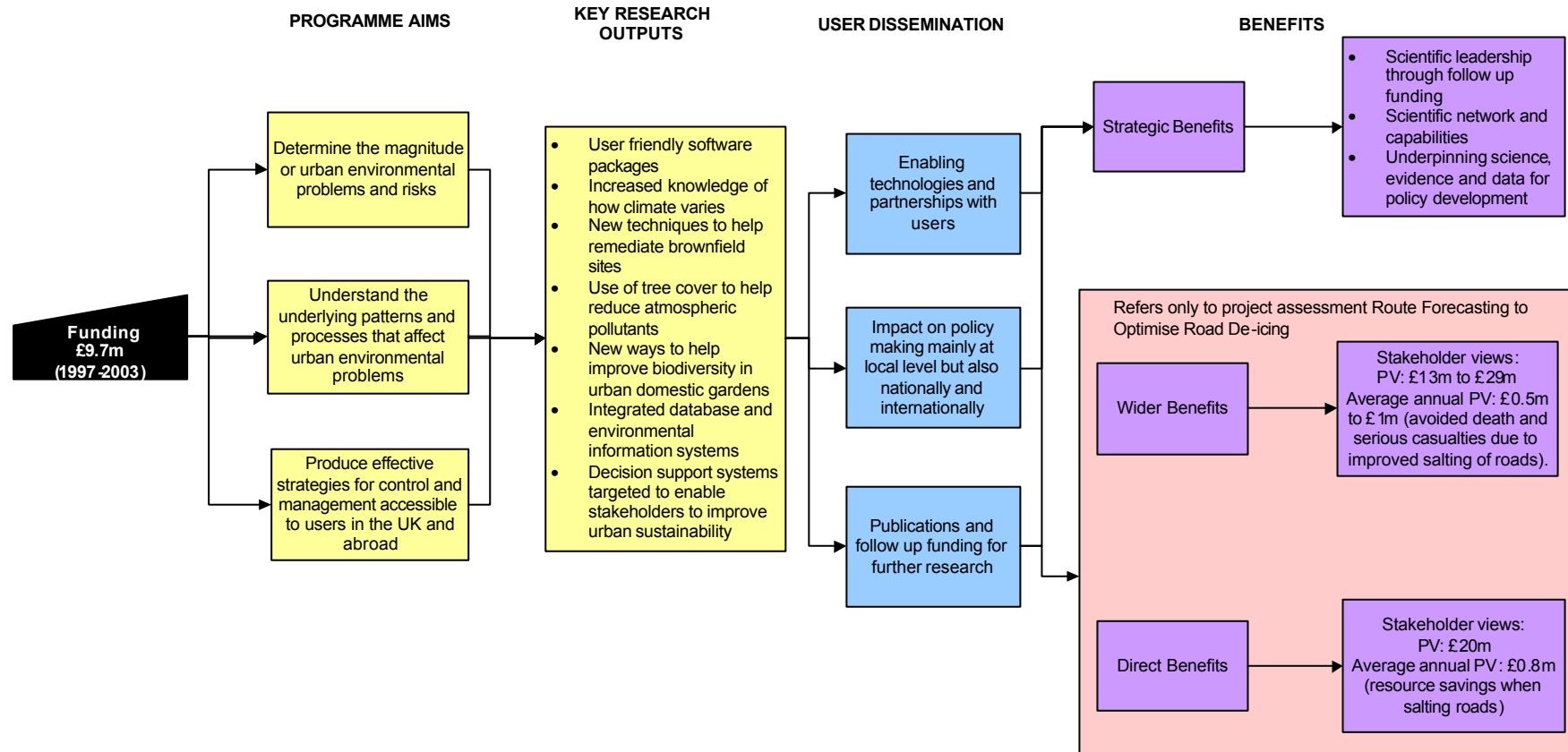
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<sup>72</sup> Loomis, Kent, Strange, Fausch, Covich (2000), Measuring the total economic value of restoring ecosystem services in an impaired river basin: result from a contingent valuation survey

<sup>73</sup> S. Georgiou, I. Bateman, M. Cole and D. Hadley (2000) Contingent Ranking and valuation of river water quality improvements: testing for scope sensitivity, ordering and distance decay effects", CSERGE Working paper

<sup>74</sup> Scenario 1 – small improvements arising from improved water quality, these improvements will be the return of few species to the river and a few more plants, as well as the river becoming suitable for boating; Scenario 2 – medium improvements, with game fish species making the river suitable for fishing and boating. Number of insects living around the river would increase, attracting greater number of birds and wildlife. People would still not be able to paddle or swim in the river; Scenario 3 – large improvements with the water quality restored to what it was before the industrial revolution, trout and salmon living in the river, and the water would be good enough to paddle and swim in, as well as fishing and boating

# URGENT's Value Chain



## 9 CASE STUDY 5 – Marine and Freshwater Microbial Biodiversity

### 9.1 Case study description

#### Summary

The Marine and Freshwater Microbial Biodiversity (M&FMB) programme aimed to improve scientific knowledge of the biodiversity in the marine and freshwater environment, and to understand the nature and stability of these systems.

The Marine and Freshwater Microbial Biodiversity (M&FMB) Programme may have the potential to contribute to realise wider benefits to the UK Economy by helping to increase the market share of the UK in the marine biotechnology products market through a series of potential spin-offs that commercialise products in this market.

**Start date:** 2000    **End date:** 2005

#### Funding

£6.9 million and £250,000 follow-on funding provided for knowledge transfer activities (in 2004-06).

#### Background

In order to improve the scientific understanding of the Earth's systems as a whole, it is necessary to improve the knowledge of micro-organism biodiversity. Micro-organisms (microbes, including bacteria, archaea, viruses, protozoa and phytoplankton) are the driving force behind global biogeochemical cycles and aquatic microbes have a major influence on the composition of the ocean, freshwater environments and atmosphere. However, the taxonomy of many microbes, if not most, remains undescribed. There is therefore a need to improve our knowledge of this biodiversity and understand the nature and stability of these systems.

Efforts to characterise the biodiversity in the oceans have traditionally relied upon morphology and biochemical methods. However, these techniques can be inappropriate and impractical. A technological revolution in genomics has provided the scientific community with techniques such as gene probing, which have enabled a much more rapid means of identifying new organisms.

In order that maximum advantage is taken of these new techniques and the growing interest in using microbes for biotechnological applications, a co-ordinated programme was required to take forward the basic and blue skies science that was being done in that field. The reasoning behind having a combined marine and freshwater programme was that it brought together expertise in aquatic microbiology in a way that has not previously been achieved.

## Objectives

The objectives of the M&FMB research programme<sup>75</sup> have been to:

- improve descriptions of marine and freshwater microbes and better understand their community interactions, through the use of new molecular techniques
- relate phylogenetic diversity of microbes to physiological diversity, ecological function and biogeochemical processes
- develop methods for the isolation and growth of those microbes that have not been amenable to traditional culture methods
- understand the phenotypes of microbes and, through understanding gene expression, identify potential applications of novel enzyme systems and proteins in biodegradation, biocatalysis and the biomedical sector
- improve the theoretical understanding of aquatic ecosystem structure and dynamics, evolution of microbes, and the relationship between microbial biodiversity and ecosystem function.

## Key research outputs

The programme has succeeded in fostering a research community in this field, bringing in new researchers and providing leverage for international collaboration. It has greatly enhanced the national capability for research on marine microbiology and molecular biology.

Despite the programme being primarily a research activity and not a government advisory service, it has managed to foster good links with several government departments, especially the DTI. Links with business have also been developed.

The programme has had an immediate impact and will continue to have an impact over the next 25 years and beyond. In the near term, it has had a tangible impact in supporting scientists to bring their applications nearer to market. In the long-term, stakeholders were keen to stress the real potential of exciting new avenues for exploitation that the programme has opened up.

The main outputs of this programme have been in the form of scientific and technological discoveries, which have helped provide responses to the objectives listed above. Examples of particularly interesting discoveries include:

- the ability of settling seaweed spores to 'eavesdrop' on bacterial cell signalling activity
- that viruses infecting photosynthetic bacteria (cyanobacteria) can themselves carry genes for photosynthesis
- insights into microbial community structure and geochemical cycles.

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<sup>75</sup> Marine and Freshwater Microbial Diversity Science Plan:  
<http://www.nerc.ac.uk/research/programmes/mfmb/documents/MFMBsciplan.pdf>

## Dissemination and users

All those who received M&FMB funding published scientific papers, some projects generated 1 or 2 papers, whilst others produced 20-30. The outcomes of the projects were presented at the finale events held in Edinburgh and London in 2005, primarily intended for non-specialists. A series of 8 non-scientific leaflets summarising the work and achievements of the programme are available on the M&FMB website<sup>76</sup>.

Even though science projects within the programme have finished, further funding (£250k) was supplied to support [BlueMicrobe](#), the knowledge transfer network which grew out of the programme, available on the web. It aims to communicate with those in the public and private sector with an interest in research, development and commercial exploitation of aquatic microbiology and marine biotechnology. A portfolio of 6-8 targeted applied R&D projects, is being developed, drawing in collaborators from a broader applied research community than is currently supported under the M&FMB programme. BlueMicrobe activities include a professionally produced DVD of 25 minutes, for release in spring 2006, to present information on the importance of marine microbial biodiversity to research users and other non-specialists.

## 9.2 Methodology

Key stakeholders (eight from the scientific community and five end user stakeholders) were interviewed to understand their informed opinion of the economic impact of the M&FMB research.

## 9.3 Findings

### 9.3.1 Strategic and policy benefits

#### ***Network and knowledge development***

Stakeholders identified that the M&FMB programme was instrumental in:

- bringing together a disparate marine and freshwater microbiology community
- building a critical mass to support a knowledge sharing network
- carrying out world leading knowledge generation
- contributing to developing the UK marine biotechnology industry.

According to stakeholders, the BlueMicrobe knowledge transfer network has assisted in the development of a new DTI-funded knowledge transfer network, Bioscience for Business. This includes partnership activities based on the exploitation of techniques, reagents and organisms relating to marine microbial biodiversity, alongside plant-based activities of the National Non-Food Crop Centre and biocatalysis work initiated by the Pro-Bio Faraday Partnership.

#### ***Scientific research addressing market failure***

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<sup>76</sup> <http://www.nerc.ac.uk/research/programmes/mfmb/>

The programme revealed the wealth of aquatic microbial biodiversity, particularly in the marine environment and built scientific knowledge in this field. Indeed, the market failure caused by the cost of exploration in the marine environment versus the risk of achieving proportionate return in a commensurate timescale meant that until the M&FMB programme, most UK bio-prospecting for biotech applications occurred on land not the sea. Stakeholders felt that without the programme, the deep sea would not be seen as a resource for bio-prospecting. Continuing market failure in this field reinforces the need for NERC to be doing the basic research that is not taken up by industry, in this programme area and elsewhere.

The programme is seen as particularly valuable to the development of future antibiotics, because the programme demonstrated the wealth of actinomycetes in the deep oceans, a group of microbes, which has been used as a source of antibiotics previously.

### ***Long-term outcomes and benefits for UK plc***

Stakeholders felt that the programme had shown the huge potential for UK competitiveness, harnessing and encouraging innovation and adding value, and that this potential is likely to be realised over next 25 years and beyond. Stakeholders thought it certain that over the next 25 years, there will be successful applications reaching the market, for example, in the field of pharmaceuticals, skin care products and anti-fouling. This was believed whether or not the research or current potential applications supported by the programme are taken to market. Stakeholders judged that this would occur for three reasons, firstly because the programme has raised awareness and interest in the wider research community and industry (e.g. pharmaceuticals) of the potential for biotechnological applications derived from marine resources. Continuing work to engage potential users and collaborators, and the BlueMicrobe website will further cement this achievement. Secondly, the UK is locationally well placed to exploit the marine environment and thirdly because the UK has now become a world leader in the M&FMB areas of research.

The programme has not had a direct impact on policy, but it has fostered good relations with the Department of Trade and Industry (DTI) in particular. DTI felt that certain programme findings were important and relevant enough for it to justify broadening the scope of its Technology Programme R&D call for proposals in the field of regenerative medicine to encompass marine research. This outcome is key to opening up further financial support for basic and applied research in the marine environment.

## **9.3.2 Wider and direct benefits**

### **9.3.2.1 Wider benefits**

According to stakeholders, M&FMB financial support to the scientific marine community has enabled the exploration and development of potential applications derived from marine resources, and to create technology spin-offs, spin-out companies and commercial opportunities. Recipients of M&FMB funding who were interviewed felt that the funding had been critical to developing their ideas. It has also generated significant interest amongst new companies looking to commercialise marine-based products and processes.

The programme supported many areas of research from basic to applied research, some of which explored using marine microbes for biotechnological applications. The more promising applications developed through the programme are closer to market than others, however,

none of those involved in application development could be 100% certain that it would reach market. However, most stakeholders seem to believe that over the next 25 years, the M&FMB programme would help generate applications that have a high probability of reaching the marine products market.

A further reason as to why it is possible to expect marketable applications is due to the development of a new screening methodology of newly-isolated strains of microbes, developed through one of the M&FMB projects. This screening method has achieved a ten-fold increase in success rate in finding microbes with useful secondary products, for example, chemicals that inhibit folic acid synthesis (hence as a potential antibiotic) or industrially-useful enzymes. This methodology will also generate efficiency savings.

In order to illustrate the potential economic impact that the programme could have over the next 25 years, it has been suggested to show the potential financial/economic value of the programme through assuming that three potential applications might get to market, any of which by themselves would overcome the initial NERC investment in the M&FMB programme. These examples have been included below.

Additionally, by using third party sources it has been gathered that the marine biotechnology products and processes market was valued at \$3.7 billion, with a projected growth of around 9% per annum<sup>77</sup>. However, this only includes products of marine origin and processed raw materials, and does not include the output of new biotechnology. A study for the *Foresight Marine Panel*<sup>78</sup> estimated that the contribution of the UK's marine biotechnology activities to global trade will eventually be between £2.2 billion and £2.8 billion<sup>79</sup>, based on two requirements; this will only be achieved if there is development of value-added products and sufficient financial support is provided to succeed in exploiting it.

As an illustrative example, using some of the assumptions presented above:

- size of the market being £3.7 billion in 2006
- market growing at 9% in the first year but then having a decreasing growth rate until becoming nil by 2030

If the UK were to gain a 1-5% share of this market in 5, 10 or 25 years, it would create economic benefits that have been summarised in the table below.

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<sup>77</sup> Business Communications Company 2003 <http://www.bccresearch.com>

<sup>78</sup> 'A Study into the Prospects for Marine Biotechnology Development in the United Kingdom', by LPM Lloyd-Evans at BioBridge Ltd, for the *Foresight Marine Panel*

<sup>79</sup> UK Marine Industries World Export Market Potential October 2000, D Westwood for the *Foresight Marine Panel* 2000

Year when the UK would get a market share in the range of 1-5%	Present value range	Average annual present value
2011	£482m to £2,408m	£19m to £96m
2021	£224m to £1,122m	£9m to £44m
2030	£57m to £290m	£2m to £11m

The two examples included below were suggested by stakeholders on the way in which this programme may be able to create wider economic benefits. Information on another example (a sunscreen) is likely to be available next year.

#### Example 1: Antibiotics and drugs

Professor Alan Bull<sup>80</sup> (with colleagues at Newcastle, and in Germany and Japan) has been developing a chemically-unique antibiotic, abyssomicin C, which was found in an actinomycete recovered from the marine environment. Abyssomicin C has demonstrated the capacity to inhibit methicillin-resistant *Staphylococcus aureus* (MRSA) and also vancomycin-resistant *S. aureus*. Furthermore, because of its mode of action, abyssomicin C may have potential as an anti-malarial and/or other parasite drug.

Since 1998, only 10 new antibiotics have been approved, and in 2005 out of 506 drugs in development, only 5 were new antibiotics<sup>81</sup>. Partly this is due to the poor hit rate of the combinatorial chemistry approach used to create new antibiotics by pharmaceutical companies. Another reason for this lack is due to the long development times required to take antibiotics to market, and the low returns on investments when compared with drugs for chronic conditions.

The lack of new antibiotics is a problem because of the growth of antibacterial resistance, especially in hospital-acquired infections, including methicillin-resistant strains of *S. aureus*, MRSA. In 2002 in the UK, MRSA was mentioned on the death certificates of 0.12% of all deaths in NHS general hospitals and for 0.07% of all deaths, and MRSA mortality rates increased over 15-fold during the period 1993 to 2002<sup>82</sup>. In 2003, MRSA was the underlying cause on 321 death certificates, up from 15 in 1993<sup>83</sup>. People who are infected with drug-resistant infections but do not die as a result are also more likely to have longer stays in hospital and need further treatment with other, possibly more expensive antibiotics. One study has shown that the median hospital stay attributable to bacterial infection was four days, compared with 12 days for MRSA, and the overall cost was \$9,661 and \$27,083 respectively<sup>84</sup>. And the numbers of infections and increasing drug resistance are increasing<sup>85</sup>, possibly set to double over the next 4 years<sup>86</sup>.

However, new antibiotics have been launched in 2005. New antibiotics (those introduced since 2000) are making a large impact on the total antibiotic market, moving from a market share of 3.9% in 2003 to a projected share of 20%

<sup>80</sup> Professor Alan Bull is Emeritus Professor of Microbial Technology at the University of Kent

<sup>81</sup> Infectious Diseases Society of America:

<http://www.idsociety.org/Template.cfm?Section=Vaccines&CONTENTID=10303&TEMPLATE=/ContentManagement/ContentDisplay.cfm>

<sup>82</sup> [http://www.statistics.gov.uk/downloads/theme\\_health/HSQ21.pdf](http://www.statistics.gov.uk/downloads/theme_health/HSQ21.pdf)

<sup>83</sup> <http://www.statistics.gov.uk/StatBase/ssdataset.asp?vink=8870&Pos=1&ColRank=1&Rank=240>

<sup>84</sup> Abramson M, Sexton DJ. Nosocomial methicillin-resistant and methicillin-susceptible *Staphylococcus aureus* primary bacteraemia: At what costs? *Infect Control Hosp Epidemiol* 1999; **20**: 408-411

<sup>85</sup> <http://www.prodigy.nhs.uk/clinicalguidance/releasedguidance/webBrowser/pils/PL707.htm>

<sup>86</sup> <http://news.bbc.co.uk/1/hi/health/3818277.stm>

by 2008. This equates to a value of \$6.2B in 2008. Growth to 2009 is expected to be flat as a result of markets adjusting to patent expiries<sup>87</sup>.

Abyssomicin C is being taken forward by Actinomix Ltd, a spin out company established in Newcastle by Alan Bull and his colleagues to identify commercial applications of scientific discoveries of novel products from actinomycetes. Taking Abyssomicin C to market would require very significant investment and take several years. Alan Bull was not able to say what the likelihood of Abyssomicin C getting to market is, but he felt that the future opportunities for success are great due to the methodology that has been developed, which combined with an intelligent sourcing of microbes from the marine environment, has increased the hit rate for finding microbes with commercial applications.

Cost of M&FMB funding: £293,400

#### **Example 2: Anti-biofouling application**

Dr Ian Joint's research<sup>88</sup> has involved the study of marine derived compounds which prevent biofouling – the growth of marine organisms on surfaces such as ships' hulls. The eventual outputs of his research would be put into a matrix to form an anti-fouling paint. However, his research could also have applications for use in the contact lens market. In this example, the focus will be on the potential anti-fouling application, which could be used by the shipping and oil industry, as well as other marine industries to prevent biofouling. The cost of the growth of marine organisms on shipping and other marine industries is \$6.5 billion annually<sup>89</sup> and this does not account for the externalised environmental and health costs. For example, the growth of organisms on a ship's hull increases its drag, decreases manoeuvrability, increases fuel consumption, and hence increases emissions of greenhouse gases. Cleaning ships' hulls also requires the use of chemicals which themselves have environmental and health impacts<sup>90</sup>.

The choice and availability of biocides for use as antifoulants will become much more restrictive within Europe with the application of the Biocides Products Directive and there is a desire for more sustainable alternatives<sup>91</sup>, which is what PML would be looking to offer.

One stakeholder suggested that if the application could get to market it would take about ten years, but that it could be worth several million pounds annually in the UK alone and several hundred million pounds annually. This seems credible as the report for the *Foresight* Marine Panel also indicates that the industrial sector, which includes anti-fouling materials, has the potential to be worth £2.0 billion annually. Due to the commercial sensitivity of the research it was not possible to calculate the economic impact of the research.

Cost of M&FMB funding: £275,700 plus £30,500

#### **9.3.2.2 Efficiency savings**

According to stakeholders, due to improved search and discovery technologies developed, the success rate of finding microbes with pharmaceutical properties can be increased significantly.

Furthermore, other technologies will increase the efficiency at which drug companies could identify and develop new drugs.

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<sup>87</sup> <http://www.bccresearch.com/editors/RB-202.html>

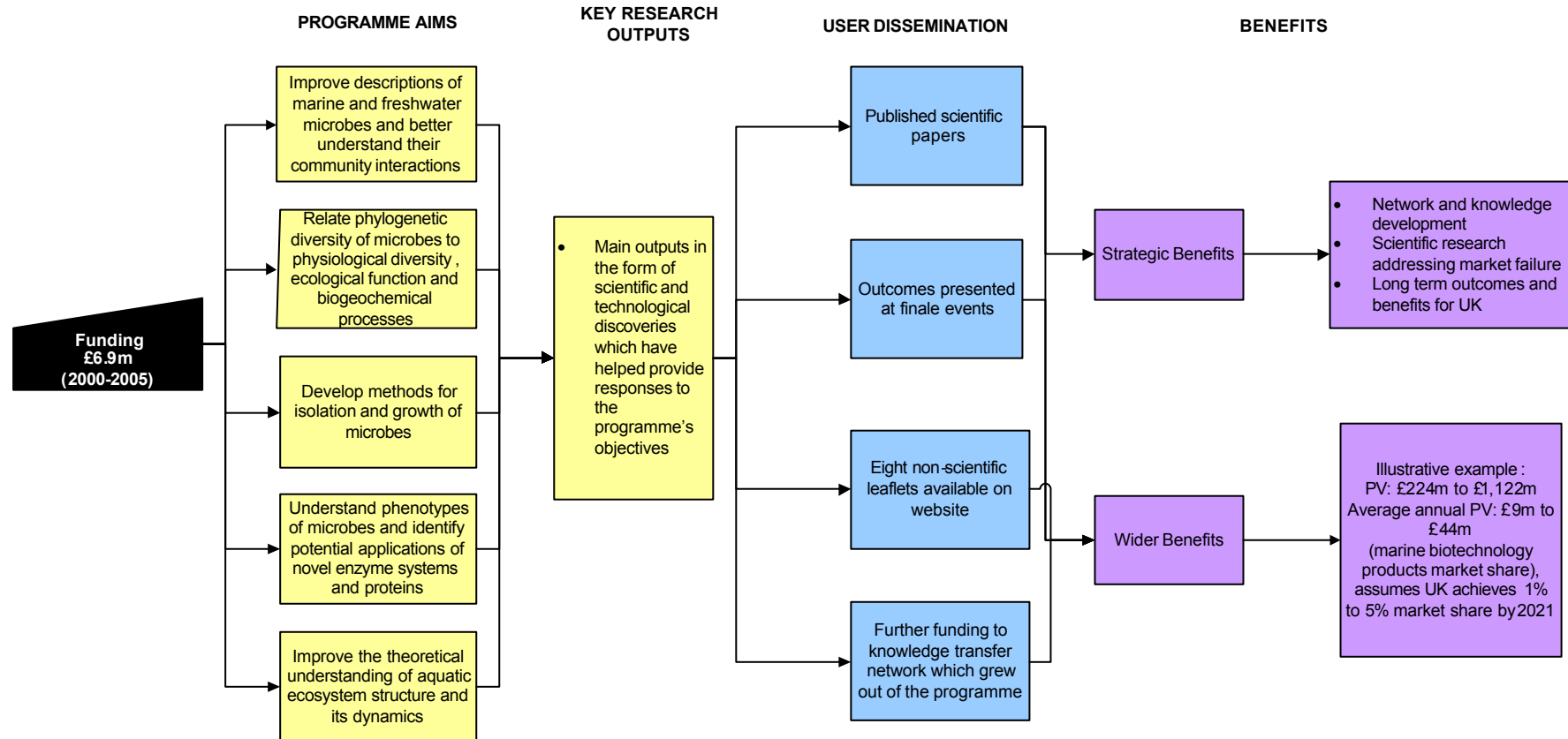
<sup>88</sup> Dr Ian Joint is a microbiologist at Plymouth Marine Laboratory

<sup>89</sup> [http://www.arc.gov.au/pdf/hr\\_scsi\\_arcsubmission.pdf](http://www.arc.gov.au/pdf/hr_scsi_arcsubmission.pdf) p.20

<sup>90</sup> <http://www.csa.com/discoveryguides/biofoul/overview.php#n4>

<sup>91</sup> [http://www.crabproject.com/files/CRAB\\_Flyer.pdf](http://www.crabproject.com/files/CRAB_Flyer.pdf)

# M&FMB's Value Chain



## 10 CASE STUDY 6 – Environment and Human Health

### 10.1 Case study description

#### Summary

The Environment and Human Health (EHH) research programme funded by NERC and other partner organisations aims to answer the overarching question on how do we manage the natural and built environment to improve human health.

The programme is expected to focus on four key research areas, pollutants, pathogens, pathways and people.

While the programme is still on its initial stages of development, it is expected that its multidisciplinary research approach will deliver unique research outcomes to a cross range of stakeholders and help address key questions in regard to identifying what elements should be central to future research in this area.

**Anticipated start date:** 2006

**End date:** not yet defined

#### Funding

The planned funding for this programme is £2.4 million (which will be uplifted for the impact of dual support reform) allocated by NERC. The Department for Environment, Food and Rural Affairs and the Environment Agency are collaborating in the programme through a 'single pot' mechanism, contributing sums of up to £500k and £250k.

Additionally, some other funders are unable to contribute to a 'single pot' for procedural, policy or financial reasons but have demonstrated interest to be involved in a joint programme. The Engineering and Physical Sciences Research Council (EPSRC), Biotechnology and Biological Sciences Research Council (BBSRC) and Medical Research Council (MRC) are interested in co-funding on a case-by-base basis, up to a maximum of £250k (EPSRC and BBSRC) and £200K (MRC). The Wellcome Trust will fund individual proposals up to £50K with no overall limit on the number of proposals. ESRC is co-funding early career fellowships with NERC and is working to identify resources for 'case-by-case' funding.

#### Background

Environment and human health issues are a high priority in UK and international circles; this is recognised by forums such as the Environment Research Funders' Forum (ERFF), the EU, the World Health Organisation and International Year of Planet Earth 2006 (Earth & Health theme)<sup>92</sup>. A consultation process carried out by NERC has also led the Research Council to

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<sup>92</sup> In June 2004 the Commission launched an Environment and Health Action Plan, covering the period of 2004-2010. It served as the Commission's contribution to the Fourth Ministerial Conference on Environment and Health, organised by the WHO in Budapest in June 2004 - [http://europa.eu.int/comm/environment/health/index\\_en.htm](http://europa.eu.int/comm/environment/health/index_en.htm)

conclude that the best way for this research to be carried out is through researchers working together across disciplines.

There are a number of gaps in the understanding of the link between environmental conditions and their impact in human health. Among others, these gaps include issues such as the implications of the persistence of pathogens, the role environmental conditions are likely to play in transmitting emerging diseases, and the vulnerability of different population groups to climate change. Currently, no clear impact assessments exist to establish what the consequences will be of a progressive increase in temperatures, or how climate change will affect the distribution of vector borne diseases among others, or the relation between presence in the air of particles smaller than 10  $\mu\text{m}$  in diameter ( $\text{PM}_{10}$ ) and respiratory problems. A programme was therefore designed that would comprehensively research into and fill in these gaps.

Organisations such as the Department of Health and the Environment Agency are tackling this issue through different research programmes, but despite that there is a need for a multidisciplinary research programme to be put in place which can look at the impact of the environment on human health from an integrated perspective. There is a need to enhance the links between the various communities involved (i.e. physical, environmental, medical and socio-economic scientists) to be able to address these pressing issues satisfactorily.

### **Objectives**

The programme aims to grow a multi-disciplinary research community that can address complex health problems globally, and answer the over-arching question of the programme:

- How do we manage the natural and built environment to improve human health?

In order to identify key research priorities a stakeholder consultation process was held. This resulted in the identification of four broad areas<sup>93</sup>.

#### Pathogens

- Global Environmental Change and Vector/Parasite range abundance; changes in microbial communities (e.g. evolution of antibiotic resistance).
- Quantifying the survival and persistence of pathogens in the environment, particularly in the absence of disease.
- Emerging diseases and novel vectors.
- Advancing knowledge of vector ecology using post-genomic techniques.

#### Pollutants

- What are the active features of particles that cause problems (e.g. surface properties, size and composition)?
- Effects of interactions of mixtures of chemicals in the environment; potential for synergistic effects; effects of exposure to chemical cocktails and improved analytical methods.
- Chronic low-level exposure to toxins, including intergenerational effects – what are the long-term effects of pollutants?
- Assessment of toxicology and exposure (including nano-particles).

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<sup>93</sup> From Report of the NERC Web Consultation on Environment and Human Health and the Environment and Human Health workshop (14-15<sup>th</sup> Dec 2004); Wellcome Trust Conference Centre, Hinxton

### Pathways

- What are the transfer mechanisms of substances (pathogens, pollutants, natural substances) from the environment into the body and what are their toxicity and function in the body?

### People

- Role of factors such as socio-economic status, age, gender, disability, illness and the implications for resilience, adaptive capacity, shaping behaviours and managing environmental health risks
- How are major global trends, for example, in trade, urbanisation and population change, impacting on environment-health interactions?
- Impact of differing perceptions of risk and attitudes and enhancing public engagement and dialogue about environment and health issues - what are the economic and social costs and benefits of environmental impacts on health?

Importantly, in order to tackle these research priorities, a key aim is going to be to facilitate collaborations between scientists that have not traditionally worked closely together. Both members of the scientific community as well as policy makers, and other stakeholders will continue to collaborate in defining the focus of the programme.

### **Key research outputs**

The anticipated result of the programme will be to:

- create a constituency for inter- and multi-disciplinary work that will underpin the understanding of the links between the environment and human health
- provide better knowledge that will improve scientists' ability to identify and predict emerging issues of potential concern
- improve the evidence base for risk assessment and regulation of activities needed by government departments and agencies, and other stakeholders.

### **Dissemination and users**

The programme will set up a Programme Management Group (PMG) and a Science Advisory Committee (SAC). The PMG will be responsible for the funding decisions and the overall strategy of the programme; the SAC will define the scientific scope of the programme, draft the Announcement of Opportunity (AO) and advise the PMG on how to engage with their communities. In the first phase of the programme, it is envisaged that investment is made in such capacity building activities as networks, exchange programmes, small proof of concept studies, 'discipline hopping', career development awards for young scientists, studentships and/or fellowships. Researchers at a number of levels (e.g. PhD, post-doctoral fellows and senior scientists) would be targeted in order to develop the right kind of skills (such as multi-disciplinary training) in order to advance this programme.

Users of the research will include policy makers at many different levels, from the EU to local councils. If effective policy is put in place, the general public as a whole will benefit as the pollutants and pathogens affect the health of everyone.

The research from the Environment and Human Health programme will help identify the clear link between the environment and human health. In addition to the pure scientific interest of this knowledge, such research will also be of use to policy makers.

For example, if the research enabled the identification of the spreading mechanisms emerging diseases follow, in a time with increased travel and population mobility, the impact of this research could contribute to provide valuable insights into disease control mechanisms and setting adequate priorities with regards to policy.

## 10.2 Methodology

Key stakeholders (two scientific community and three end users) were consulted in order to understand the potential economic impact of the Environment and Human Health Research Programme.

## 10.3 Findings

### 10.3.1 Strategic and policy benefits

At this early stage of the EHH programme, the foreseen outcomes of the programme are mainly at the strategic and political levels. Stakeholders agree about the large potential impact that such a programme will have in refining the focus for research in this area and in creating a multidisciplinary environment and health network. It is envisaged that both these outcomes would lead to policy makers being able to make better informed policy decisions and to a recognition of the UK as a leading research centre on environment and health issues.

The stakeholders that were consulted anticipated that the research could potentially deliver the following strategic and policy outcomes.

#### **Research focus**

The EHH programme is expected to help improve the science base in the UK for studying the connection between the environment and human health. Although in certain areas, such as air quality, direct links can be made between environmental issues (e.g. exposure to particles) and morbidity/mortality rates, there are important knowledge gaps that need to be addressed (e.g. which particles are directly responsible for mortality rates) to support better policy making. Given the breadth, complexity and multidisciplinary nature of the research questions that scientists face in the area of environment and human health, it is expected that for each research question several further avenues of further research will arise. Following research in each possible area would require an immense level of funding. It is therefore expected that one of the major contributions of the EHH programme will have to be in relation to identifying which research avenue will be the most appropriate to follow.

The EHH programme aims to provide an opportunity to a multidisciplinary team of scientists to better understand and define the key research questions that need to be answered in the area. This is expected to enable tailored outcomes to be generated in those areas of particular relevance, increasing the policy benefits associated with investing in this research.

In the absence of this research programme, there were concerns that the progress of research in this area would be slower and there would be reduced confidence in the quality of the results. There are other research councils which could fund research in this area (to try and fill the knowledge gaps on an ad hoc basis) but the advantage of the NERC and partner organisation funding and NERC co-ordination is that it contributes to a more directed and coherent research programme.

### ***Developing a multidisciplinary scientific network***

As our environment evolves due to natural and man-made activities, the links between the environment and human health also change. Stakeholders judged that a strong scientific network on which this continuous research will be based is important in the continued evaluation of the effects of the environment on health.

Stakeholders anticipated that the EHH programme, funded by NERC and others, will provide a unique opportunity for different members of the scientific community (e.g. environmental scientists and medical scientists) to collaborate in developing world-class science.

Stakeholders judged that the EHH programme will be key in bringing science closer to policy makers ensuring that the outcomes and knowledge generated by the programme will be translated into policy. According to stakeholders the NERC 'Science into Policy' publication demonstrates how this type of scientific network brings together scientific and policy makers' communities. Other examples, which support this assumption, are the results achieved by the 'Scientific Knowledge for Environmental Protection' programme at the EU level, which supports knowledge transfer and research coordination.

According to stakeholders, the potential benefits of knowledge transfer within the EHH programme should be capitalised by ensuring this activity area is fully embedded within the programme.

### ***Better informed policy decisions***

The EHH programme is believed by stakeholders to be of high importance in maximising the scientific benefits of investment in research. At the moment there is a need for good science to underpin answers to a set of questions around how environment affects health. Depending on the topics the programme chooses to focus on, the research could have a significant impact on government policy. A better understanding of the risks on human health associated with environmental changes will provide better information to policy makers, allowing for further research to be carried on those areas where the impact is larger.

The EHH programme could increase the efficiency of environmental and health policy making and implementation both in the UK and internationally. According to stakeholders, this research can have considerable economic benefits such as in the form of savings on policy controls. For example, if through the EHH scientists are able to isolate which specific particle might be responsible for an ailment, then the necessary controls can be better focused on the relevant material, with an associated reduction on costs.

The EHH programme would have wider benefits on actors such as the Environment Agency and the Department of Health already working on, and concerned with, the impact of the environment on human health. For the Environment Agency, the EHH programme would help

clarify what areas it should focus on in terms of regulation to improve health outcomes, for example in tackling air pollution.

### ***UK scientific leadership***

As mentioned before, the study of the impact of the environment on human health has been receiving international attention from organisations such as the World Health Organisation, as well as the media.<sup>94</sup> A fully comprehensive and multidisciplinary programme such as the EHH programme will demonstrate the UK's position at the forefront of this research, contributing positively to our reputation as a centre of excellence in this area.

Examples of the increasing importance Environment and Human Health is acquiring at the international level are represented by bodies such as the National Institute for Environment and Health Sciences (NIEHS), which receives research funding from the US Government of US\$600m. At the European level, the European Environment Agency has recently published a report on Environment and Health.

The ways in which the environment affects health are manifold, issues such as water safety and its potential to carry endocrine disruptors are still widely unexplored. While much literature exists in relation to human health and climate change, and links are increasingly being identified, research is still in its early days. The implications of socio-economic issues such as genetic constitution, age, nutrition and lifestyle, poverty and level of education also need to be considered within the environment and human health area. If NERC's EHH programme is able to contribute to advancing understanding in these areas it would make a considerable positive contribution to the reputation of the UK's environmental research community.

### **10.3.2 Wider and direct benefits**

Given that the Environment and Human Health programme is developing its research focus, it has not been possible for stakeholders to identify the potential specific wider and direct contributions that the programme is expected to provide to the UK economy.

Nevertheless, by developing collaborative networks and institutional capacity and by helping to supply evidence for policy making, some of the economic benefit areas where the EHH may make a difference include the potential to avoid costs to the economy of human health problems caused particularly by pathogens, pollutants and more broadly by the environment where people live.

Pathogens and pollutants cause relevant costs on the UK economy. Some examples of the economic costs of environmental issues on health include:

- the Department of Health (1999)<sup>95</sup> suggests that the Willingness to Pay (WTP) to reduce air pollution mortality risks is from as low as £2,600 (for a loss of life expectancy of 1 month and a low quality of life) to £1.4 million (upper bound for longer life expectancies). Additionally the report suggests that the benefits of reducing air pollution related morbidity are made up of reductions in NHS costs,

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<sup>94</sup> "Feverish Analysis: Global warming may damage health and cause fatal disease. Perhaps", The Economist, November 5<sup>th</sup> 2005, p. 109

<sup>95</sup> DoH (1999) Economic Appraisal of the Health Effects of Air Pollution

private costs (e.g. travel to doctor or costs of aversive behaviour), lost output (e.g. if people are prevented from working) and welfare costs (e.g. reflecting the pain and discomfort of illness). In terms of NHS costs, the average cost for all ages for a respiratory hospital admission is around £1,400 but it can be up to £2,500 in the case of elderly people

- the 1998 report from the Committee on the Medical Effects of Air Pollutants (COMEAP) concluded that up to 24,000 deaths were 'brought forward' in the UK in 1995/1996 due to the short-term effects of air pollution<sup>96</sup>
- the National Asthma Campaign suggests that poor air quality is considered one of the triggers of respiratory illnesses such as asthma. Treatment for asthma alone costs the NHS an estimated £850 million a year<sup>97</sup>
- the Environment Agency report that the summer 2003 heatwave caused the poorest air quality for years, with the hottest days taking place in early August 2003<sup>98</sup>
- between August 4 and 13 2003, the UK Office for National Statistics reported an excess of 2,045 deaths above the 1998-2002 average at this time of the year
- Stedman (2003)<sup>99</sup> suggests that between 225 and 593 additional deaths were due to ozone, and 207 due to PM10
- in Europe, the 2003 heatwave was linked to 26,000 premature deaths and cost US\$13.5 billion.<sup>100</sup>

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<sup>96</sup> COMEAP (1998), *Quantification of the effects of air pollution on health* in the UK

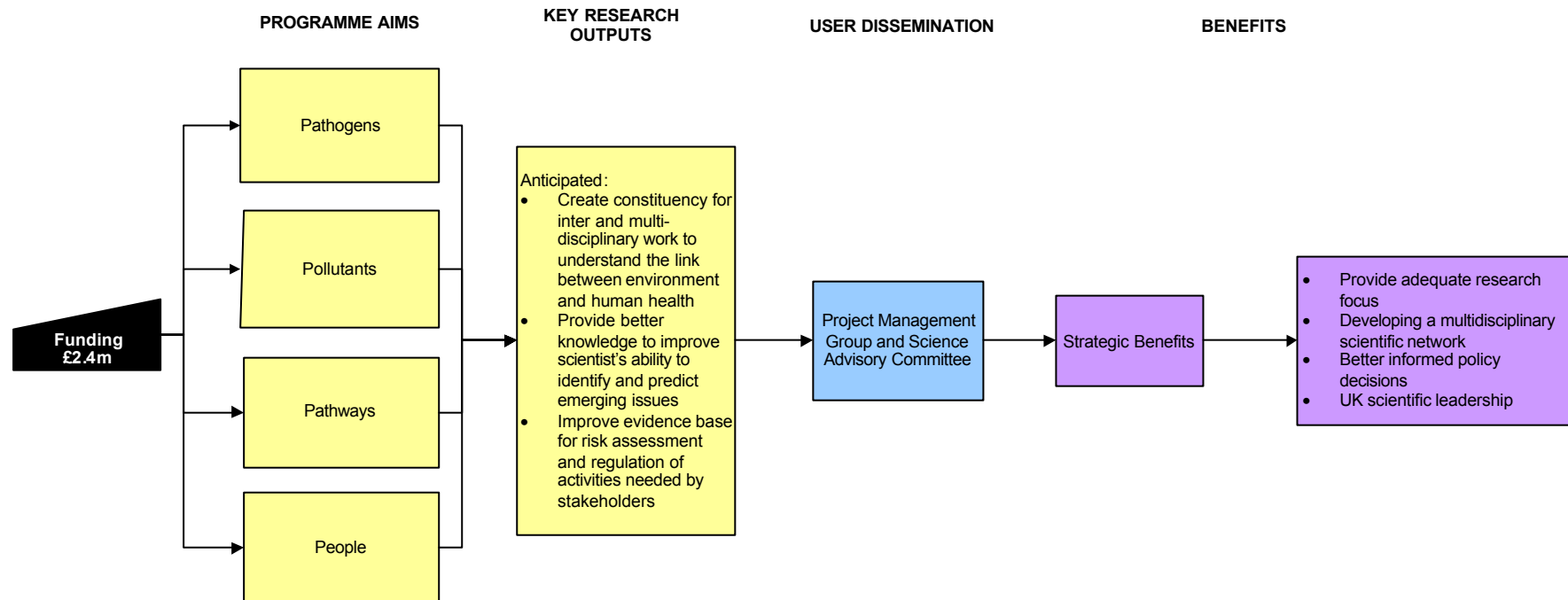
<sup>97</sup> National Asthma Campaign, *Asthma Audit 2001, Out in the Open A true picture of asthma in the United Kingdom today*, The Asthma Journal, September 2001, p. 11

<sup>98</sup> Environment Agency, *The Climate is Changing, Living in the Twenty-first century*, 2005, p. 20

<sup>99</sup> Stedman, J. , *The predicted number of air pollution related deaths in the UK during the August 2003 heatwave*. *Atmospheric Environment*, 38, p. 1087

<sup>100</sup><http://www.g8.gov.uk/servlet/Front?pagename=OpenMarket/Xcelerate/ShowPage&c=Page&cid=1098795669277>

# EHH's Value Chain



## 11 CASE STUDY 7 – Lowland Catchment Research

### 11.1 Case study description

#### Summary

The Lowland Catchment Research (LOCAR) programme funded by NERC is researching the on-going processes controlling the movement of groundwater and the factors affecting the interactions between surface water and ground water. LOCAR is providing new understanding of the processes by which land management affect the water quality and quantity of rivers. The outcomes of the LOCAR programme are expected to contribute extensively to the implementation of the Water Framework Directive in the UK.

**Start date:** 2000    **End date:** 2006

#### Funding

NERC has allocated £7.75 million to the Lowland Catchment Research (LOCAR) programme. A key component of LOCAR is to establish high quality field research facilities in contrasting permeable lowland catchments, the Frome/Piddle in Dorset, the Pang/Lambourn in Berkshire and the Tern in Shropshire, through a £5 million programme of equipment installation and maintenance. The funding of the infrastructure comes jointly from a £2 million Joint Infrastructure Fund (JIF) grant to a consortium of universities and institutes and from the £7.75 million allocated by NERC to the LOCAR programme. Almost 50% of this sum has been allocated for research grants and/or studentships, with the remainder being spent on purchasing, installing, operating and maintaining the catchment infrastructure outlined above, operating the data archive and project administration<sup>101</sup>.

#### Background

Lowland permeable catchments contain vital groundwater resources and important aquatic habitats at the groundwater/surface water interface that are becoming increasingly subject to increased demand for water, widespread and complex environmental pressures, and new regulations. The scientific understanding necessary to achieve environmental sustainability in lowland catchments is limited by a lack of catchment research facilities and an integrated science base.

#### Objectives

LOCAR focuses on researching the processes controlling the movement and quality of groundwater and the factors affecting the interactions between surface water and ground water in river corridors. Therefore LOCAR will help to understand the processes by which land management affects the water quality and quantity of rivers.

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<sup>101</sup> <http://www.nerc.ac.uk/research/programmes/locar/>

The major objective of LOCAR is to undertake detailed, interdisciplinary programmes of integrated hydro-ecological research relating to the input-storage-discharge cycle and in-stream, riparian and wetland habitats within groundwater dominated systems. An essential requirement for this is the use of high quality field research facilities in contrasting permeable lowland catchments.

### Key research outputs

The long-term deliverables from the programme are expected to be:

- improved characterisation of subsurface flow and transport processes
- improved knowledge of the impacts of land use and land use change
- better understanding of the hydrological controls on stream and wetland ecology
- new holistic methods to evaluate the impacts of natural and anthropogenic change on lowland catchment systems.

It is important to note that, as planned, by 2006 the LOCAR infrastructure will cease to receive support centrally from NERC. However, the Centre for Ecology and Hydrology (CEH), one of NERC's Research Centres, has agreed to take responsibility for the decommissioning of sites at the end of the programme. As part of this, some of the infrastructure will receive support, possibly in partnership with other interested organisations, and therefore be maintained.

Some research highlights from LOCAR to-date have been:

- **river valleys and climate change:** chalk streams are significant sources of the greenhouse gases CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O
- **river valleys as the kidneys of the environment:** the river valley floor and stream channel form a significant bioreactor, transforming the states of N and P supplied from the catchment, and helping to modify the flux of nutrients to major rivers and coastal zones
- **the nutrient time-bomb:** complex groundwater flows in the chalk mean that much of the mass of nutrients applied to fields in the past is still in the groundwater body and may take 15 years to reach stream channels. Changes in land use practices will not lead to river water quality improvements for more than a decade
- **making space for water and plant life:** by modifying channel hydraulics and trapping sediments, riparian and aquatic plants change habitats, contribute to biogeochemical processes and alter conditions for fish. Here, biodiversity, habitat and water quality issues are linked to channel maintenance for flood and fisheries management

### Dissemination and users

LOCAR outputs are expected to be integrated into models and maps, which are both being published and presented via stakeholder meetings with scientific peers and policy makers. Data has not yet been fully disseminated as the field-work/data collection is on-going and analysis is still progressing.

Policy makers, in government, in the regulatory body (the Environment Agency) and in the private sector (water utilities and consultants) are amongst the expected users of the LOCAR research both at national and local levels. Some water companies have already accessed parts of the data produced by LOCAR. Stakeholders have mentioned that data created by LOCAR could also be of use at an international level to provide evidence to support, particularly, the implementation of the WFD across Europe.

Additionally, the intensive groundwater monitoring LOCAR provides is unique within UNESCO's International Hydrological Programme – Hydrology for the Environment Life and Policy (HELP). LOCAR's study sites are well equipped for experimental hydrology and set high standards in meeting the science needs of water-land management and water policy development.

## 11.2 Methodology

Key stakeholders (three from the scientific community and two end users) were interviewed in order to understand their informed opinion of the economic impact of LOCAR.

## 11.3 Findings

The following findings are the result of stakeholder consultation and economic analysis.

### 11.3.1 Strategic and policy benefits

#### ***Policy making and implementation***

According to stakeholders, LOCAR will provide some of the fundamental background required for policy and decision-makers in the implementation of EU Directives, such as the Water Framework Directive (WFD), the Nitrate Directive and the Habitats Directive.

For instance, the WFD<sup>102</sup> introduces a radically different criterion for regulating water quality. Under the Directive water quality will be judged, not by its chemical composition, but rather by its ecological status. It will be the Environment Agency's role to oversee the management of river basins to meet this new criterion.

Stakeholders believe that, LOCAR has been timely in the development of thinking to support the Environment Agency to implement the WFD. Its research outputs will support the Environment Agency by:

- developing better the understanding of how river systems work and the integrated nature of land and water management
- providing the underpinning evidence for policy and technical guidance that is being developed by the Environment Agency over the next few years, in order to implement the WFD 'on the ground' in the UK.

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<sup>102</sup> The compliance date for the WFD is 2015 when monitoring will take place to see if there will be any changes as a result of the River Basin Plans which are being introduced in 2009

Additionally, stakeholders believe that LOCAR may help the water industry to save money by identifying the real causes of pollution in rivers as well as those responsible for bearing the costs. At the moment the water industry needs to invest in cleaning water that may be contaminated by agro-chemicals. Under the 'polluter pays' principal, farmers may need to pay a charge for their impact on water quality, rather than the customers of the water industry paying the price for 'end of pipe' treatment. The WFD will facilitate the allocation of costs to those responsible for pollution therefore understanding the sources of pollution and interaction between ground and surface water is crucial. The UK Government would also be able to make better policy decisions in terms of how to support the agriculture sector.

### ***Scientific networks, leadership and collaboration***

LOCAR is bringing together a range of environmental scientists and it has started promoting national and international collaborations. LOCAR has directly funded 15 PhD students who have acquired new skills in interdisciplinary research and will be able to meet some of the scientific needs of the EU Water Framework Directive.

The benefits of the research facilities established during the LOCAR programme are already being realised through the utilisation of the equipment by non-LOCAR funded students. Once the programme has ended key parts of this infrastructure are likely to be maintained to the benefit of the research community.

It is important to note that some stakeholders believe that the benefits arising from LOCAR will depend on the project observation installations being funded in full following the end of the programme. Their view is that data has been produced by these installations for about three years, which is a short period of time to form reliable conclusions for stakeholders such as the UK Water Industry Research (UKWIR).

## **11.3.2 Wider and direct benefits**

### **11.3.2.1 Direct benefits**

#### Potential areas of economic impact

Conversations with stakeholders imply that LOCAR will add value to users and beneficiaries by **helping to implement the EU Water Framework Directive (and potentially other directives) more efficiently.**

As was discussed in section 1.3.1, LOCAR is expected to provide policy implementers with observation data and research outputs that could facilitate policy implementation and monitoring. In the absence of LOCAR there could be a loss in the efficiency of implementing policy as similar research may have been organised in a different way and at a later stage, potentially in a more costly form and certainly in a less timely manner.

LOCAR does not achieve economic benefits by itself; it achieves direct economic benefits through supporting the efficiency of policy implementation. Therefore benefits of the implementation of the WFD should be allocated to policy implementation, but as research could help a cheaper implementation, efficiency savings could be allocated, to some extent, to LOCAR's contribution.

### Extent of impacts

Although some stakeholders have estimated the difference that LOCAR would make in terms of improved water quality and supporting the WFD implementation through to 2015, stakeholder evidence is conflicting, with some stakeholders suggesting LOCAR outputs will not be realised until after WFD implementation is complete.

The compliance date for the WFD is 2015, when monitoring will take place to see if there will be any changes as a result of the River Basin Plans. It has been evidenced by stakeholders that a limited amount of the outputs of LOCAR have been used by the Environment Agency to date and it usually takes up to five years for scientific knowledge to filter through into policy development. This suggests that benefits from LOCAR may arise only after 2015, in the second round of monitoring the implementation of the WFD.

Stakeholders do believe that at least by 2015 LOCAR will strongly support the implementation of the WFD (and other related policies); stakeholders have also noted that the contribution of LOCAR will depend on the following:

- the continued operation of the full research installations after the programme ends to gather more data that builds from LOCAR but increases the reliability of the observations made so far
- the usage of LOCAR research outputs by policy makers
- the scientific community brought together by LOCAR, including PhD students, having an ongoing contribution to improve policy implementation based upon knowledge gained through the programme.

### Projection of benefits

The economic benefits of the efficiency savings that could be allocated to LOCAR will not be modelled as stakeholders have not been able to define the extent to which LOCAR may help to reduce costs in implementing or monitoring the implementation of the WFD. However, presented in the rest of this section, as a matter of context setting, are the anticipated costs of monitoring and implementing the Water Framework Directive where LOCAR could potentially make a difference.

Costs of implementing the WFD in the UK (all figures in 2002 prices).

- The WFD Final Regulatory Impact Assessment<sup>103</sup> reports that the identifiable costs for monitoring, planning and implementing the Directive are of the order of £13 million per annum in England and Wales (equivalent annual value over the long term, at a 3.5% discount rate and in 2002 prices).

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<sup>103</sup> DEFRA (2003) Water Framework Directive Final Regulatory Impact Assessment. ([www.defra.gov.uk](http://www.defra.gov.uk))

- ERM (2003)<sup>104</sup> suggests that the monitoring and administration of implementing the WFD in Northern Ireland are estimated to be of the order of £2.4 million per annum in 2002 prices.
- Andrews (2002)<sup>105</sup> suggests that only administration costs of implementing the WFD in Scotland could be quantified and that they will be in the lines of £1 million per annum in 2002 prices.
- However, the data presented for the UK excludes costs for some elements of monitoring (groundwater, priority substances) and for river basin planning and consultation exercises and costs arising in organisations other than the Environment Agency. The Partial Regulatory Impact Assessment: Groundwater Proposals under Article 17 of the Water Framework Directive by DEFRA (2003)<sup>106</sup> concludes that additional costs in the lines of £2.3 million / year at 2002 prices will be needed to monitor (operational costs only) the implementation of Groundwater Proposals in the UK for a 100 year period.
- The WFD, including Groundwater proposals, could come to cost around £19 million / year [£13m + £2.4m + £1m + £2.3m]. This value brought to 2006 prices equals £20.6 million/year.
- It is expected that most of the capital and implementation expenditure will happen in the period between 2008 and 2012 when all the measures to comply with the WFD need to be in place. However, it is expected that monitoring expenses will increase during this period but will need to continue towards 2015 when objectives need to be achieved and beyond.
- It has been assumed that costs remain constant on a yearly basis throughout the assessment period but that benefits would be realised only after 2015 (year when the second round of monitoring may commence).

As a matter of illustration, given the above assumptions, a reduction of 1-5% on the costs of monitoring and implementing the WFD after 2015 would provide present value savings in the range of £2 million to £9 million, or an average present value in the range of £73K to £365K per annum.

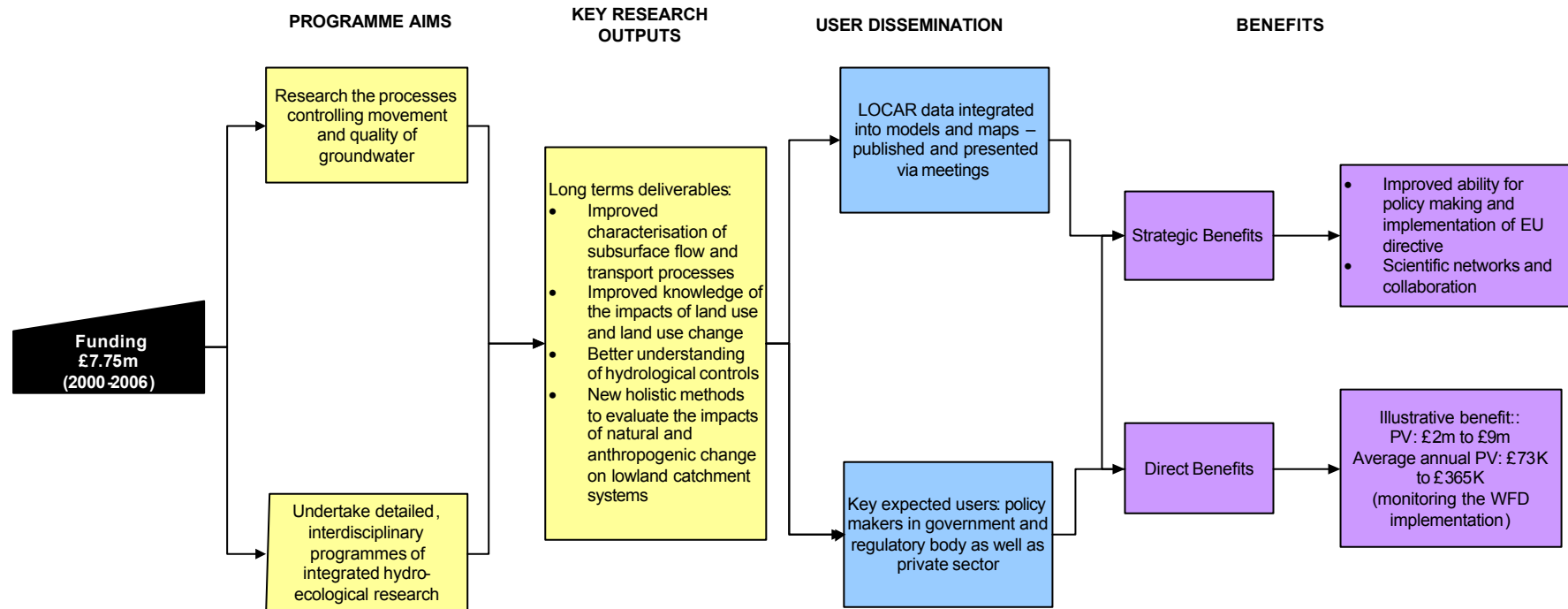
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<sup>104</sup> ERM (2003) Regulatory Impact Assessment Water Framework Directive 2000/60/EC Final.

<sup>105</sup> Andrews K. (2002) Costs and benefits of implementation of the EC Water Framework Directive (2000/60/EC) in Scotland

<sup>106</sup> DEFRA (2003b) Partial Regulatory Impact Assessment: Groundwater Proposals under Article 17 of the Water Framework Directive

# LOCAR's Value Chain



## 12 CASE STUDY 8 – The Flood Estimation Handbook

### 12.1 Case study description

#### Summary

The Flood Estimation Handbook (FEH) drew on the Flood Studies Report originally funded by NERC. The FEH aimed at providing improved methods to estimate flood frequency. The FEH also provided methods for assessing the rarity of notable rainfalls or floods, which are of interest to insurers and others. The techniques for estimating flood frequency contained in the handbook also included computer software and extensive data sets to help apply the new procedures. The main benefits of this research have been in the areas of risk management and policy implementation.

**Start date:** 1994    **End date:** 1999

#### Funding

NERC's contribution to the research came via the budget it provides to the Institute of Hydrology (now the Centre for Ecology and Hydrology). The Institute of Hydrology provided £100,000 in support of the research from this NERC allocated budget. This money would have gone towards administrative and infrastructure support. NERC also paid for the publishing of the report and the production of some of the supporting software.

The majority of the funding came from commissions funded by government departments and agencies, namely:

- MAFF (now DEFRA)
- Scottish Office (now Scottish Executive)
- Dept. Agriculture NI (now Dept. Agriculture and Rural Development NI)
- National Rivers Authority (which became the Environment Agency).

The commission totalled £1.89 million over 5 years.

The FEH draws heavily on the initial Flood Studies Report (FSR) of 1975, effectively modernising and updating the information in the original report. The original FSR was commissioned and entirely funded by NERC. Because the handbook is so dependent on the initial NERC funded FSR, it is necessary to consider this as a further contribution from NERC to the FEH.

The Meteorological Office and the River Gauging Authorities also provided other indirect support.

## Background

Flooding is a natural feature, which regularly brings disruption and damage to different parts of the UK. The impacts of floods can be enormous and range from waterlogged fields and blocked roads to widespread inundation of houses and commercial property and, occasionally, loss of life.

Flood frequency estimates are required for the planning and assessment of flood defences, and the design of other structures such as bridges, culverts, and reservoir spillways. There is an increased demand for accurate methods to estimate the flood frequency to avoid under or over estimation for flood scheme design. There is also an increasing demand for estimates that can form the base for flood risk maps, important in the planning of new developments.

## Objectives

The Flood Estimation Handbook (FEH) is a publication from the NERC Centre for Ecology and Hydrology (CEH), Wallingford. It addresses the issues mentioned above by providing flooding specialists with guidance on rainfall and river flood frequency estimation in the UK. The FEH also provides methods for assessing the rarity of notable rainfalls or floods, which are of interest to insurers and others. The techniques for estimating flood frequencies contained in the handbook are supported by computer software and extensive data sets to help users apply the new procedures.

The publication of the FEH was the culmination of a five-year research programme at CEH, Wallingford. The major objective of the research that culminated in the production of the FEH was to update the methods found in the Flood Studies Report (FSR) of 1975, for the estimation of flood peak flow for a defined return period.

Additionally to the FSR, the FEH includes:

- the use of new methods of pooling data from several sites to increase estimation accuracy
- the use of digital terrain data to physically characterise catchments in support of flood estimation at ungauged sites
- new ways of establishing uncertainty of storm and flood estimates
- revised procedures for better estimating rainfall and flood extremes.

The FEH also builds on the FSR by increasing the statistical reliability of the flood calculations being carried out. The FEH achieved this by not only using data collected from the location of interest but also from data from catchments with similar hydrological characteristics. Where the data monitoring for a river may go back 30 years, adding in data from similar catchment areas increases the reliability of an estimation of the likelihood of a 1 in 100 year or 1 in 1,000 year flood.

Additionally, the rainfall depth duration frequency data and the CD ROM that accompanies the handbook have been mentioned as particularly useful additions to the original FSR.

## Key research outputs

The key research outputs from the project have been a **handbook**, plus a **CD ROM** and a **software tool** to help implement some of the design rainfall and flood estimation procedures recommended that will enable a user to:

- (a) design structures that will assist in effective flood alleviation
- (b) check whether a structure has been designed adequately to withstand estimated flooding levels.

## Dissemination and users

The main users of the FEH are hydrologists based at government agencies, consultancies, local authorities and universities. Engineering consultants principally use the handbook to design structures such as drains, culverts, flood alleviation schemes and reservoirs. The Environment Agency uses it principally for checking designs in applications for planning permission. Universities are most likely to use the handbook for research purposes.

The FEH enables users to estimate the flood hydrograph and peak flow for a defined frequency of occurrence. It helps to determine the storm rainfall and flood runoff characteristics of any catchment in mainland UK with a topographic catchment greater than 0.5 km<sup>2</sup>. These data can be combined with hydraulic river models to provide an estimate of the likelihood of a certain level of flood and the extent of the flood, at any point in the UK.

The handbook and CD are available to the public for purchase. The handbook costs £250. A lower price of £220 is charged to recognised academic institutions. The FEH CD ROM costs £750 + VAT (£190 + VAT for academic institutions) and the WINFAP-FEH costs £1500 + VAT (£300 + VAT for teaching purposes)<sup>107</sup>.

According to stakeholders, approximately, 800 copies of the handbook and 520 copies of the accompanying CD-ROM software have been sold since December 1999. A number of hydrologists in the same office may use a single licence for the FEH. Estimating that the typical set up in a consultancy is one copy of the FEH shared between 4-6 engineers or consultants.

As the FEH assists in flood alleviation, those who live in flood vulnerable areas are the greatest beneficiaries of the research. The general public benefits from the applications of the handbook.

## 12.2 Methodology

Key stakeholders were interviewed (four from the scientific community and three end users) to understand their informed opinion of the economic impact of the FEH.

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<sup>107</sup> Centre for Ecology and Hydrology (2003) FEH Software [Online] Available at: <http://www.nwl.ac.uk/ih/feh/html/software.html> [Accessed 23<sup>rd</sup> November 2005]

## 12.3 Findings

### 12.3.1 Strategic and policy benefits

Flooding is one of the top natural disrupters of our society, often resulting in massive expenditure through insurance claims. The FEH is an important tool in helping to design measures that will reduce the frequency of flooding in our communities. It contains knowledge gained over more than 30 years<sup>108</sup> and it enables the community to build better in the future with less risk.

As such, the FEH has a vital role in enabling the Government to meet its Spending Review 2004 target:

Defra will manage flood and coastal erosion risk so as to contribute to sustainable development, including minimising loss of life and improving the standard of protection for at least 100,000 households using efficiency savings to maintain outputs at equivalent levels to 2005-06.

The FEH supports DEFRA and the Environment Agency in their local policy implementation activities. For instance in order to comply with the Water Framework Directive, the UK Government must be well equipped to effectively deal with flooding. Under its role to implement the WFD, the Environment Agency is required to manage rivers holistically, to better identify flood vulnerable areas and to predict the likelihood of flooding as accurately as possible.

The handbook is of strategic importance for policy makers for the protection of UK's population and property. It helps authorities and developers to identify sites that are inappropriate for new development due to potential risks of flooding. By helping regulators to avoid construction on floodplains and flood vulnerable areas, FEH can reduce insurance costs for new homeowners and claims for the insurance companies.

The handbook also supports the design of flood defences and protection structures, such as culverts, drains, flood storage reservoirs, strengthened embankments and bridges; that are needed to safeguard existing developments. These reduce the flood damage risk on property, the environment and human life. This is a live issue in the South East of England where there are 1.5-2 million properties at risk from flooding (predicted to rise to 3.5 million with the effects of climate change), and 200,000 new homes being built in flood risk areas. The need for careful design of culverts, drains and embankments is manifest if the damage flooding causes to property is to be mitigated. However, it is important to note that the risk for many properties is tidal flooding rather than river flooding. The FEH can help to reduce the frequency of fluvial flooding only.

The FEH provides the authoritative 'standard of practice' in the UK to be followed in the design and planning of schemes affected by, or designed to mitigate, flooding. It is important to have a rigorous, standardised method for estimating flood size and frequency across the UK. Without an agreed upon method, each consultant would need to create their own

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<sup>108</sup> Refers to the experience gained since the publishing of the FSR in 1975

estimation method, which may not be so well informed as that using the FEH. The question over the validity of the estimation procedures used would increase the uncertainty surrounding the resulting flood peak estimation.

### 12.3.2 Wider and direct benefits

As described above the main reason why users find the FEH of value is because the handbook provides them with a standard approach used by the vast majority of hydrologists and engineers in the UK, which allows for estimating flood size and frequency across the UK.

- Without the FEH, all current users of the handbook would have to develop their own method for estimating flood peak flows.
- Users agree that if the FEH was not there it would certainly need to be developed as it is an essential tool of experts working in the area.

A software package (WINFAP-FEH) also enables users to execute routine calculations faster than before the FEH was introduced.

- The FEH and accompanying software provides users with digital catchment information (such as soil characteristics) at the touch of a button, thereby replacing the method of map analysis by hand, which was previously required in order to extract this information.
- The added features of the software, such as for finding out soil characteristics in a catchment, also have additional time saving benefits for the users. They enable a user to instantly consider additional information in their flood estimation calculation that they might not have otherwise included.

These contributions from the FEH help to achieve economic benefits that are **efficiency savings** across users in the UK economy.

Additionally, users judged that the FEH has an indirect contribution to **avoid potential costs** of flooding (e.g. damaged commercial or private property and impacts on human health) in the UK by:

- helping to identify flood risk areas where development should be prevented
- contributing to the accuracy of flood scheme design, both to be developed in the future as well as for maintenance of existing defences, for areas which are vulnerable to fluvial flooding and therefore reducing the likelihood of flooding in these areas.

This analysis has focused on assessing avoided costs in terms of the built environment (i.e. damage to property), however, there are other costs that flood related tools, such as the FEH, will make a contribution towards avoiding. Some of these include costs in terms of loss of human life, adverse effects on human health and productivity losses.

### 12.3.2.1 Direct benefits

#### Extent of impacts

In terms of efficiency, stakeholders have supplied the following data (all figures supplied below are assumed to be in 2005 basic prices).

1. When a hydrologist carries out a flood risk assessment (FRA), the hydrological component takes around 4 hours at an average cost of £100.
2. Without the FEH, the hydrologist would have to go back to the traditional method of consulting maps to carry out the calculation, which would take them an extra 4 hours, at a cost of £100.
3. If a typical consultancy comprises 5 hydrologists (with each hydrologist carrying out flood risk assessments independently of one another), then they would be able to only do 100 of these assessments per year if it was costing them around £200 per assessment.

According to the Centre for Ecology and Hydrology (CEH), approximately, 800 copies of the handbook and 520 copies of the accompanying CD-ROM software have been sold since December 1999. A number of hydrologists in the same office may use a single licence for the FEH. The CEH estimates that the typical set up in a consultancy is one copy of the FEH shared between 4-6 consultants and that there may be between 2,000-4,000 users of the FEH in the UK. However, other stakeholders believe that the number of real users affecting design is around 10% of that (i.e. 200-400 users across the UK). For the purpose of this assessment, the existence of between 400 and 2000 users of the FEH has been assumed.

While the FEH was not directly funded by NERC, it did fund the FSR, which provides the basis for one of the two main methodologies used within the FEH. NERC also supported the funding of the publishing of the handbook and accompanying software WINFAP-FEH. Additionally the CEH, which developed the FEH, is one of NERC's Research Centres and is therefore funded by it. Given NERC's direct contribution to the key elements of the FEH, PWC assess therefore that the FEH would not have been possible without NERC funding and that therefore the benefits from the FEH may be linked back to NERC. However, one stakeholder felt that the FSR only provided the FEH with one of its two methodologies, and that therefore only 50% of the FEH benefits should be allocated to NERC funding. Given that view it is assumed that only 50% of FEH's benefits may be allocated to NERC.

#### Projection of benefits

According to the information supplied by stakeholders, the **counterfactual baseline**, in terms of efficiency savings, is:

- the cost of having to do a FRA without the FEH would be of the order of £200.

The undiscounted efficiency savings per year for an estimated number of users of the FEH across the UK has been calculated. It has been assumed that the FEH will continue to be used in the long term. This is because the FEH enables hydrologists to have a shared standard approach to flood estimation and because it is a tool that is likely to be updated in the future. Currently its use is mandatory in the design of flood defence schemes across the

UK. Therefore, it is assumed that the FEH will accrue efficiency savings during the entire appraisal period.

The following are the steps of the calculation that PwC followed to quantify the efficiency savings associated to the FEH.

1. The annual savings to a consultancy of 5 hydrologists has been estimated to be around £10,000 per year [ $£100 \text{ saved} * 100 \text{ assessments per year}$ ].
2. For a consultancy comprised 5 hydrologists, the efficiency savings per user would be of the order of £2,000 per user of the FEH [ $£10,000 \text{ of savings divided by the } 5 \text{ hydrologists/users of the FEH in a consultancy}$ ].
4. If a £2,000 saving is considered for 400 users, then the FEH could potentially be helping users to save around £0.8 million per year across the UK [ $£2,000 \text{ savings} * 400 \text{ users}$ ].
5. These savings could be as high as £4 million if the highest estimate of user numbers are taken into account [ $£2,000 \text{ savings} * 2000 \text{ users}$ ].
6. Therefore the potential efficiency savings out of using the FEH could be in the range of £0.8 million to £4 million per annum (2005 prices) for the community of FEH users in the UK.
7. Only 50% of these benefits would be allocated to the FSR/NERC-funded research.

The present value for these savings for a 25-year period would potentially be within a range of £7 million to £34 million or an average present value in the range of £0.3 million to £1.3 million per annum (2006 prices).

#### 12.3.2.2 *Wider benefits*

##### Extent of impacts

In terms of avoided potential costs, stakeholders emphasised that although there may be some contribution from the FEH, it is not possible to quantify to what extent the handbook helps to achieve current or future flooding costs being avoided. The main reasons for this are:

- the FEH supplies methodology, yet data is a lot more important than methods to achieve accuracy in flood estimation
- other projects (e.g. the High Flow project), different to the FEH, are providing the most updated data that is in use by users of the FEH
- a lot of the fluvial flooding related defences in the UK were built before the FEH and in many cases before the FSR.

Although some estimations have been provided by stakeholders about the FEH potential contribution to avoiding fluvial flooding costs to the UK economy, none of the stakeholders have validated each other. Additionally, stakeholders have found it difficult to justify their views with solid arguments as more than just speculation. Nevertheless, stakeholders consulted accepted that:

- the FEH does have a contribution to avoid costs of flooding to the UK economy through its contribution to improve the accuracy of flood estimation
- regardless of the level of contribution, due to the magnitude of the costs of flooding in the UK economy, the benefits of the FEH will be greater than the initial investments.

Using reliable third party sources, according to a DEFRA report<sup>109</sup> (all amounts in 2000 prices):

- 10% of the population of England and Wales live within areas potentially at risk from flooding or coastal erosion, 12% of the agricultural land is also located in these areas
- property worth over £220 billion and agricultural land worth approximately £7 billion is located within these areas potentially at risk
- without any flood and coastal defences, the annual average economic damage from flooding and coastal erosion in these areas (on property, agriculture and traffic) would be over £3.5 billion/year
- these damages are mostly associated with properties affected by flooding, and are spread between fluvial (40%), tidal/sea areas (44%), foregone agricultural production (14%) and coastal erosion losses (2%)
- current standards of defence reduce annual average damages to approximately £0.8 billion/year
- continuing to invest at present levels of approximately £0.24 billion per year will result in increasing annual average damage possibly at the rate of some £10-15 million per year
- the capital works and maintenance investment needed to continue to provide and maintain present defence standards is in excess of £0.3 billion/year.

This suggests the current measures for withstanding floods save the UK economy £2.7 billion. [£3.5 billion p.a. – £0.8 billion p.a.] and £1.1 billion per annum [£2.7 billion.\*40% of properties affected by fluvial flooding] represents the damages associated with properties affected by fluvial flooding. Additionally, it is evident from the figures presented above that current levels of investment are relatively low in relation to the cost savings being achieved by flood defences (i.e. £0.24 billion invested for £2.7 billion of avoided costs). Further, a higher investment is being proposed (i.e. to go from £0.24 billion to more than £0.3 billion).

In the light of this third party information, due to the costs of flooding to the UK economy on a yearly basis and the potential of costs increasing due to climate change, this confirms stakeholder evidence that even a small FEH contribution to avoiding those costs will exceed the initial investment in the handbook.

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<sup>109</sup> DEFRA (2001) National Appraisal of Assets at Risk from Flooding and Coastal Erosion, including the potential impact of Climate Change- Final Report [Online] Available at <http://www.defra.gov.uk/environ/fcd/policy/NAAR1101.pdf> [Accessed 22<sup>nd</sup> November 2005].

### Projection of benefits

The economic benefits of the avoided costs as a result of the usage of the FEH will not be modelled due to the lack of an estimation of stakeholders of the extent to which the FEH can make a difference in this area. However, for the purpose of providing an illustrative example it is noted that, if the current costs of flooding were to increase (or avoided costs decrease) in a range of 1-5% then this would equate to a range of £12 million to £45 million of additional costs per year. These would have a present value in the range of £197 million to £746 million, or an average present value of £8 million to £30 million per year.

The box below comments on some other costs of flooding that have not been assessed in this study.

#### **Other potential economic costs of flooding**

Environmental and human health impacts can also be accounted for in economic appraisals. In terms of flooding, there may be short-term physical effects (colds, coughs, flu, shock, gastro-intestinal illness, respiratory illness, cuts and bruises) and long-term psychological effects (anxiety when it rains, anxiety over insurance claims, increased stress levels and sleeping problems).

In a recent document on the UK Health Impacts of Climate Change, the Parliamentary Office of Science and Technology (POST) noted that as a result of climate change, there was likely to be an increase in frequency of severe coastal and river floods. They reported that the most important health impact on flood victims was in fact mental health problems, due to the experience of personal and economic loss and stress<sup>110</sup>. By managing floods effectively, the stress to individuals can be reduced. Indirect effects of this include reduced costs to the health services, and reduced costs to UK industry in terms of paid sick leave to employees affected by flooding.

A study by Defra and the Environment Agency<sup>111</sup> into the human related intangible impacts found that there was an average willingness to pay £200 per affected household towards flood alleviation measures in order to avoid these human impacts of flooding.

Increased accuracy in flood forecasting is also of great benefit to the insurance industry. By ensuring that insurance fees match the potential for damage, the insurance companies are less likely to be adversely affected by homeowners' claims following extreme flood events. Very few people have died in flooding incidents in the UK. In the catastrophic floods in Carlisle in January 2005, millions of pounds worth of damage was done to property but only three lives were lost, and two directly due to the flooding<sup>112</sup>.

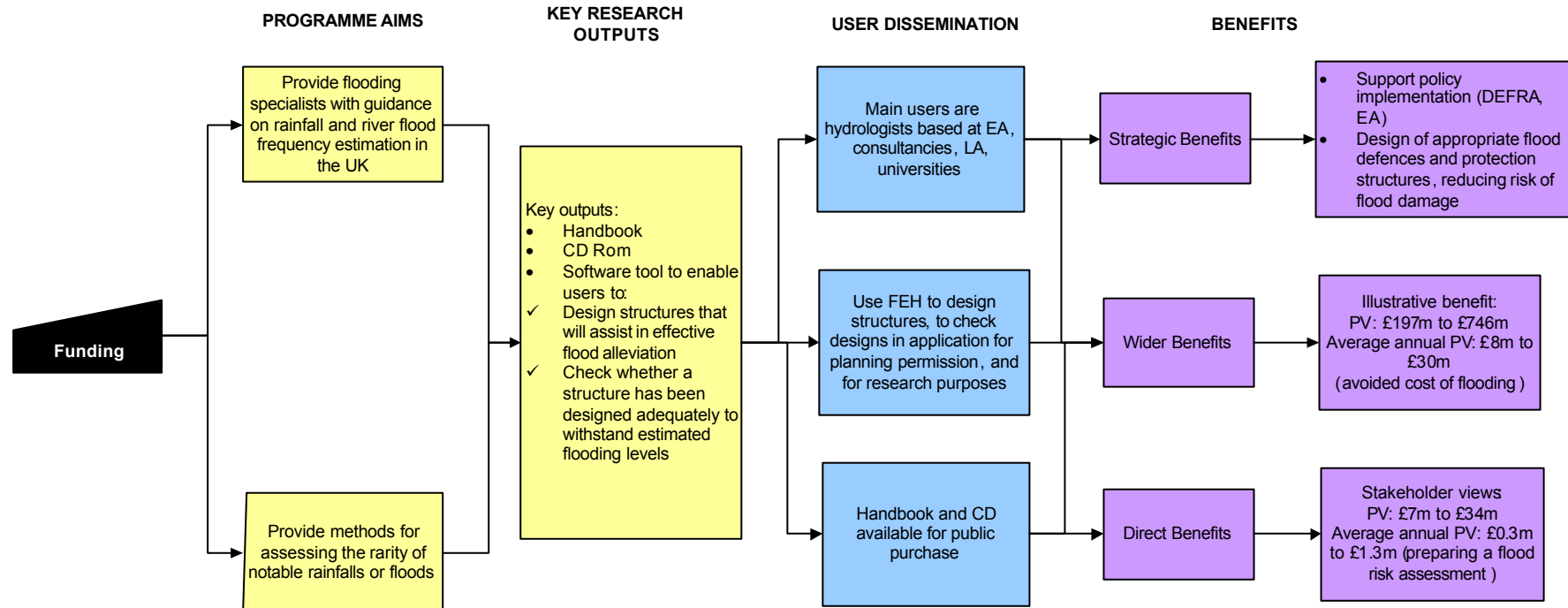
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<sup>110</sup> POST (2004) POST note 232: UK Health Impacts of Climate Change. [Online] Available at: <http://www.parliament.uk/documents/upload/POSTpn232.pdf> [Accessed 21<sup>st</sup> November 2005]

<sup>111</sup> DEFRA/Environment Agency (2003). *The Appraisal of Human Related Intangible Impacts of Flooding*, R&D Project FD2005, Defra Flood Management Division, London

<sup>112</sup> Defra (2005) Flood Management Stakeholder Forum: 6<sup>th</sup> meeting. [Online] Available at: <http://www.defra.gov.uk/environ/fcd/policy/forummtgs/04feb05.htm> [Accessed 21<sup>st</sup> November 2005].

# FEH's Value Chain



## 13 CASE STUDY 9 – Geo-reports and Subsidence Information

### 13.1 Case study description

#### Summary

The British Geological Survey (BGS) currently derives around 50% of its funding from NERC and could be said to be a supplier to the demands of the information age. BGS provides information on the likelihood of natural ground instability, enabling any potential investor in a house, development or piece of land to make informed decisions about the risk of future subsidence events and associated costs.

The value of this service is becoming more important with the impact of climate change and erratic weather patterns changing the ground we stand on. The annual cost of subsidence to the insurance sector is already around £300million, and this is expected to increase as a result of climate change and denser housing, particularly in the South East of England.

**Start date:** NERC has been the parent body for the British Geological Survey (BGS) since 1965.

#### Funding

BGS receives annual funding from NERC. In the 2004/2005 financial year, BGS received £27 million. Approximately £300k of this was spent on work related to improving the data and information for the BGS Geosure ground stability database, which is derived from the digital geological data.

#### Background

The Geological Ordnance Survey was set up formally in 1835 to further geological science but also to enable the country to know the location of natural resources to support the industrial revolution, the building of bridges and canals. The publication of the Geological Survey Act in 1845 provided the Survey with a legal framework designed 'to facilitate the Completion of a Geological Survey of Great Britain and Ireland.' The Geological Survey has had various names since it was first established but it formally became the British Geological Survey in 1984.

The BGS carries out core strategic work, which entails long-term surveying, monitoring and databasing, underpinned by applied research. It also undertakes commissioned projects in line with the core strategic work.

BGS has extensive international expertise in a range of geohazard related events, including earthquakes, tsunamis, and worldwide experience in disciplines related to geohazard assessment, recovery and reconstruction (including groundwater protection, engineering geology, seabed imaging and hazard mapping). For example, in the West Indies, BGS

monitors volcanic activity on Montserrat and assess the hazards and associated risks it poses. If BGS did not carry out this role, then the inhabitants would not be able to live there.

In the UK, BGS' geohazard research has focused on landslides, swelling and shrinking clays, dissolution, running sands, collapsible and compressible ground and contributes to information related to flooding.

Through discussions with BGS, it was decided to focus on their data related to natural ground instability, which as part of their commissioned work, supplies Geohazard information detailed below in the 'Key research outputs' section. The provision of GeoReports and natural ground stability data by BGS to environmental and insurance sectors is a good example of knowledge transfer. Such knowledge transfer meets the requirements of the DTI's for Public Sector Research Establishments such as BGS to enhance UK business. BGS GeoReports was used as a best practice example in DTI's Knowledge Transfer Partnerships report of October 2004<sup>113</sup>.

BGS produce geological maps, which have relatively limited use to the reader unless the reader is a geologist. Since 1991, BGS have added value to these maps through interpreting the data to produce risk parameters for ground movement – natural subsidence (e.g. through clay shrinkage/expansion or historical non-coal mining). Users of these maps benefit in that they can easily access data regarding the likelihood of natural subsidence in a particular area.

### **Context to the economic importance of subsidence information**

The average annual cost of subsidence is £300 million to insurance companies<sup>114</sup>. This cost can double in a year of extreme weather conditions and costs are predicted to rise with the impact of global warming.

### **Objectives**

The high-level objective of BGS is to provide expert services and impartial advice in all areas of geoscience. Their clients include both the public and private sectors in the UK and internationally.

The BGS mission<sup>115</sup> is:

- to advance geoscientific knowledge of the United Kingdom landmass and its continental shelf, by systematic surveying, long-term monitoring, effective data management, and high quality applied research
- to provide comprehensive, objective, impartial and up-to-date geoscientific information, advice and services, to the client and user community in the United Kingdom and overseas, enabling safe, sustainable and efficient choices to be made in managing the environment and utilising its resources, thereby contributing to

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<sup>113</sup> DTI Knowledge Transfer and Public Sector Research Establishments

[http://www.ost.gov.uk/enterprise/knowledge/KTP\\_CaseStudies.pdf](http://www.ost.gov.uk/enterprise/knowledge/KTP_CaseStudies.pdf)

<sup>114</sup> Find a property (2004) Someone called Noah [Online] Available from:

<http://www.findaproperty.com/story.aspx?storvid=6193> [Accessed 14<sup>th</sup> December 2005]

<sup>115</sup> British Geological Survey Strategic Science Programme 2005 – 2010:

<http://www.bgs.ac.uk/about/docs/StrategicScienceProgrammeBrochure.pdf>

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national economic competitiveness, the effectiveness of public policy and the quality of life

- to disseminate information in the community, and promote the public understanding of science, to demonstrate the importance of geoscience to resource and environmental issues.

### **Key research outputs**

BGS produce geological maps based on geological data going back to 1885, the collection of which was publicly funded. As mentioned above, BGS have added value to these maps through interpreting the data to produce risk parameters for ground movement – natural subsidence, which generates commercial value from both the public and private sector.

BGS produce GeoReports<sup>116</sup>, which provide advice on site geology in support of site assessments or investigations. The advice they provide is based upon the best available geological data. A range of standard reports are produced, each providing varying levels of detail.

BGS also provide advice on ground subsidence issues relating to natural geohazards. The Ground Stability Report will indicate whether any natural ground stability hazards have been found for the site of interest, such as swelling clay, landslip, ground solution, running sand, collapsible or compressible ground. If any of these hazards are identified, estimations as to their possible severity are provided as are maps indicating where these hazards may or may not occur.

Information provided by the BGS is improving as more data is collected and interpreted. At present the data's resolution allows a 50m search around specific properties or alternatively data can be supplied at full postcode level.

### **Dissemination and users**

GeoReports can be ordered from the BGS website for specific areas by inputting an address, grid reference or site plan. These plans range in price from £23.75- £705. The GeoReports are marketed to the public as well as private sector clients, with the ground stability report providing more detailed information as a follow-up to that provided within more general environmental reports.

BGS also licence natural ground stability data directly to the public sector (e.g. local planning authorities, the Environment Agency, and the private sector). Companies that undertake risk modelling and analysis for the insurance industry, which provide land and property search information, and planning and environmental risk information are important clients for BGS data.

Users of the BGS UK subsidence data include:

- UK Central Government
- local and regional planning authorities

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<sup>116</sup> <http://www.bgs.ac.uk/georeports/>

- general public (e.g. house buyers)
- insurance companies
- utilities
- rail and engineering companies
- software developers for the insurance sector
- universities.

## 13.2 Methodology

Stakeholders (three from the scientific community and four end users) were consulted in order to understand their opinions on the economic impacts of the BGS subsidence data.

## 13.3 Findings

### 13.3.1 Strategic and policy benefits

#### ***Enhanced decision-making and empowerment***

Stakeholders advised that information from BGS relating to the risk of natural subsidence in a particular location is used to inform and improve decision-making by the public (house buyers), mortgage companies, developers, insurance companies, local and regional planning authorities and others as listed above. Users of this information can help to assist in the decision as to whether to build/buy a property/development in a particular location or what remedial action is required for an existing property/development to be made safe. The data may be used to predict ground conditions and help inform the design of foundation structures to prevent subsidence occurring at a later date.

Stakeholders also judged that decision-takers are empowered to make better informed decisions, based on this information, and this leads to avoiding future costs and preventing loss of investment through avoiding or mitigating a subsidence incident later. One household insurer, is encouraging householders to undertake subsidence surveys and warns that if householders continue not to pay for a subsidence survey when buying their property, then insurers could end up paying to fund the subsequent cost of repairs. It is not just the financial losses or repair costs for householders and insurers that are avoided but also the stress and disruption associated with loss of property and finances.

#### ***Wide usage of BGS subsidence information:***

- Currently around 500,000 house buyers annually obtain reports, which include ground stability information from BGS's Value Added Resellers .BGS also sells around 8,000 GeoReports per annum, many of these as a follow-up to the more generalised private sector reports. It is reported that only one in four house buyers undertake a full survey<sup>117</sup>. However, BGS expect that with the introduction of the statutory Home Information Packs in June 2007, which according to draft

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<sup>117</sup> [http://www.silsoe.cranfield.ac.uk/svl/npd/b\\_buyers.htm](http://www.silsoe.cranfield.ac.uk/svl/npd/b_buyers.htm)

regulations<sup>118</sup> may include reports 'relating to ground stability, the effects of mining or extractions, or the effects of natural subsidence', the number of householders and house buyers requesting GeoReports/subsidence information/full surveys for property transactions will increase. In the future, legislation may make subsidence reports statutory, in which case, the value of the BGS natural subsidence database would partly be based on the health of the housing market.

### ***Supporting the information age and responding to climate change***

The increasingly localised information on risk of subsidence provided by BGS, which is currently provided at postcode and household level, meets the needs of the information age, which demands fast access to reliable and up-to-date information. Stakeholders indicated that they can get the necessary information easily from BGS, that it is accurate and relevant to their needs.

Also with the likely increase in erratic weather caused by climate change, stakeholders predicted that the demand for accurate subsidence data will increase further. In addition, with the increased use of groundwater in London, the water table has gone down. This causes the clay in the ground to dry out, changing its character. If this is combined with excess rain, the result is sink and swell of clays, resulting in groundwater movement and subsidence in properties. One insurer has reported that due to climate change and denser housing, particularly in the South East, subsidence affected tens of thousands of homes in 2003. Therefore the risk of subsidence in a particular area needs to be updated regularly, and BGS do update their subsidence risk analysis to their Value Added Resellers on an annual basis. However, the underpinning mapping data is continuously updated, allowing new assessments of ground stability to be made.

### ***In a world without BGS***

In the absence of the BGS data, stakeholders judged that it would be difficult for users to go elsewhere for similar data of such high resolution. (For example, soils data, from Cranfield – Silso, from which particular characteristics can be inferred). Alternatively, subsidence maps could be inferred from the 200,000 subsidence claims that have been made over the last 30 years. However, stakeholders asserted that neither source would be as precise as the BGS data. Therefore, they judged that any user of these two other potential sources of information would not be as well informed to make decisions as if they were to use BGS data, and this could lead to costs at a later date.

### **13.3.2 Wider and direct benefits**

#### **Potential areas of economic impact**

Subsidence data has a financial value as the public and businesses are willing to pay for the information. The biggest market for subsidence information is the domestic housing market followed by the insurance sector. Subsidence information for domestic and commercial properties generates around £1 million in value for BGS annually, approximately £120,000

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<sup>118</sup> <http://www.odpm.gov.uk/index.asp?id=1161272>

from the insurance sector, and around £300,000 related to licensing data to a range of end-users<sup>119</sup>.

Indeed, stakeholders stated that the insurance industry approached BGS initially with a request for accurate data relating to ground movement as they were paying out relevant amounts of money against subsidence claims. If a high proportion of the entire British insurance industry uses this information, then there is no competitive advantage gained. The entire industry may have reduced subsidence claims on existing homes, but this would be exactly offset by some homeowners being priced out of the insurance market and suffering subsidence losses without any cover.

Subsidence data is used by businesses to help provide risk-modelling software to insurance companies and enable insurance companies to set more accurate insurance premiums. This may be generating efficiency and financial savings for the insurance industry. Another commercial user of BGS subsidence information provides reports on the potential for ground movement or subsidence, which can help inform homebuyers and planning decisions. This company claims that users of their reports (based on BGS data) do not need to consult other data providers in order to make their own assessment, saving them time and money.

The economic impact of the use subsidence data (e.g. when making decisions about property/development purchase is partly invisible as financial, environmental and social costs are avoided). For example, if a developer or house buyer finds that there is a high risk of subsidence in a particular location, they can decide not to build/buy there or alternatively put in place relevant measures to reduce/remove the risk of subsidence therefore avoiding loss of investment. It is not clear how many 'avoided subsidence' cases exist each year or where this occurs. However, one insurance company recorded an average household subsidence claim of about £6,500 in 2003<sup>120</sup> and that the claim could rise to tens of thousands of pounds. If the number of 'avoided subsidence' cases was known then it would be possible to calculate the economic impact of using BGS subsidence data.

In summary, PwC's understanding is that the economic benefits of BGS subsidence data assumes an impact pathway where groups such as house buyers, developers and insurance companies buy and act on the data to best effect. In cases where this occurs, financial and social costs can be avoided through avoiding investing in areas at risk of subsidence, or taking pre-emptive action and mitigating subsidence. Therefore, BGS subsidence data may help to produce the following benefits:

1. Direct Benefits – the provision of subsidence data by BGS may help to save time and money to industry that do not need to carry out their own subsidence data collection
2. Wider Benefits - the provision of subsidence data by BGS may help to avoid and reduce insurance costs of subsidence claims

Due to commercial sensitivity, the efficiency and financial savings arising from the use of subsidence data to insurance companies and to companies could not be made available by the commercial stakeholders consulted. Therefore, the section below focuses on assessing wider benefits, which are expected to be more relevant.

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<sup>119</sup> Information provided by BGS consultee

Additionally, it was noted that BGS subsidence data may be able to help achieve other type of wider societal benefits that have not been assessed in this study. Some of these may be the costs of stress and disruption associated with loss of property or the environmental costs of subsidence.

### 13.3.2.1 Wider benefits

#### Extent of impacts

According to stakeholders consulted, although BGS subsidence data gets sold to different types of users, there are no estimations of the number of new dwellings that have been built with full consideration of subsidence data, the extent to which it makes a difference for new dwellings or the extent to which the data is used by insurers when setting premiums. However, through stakeholder views and third party documents it seems that:

- insurers do promote the use of subsidence data and assessments
- many dwellings are being build without the consideration of subsidence data
- there is a possibility that the statutory Home Information Packs will help to increase the usage of subsidence data.

From these views, it is assumed that BGS data provides information that changes practices that may help reduce and/or avoid the costs of subsidence to some extent.

In terms of associated costs, according to third party sources<sup>121</sup>, the average annual cost of subsidence insurance claims in the UK was around £317 million/yr in 2004 at 2006 prices. Additionally, claims are expected to double by 2050, which implies a growth rate of 2.3% per year.

#### **Example of the impacts of subsidence**

An extreme example of the cost of subsidence is the collapse of the tunnel at Heathrow in 1994, which cost £150 million to recover and resulted in a 6-month delay to the project. Although there were many contributing factors to the collapse of the tunnel, poor management was one of them. The risk of subsidence was high and workers in the tunnel reported that subsidence was excessive<sup>122</sup>. This example illustrates that if the evidence of the risk of subsidence was taken note of, the £150 million cost could have been avoided. However, this example also demonstrates that even when the necessary subsidence information is provided, this does not necessarily mean that the risk of subsidence will be addressed and costs avoided.

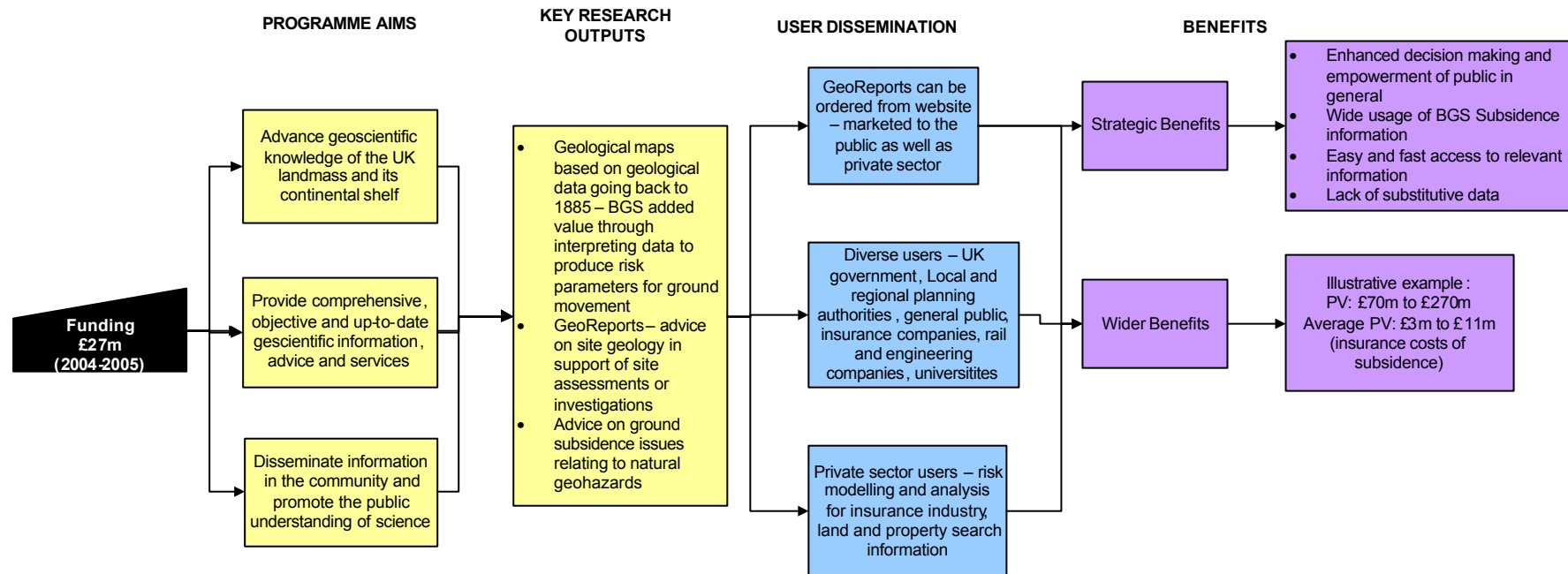
#### Projected economic benefits

The wider economic benefits of BGS subsidence data will not be estimated. However, for the purpose of providing an illustrative example, if it is assumed that the subsidence insurance claims will continue to grow at a rate of 2.3% per year between 2004 and 2030, a saving of 1-5% over this baseline (could be considered as avoided cost) would provide a present value in the range of £70 million to £270 million, or an average yearly present value in the range of £3 million to £11 million.

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<sup>121</sup> <http://www.findaproperty.com/story.aspx?storyid=6193>

# BGS's Value Chain



## 14 CASE STUDY 10 – Discovery of hole in the ozone layer and subsequent research

### 14.1 Case study description

#### Summary

British Antarctic Survey (BAS) scientists discovered the hole in the ozone layer in 1985, now widely known as a notorious environmental phenomenon. Their discovery, based on robust and long-term data, led to a major realisation and international acknowledgement that human activity was having a significant and negative impact on the global environment. They provided a crucial part of the argument for a ban on chlorofluorocarbons (CFCs) and gave impetus to the implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer.

The discovery of the hole in the ozone layer made a scientific, political, social, environmental and economic splash, the waves of which remain. BAS continue to monitor the ozone layer, providing records which are seen as irreplaceable and as key to understanding the impact of climate change on the ozone layer.

**Start date:** 1985    **End date:** Ongoing

#### Funding

BAS, a component of NERC, receives from the research council an annual budget of £40 million. For the purposes of this case study, the annual cost of monitoring the ozone layer is around £70k, which includes funding for two staff, one in Antarctica and one in the UK, and training and maintenance of equipment.

#### Background

Ozone is found in the stratosphere, peaking approximately 24km above the Earth's surface, where it acts as a shield, protecting the earth from the sun's harmful ultraviolet (UV) rays. This UV radiation can cause skin cancer, cataracts and deplete the immune system of humans. UV radiation also impacts on microbes involved in regulating nutrient cycles. Therefore, an intact ozone layer is vital to human health and biogeochemical cycles.

Observations of the ozone layer in the Antarctic started in 1957 and were originally blue skies research. The research took the form of long-term monitoring to understand the role of ozone in the atmosphere.

The discovery of the depletion of the ozone layer over the Antarctic in 1985 came somewhat as a surprise but interest in pollution of the stratosphere had risen substantially through the 1970s to try to determine the impact of high latitude aircraft, such as Concorde.

Since the discovery, ozone layer monitoring has continued, so BAS now has nearly 50 years of ozone measurements.

### **Objectives**

British scientists initially began measuring levels of ozone in the Antarctic in order to gauge the relative importance of ozone's role in absorbing solar energy, in determining the temperature profile of the stratosphere and wind circulation.

Since the discovery of the ozone hole, the monitoring has continued in order to catalogue the recovery of the ozone layer in this region.

### **Key research outputs**

The amount of ozone overhead should follow a regular seasonal pattern and for the first 20 years of monitoring, this is what BAS scientists observed. However, significant variations from this pattern were observed thereafter; each spring, the ozone layer was seen to be progressively weaker. By 1985, BAS had ascertained that the depletion in ozone in Antarctica had become so great that there was actually a hole. This discovery had major implications for human health and international policy as discussed below.

BAS has therefore produced nearly 50 years of accurate ozone level monitoring data for the Antarctic and continue to observe the change in behaviour of the ozone hole layer. These data are used to identify long-term trends and the impacts of effects such as global warming (cooling in the stratosphere) on the ozone hole.

### **Dissemination and users**

The paper on the discovery of the ozone hole was published in the journal *Nature* in 1985<sup>123</sup>. It provided a crucial part of the argument for a ban on chlorofluorocarbons (CFCs) and gave impetus to the implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer.

Following the publication of the paper, its authors, Joe Farman, Brian Gardiner and Jonathan Shanklin, travelled nationally and internationally speaking to governments, scientists and the public about their findings.

Currently, outputs from the BAS ozone monitoring programme are disseminated via the [BAS webpage](http://www.antarctica.ac.uk/key_topics/the_ozone_hole/index), (www.antarctica.ac.uk/key\_topics/the\_ozone\_hole/index) and internationally (e.g. through the World Meteorological Organisation).

## **14.2 Methodology**

Key stakeholders (six from the scientific community and two end users) were interviewed to understand their informed opinion of the economic impact of the ozone monitoring research.

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<sup>123</sup> Farman, J.C., Gardiner, B.G., Shanklin, J.D. 1985. Large losses of total ozone in Antarctica reveal seasonal ClO<sub>x</sub>/NO<sub>x</sub> interaction. *Nature* 315: 207-10

## 14.3 Findings

### 14.3.1 Strategic and policy benefits

#### **Key strategic/policy benefits**

Stakeholders judged that the discovery of the hole in the ozone layer was key in demonstrating the value of:

1. long-term monitoring and observations in itself
2. long-term monitoring and observations to policy makers.

#### **High quality science**

Stakeholders advised that the finding of the ozone hole underlined the value of long-term monitoring of the ozone layer and showed the importance of collecting data to monitor environmental trends. The data was also of **high quality**, carefully calibrated and hence reliable, meaning that measurements could be compared over time. Without long-term monitoring, stakeholders were clear that there would have been no historical and robust data to provide the evidence for change, which enabled the BAS scientists to publish their paper on the discovery of the ozone hole, published in the journal *Nature* in 1985. Stakeholders felt that the BAS ozone team's contribution to **ozone research** was of the highest importance. They also indicated that other long-term monitoring programmes, both within NERC and outside, have benefited from the initial demonstration of the value of commitment to such programmes.

Additionally, the discovery of the ozone hole in the Antarctic by BAS stimulated scientists to look for (and subsequently find) an ozone hole in the Arctic. Although the hole is not as deep as that in the South, it affects many more people.

#### **Enhanced UK position**

Stakeholders believed that the 1985 *Nature* paper provided the UK Government, and international policy makers and negotiators, with the crucial part of the argument for a ban on CFCs and gave impetus to the agreement and implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer. Prior to that paper, misleading US data was being used in a way that dampened any expectation of concentration changes amongst most of the science community and all policy makers. Stakeholders felt that if the BAS team had not made the discovery, someone else would have done but 5-10 years later; it was the timing of their discovery, which is seen as particularly significant. Stakeholders see their evidence as a critical scientific step in the evolution of the scientific and policy debate.

The Montreal Protocol was signed in 1987 and as at September 2002 has been ratified by 183 countries<sup>124</sup>. It required that industrialised countries reduce their consumption of chemicals harming the ozone layer. It was the first international treaty to try to limit human

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<sup>124</sup> United Nations Environment Programme

<http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=264&ArticleID=3130&l=en>

activity for the benefit of the environment and humans. The treaty has been largely successful and has resulted in a reduction in emissions harmful to the ozone layer<sup>125</sup>.

The BAS team continued to have an impact on policy development. Joe Farman and Brian Gardiner were invited by Margaret Thatcher in 1988 to discuss the depletion of the ozone layer. Stakeholders see this meeting as the catalyst, which led Margaret Thatcher to be the central force in pushing for a tightening up of the requirements of the Montreal Protocol, known as the 1990 London Amendments. These called for a phase out of the production of the most damaging ozone-depleting substances in developed nations by 2000 and in developing nations by 2010.

The Montreal Protocol has been successful in achieving its aims. The total abundance of ozone-depleting substances such as CFCs has begun to decrease and by 2050, the ozone layer is expected to recover. By this point, it is expected that the levels of the substances banned by the Protocol will fall to values present before the Antarctic ozone hole began to appear in the early 1980s.

Stakeholders felt, that on a scale of one to ten, with ten being the most important, the BAS ozone team's social and political impact had a value of ten.

Stakeholders asserted that on the basis that the BAS researchers proposed the fundamental link between human activity and the hole in the ozone layer, the strategic benefits can be attributed to their initial discovery, and hence NERC funding.

### ***Raising awareness of human induced environmental damage and its impacts***

Stakeholders judged that the discovery of the hole in the ozone layer led to a widespread appreciation and acknowledgement that human activity had an impact on the global environment. The researchers had shown that the hole in the ozone layer was being caused by reactions between UV light and the large amounts of CFCs released by humans from aerosols and refrigeration units. Their evidence woke up the public to the link between human behaviour and environmental problems and the realisation that this human induced change would incur a negative impact on human health as a result of increased exposure to UV light.

In the view of stakeholders the paper, the communication exercises and the presentations made by the BAS scientists not only contributed to an increased understanding of the impact of human behaviour but helped gain wide spread acceptance by politicians, policy makers, public and press of the need for change in behaviour. Fortunately, the chemical industry, led by Dupont, was able to respond with chemicals to replace CFCs.

In wider society stakeholders judged that the discovery of the hole in the ozone layer united environmental campaigners around a single issue and it is still viewed by stakeholders as a seminal debate. It also gave profile to the agendas of health specialists and lobbyists, because the impact of the hole was presented in terms of the impact of UV on skin cancer incidence, hence giving their own campaigns a higher profile.

### ***Now and over the next 25 years***

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<sup>125</sup> World Meteorological Organisation: Twenty questions and answers about the ozone layer.  
[http://www.wmo.ch/web/arep/reports/ozone\\_2002/q&as.pdf](http://www.wmo.ch/web/arep/reports/ozone_2002/q&as.pdf)

Stakeholders view the ongoing ozone layer studies by BAS as highly important, and its value is seen as the same now as in 25 years time; that is BAS has an essential role in long-term monitoring of the ozone layer, so that the impact and effectiveness of policies can be followed.

BAS has produced nearly 50 years of ozone level monitoring data for the Antarctic, which is seen by stakeholders as irreplaceable. The data are still being used for climate change studies, in order to understand the impact of climate change on the ozone layer and the recovery of the ozone hole. The view of stakeholders was that if BAS stopped monitoring the ozone layer, it would be disastrous.

### ***Decision-making***

BAS's work still has a public profile. The MET (Meteorological) Office uses BAS ozone data to provide the public with UV index forecasts, and enables anyone to make personal decisions on their UV exposure. The public are aware of link between ozone layer depletion, increased UV exposure and the risk of skin cancer as a result of the work done by BAS and others (e.g. the Department of Health and the World Health Organisation). Indeed ozone layer and CFCs are seen as household words.

### **14.3.2 Wider and direct benefits**

#### **14.3.2.1 Wider benefits**

#### **Potential areas of economic impact**

Stakeholders were able to link the discovery of the hole in the ozone layer with significant impacts on international policy development. In summary, firstly the discovery by BAS gave impetus to the Montreal Protocol, Secondly, the BAS scientists' meeting with Margaret Thatcher catalysed the strengthening and tightening of the Protocol's requirements regarding halogen gases with the London Amendments in 1990.

#### **Extent of impacts**

Although stakeholders were not able to attribute the proportion of the BAS scientists' work to the development of the establishment and development of the Montreal Protocol, stakeholders believe that BAS scientists were key in shifting the argument forward and giving impetus to the Protocol discussions which in turn is attributed with reducing the number of excess skin cancers, see below. Therefore it is useful to set the discovery of the hole in the ozone layer and consequent work in context of the impact of the Montreal Protocol on skin cancers, agriculture and fisheries in particular.

To focus on skin cancers, third party sources provide the following information:

- A report<sup>126</sup> by the World Meteorological Organisation has projected the different chlorine and bromine emissions under different scenarios, from a scenario with no regulation (i.e. no Montreal Protocol) and then UV and skin cancer scenarios concerning the projected impact of the Montreal Protocol and its subsequent amendments. The report relates these different emission scenarios with the number of excess skin cancers due to the increased levels of chlorine and bromine in the stratosphere, and hence an increased dangerous UV-B incidence at the Earth's surface causing a rise in skin cancers.
- By 2020, the WMO estimate that without the Montreal Protocol, there would have been 100 excess cases of skin cancers per million people per year. With the Copenhagen amendments, the final amendments made to the Protocol in 1992, it is projected that there will be around 40 extra cases per million people per year. Therefore, the Montreal Protocol and its subsequent amendments have reduced the number of excess skin cancers by 60 cases per million people per year.
- The total cost of skin cancer in England in 2002 was estimated by Imperial College to be in excess of £190 million<sup>127</sup> (2001 prices) or £209 million at 2006 prices.

#### Projection of benefits

For the purposes of this study it is assumed that:

- England's population is around 84% of UK's population<sup>128</sup>, if PwC assumed that the costs of skin cancer are proportional to the size of the population, the cost of skin cancer in the UK would be around £250 million per year [ $£209 \times 100/84$ ]
- if the Montreal Protocol has reduced the number of excess skin cancers by 60 cases per million people per year, and it is assumed that this figure applies in the UK, then there are approximately 60 million people in the UK<sup>129</sup> then the Protocol has reduced the number of excess skin cancers per year by 3,600 [ $60 \times 60$ ]
- the mean total cost of malignant melanoma skin cancer, which accounts for 63% of all skin cancers in the UK, is £20K and the mean total cost for other malignant skin neoplasms is £1,4K (see Imperial College report). Therefore, the total cost of cancers avoided in the UK as a result of the Montreal Protocol is around £47 million per year [ $£20K \times 3600 \times 63\% + £1.4 \times 3600 \times 27\%$ ] in 2002 prices. Assuming that the number of skin cancer cases remains constant, this would equate to around £51 million in 2006 prices.

Therefore, using these assumptions derived from third party sources, in the absence of the Montreal protocol, the cost of skin cancer for the UK could be in excess of £51 million over

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<sup>126</sup> World Meteorological Organisation: Twenty questions and answers about the ozone layer.

[http://www.wmo.ch/web/arep/reports/ozone\\_2002/q&as.pdf](http://www.wmo.ch/web/arep/reports/ozone_2002/q&as.pdf)

<sup>127</sup> Imperial College, London. Cost of skin cancer in England:

<http://www3.imperial.ac.uk/pls/portallive/docs/1/43013.PDF>

<sup>128</sup> ON (2004) Regional Trends

[http://www.statistics.gov.uk/downloads/theme\\_compendia/Regional\\_Trends\\_38/rt38.pdf](http://www.statistics.gov.uk/downloads/theme_compendia/Regional_Trends_38/rt38.pdf)

<sup>129</sup> CIA World Fact Book: <https://www.cia.gov/cia/publications/factbook/docs/gallery.html>

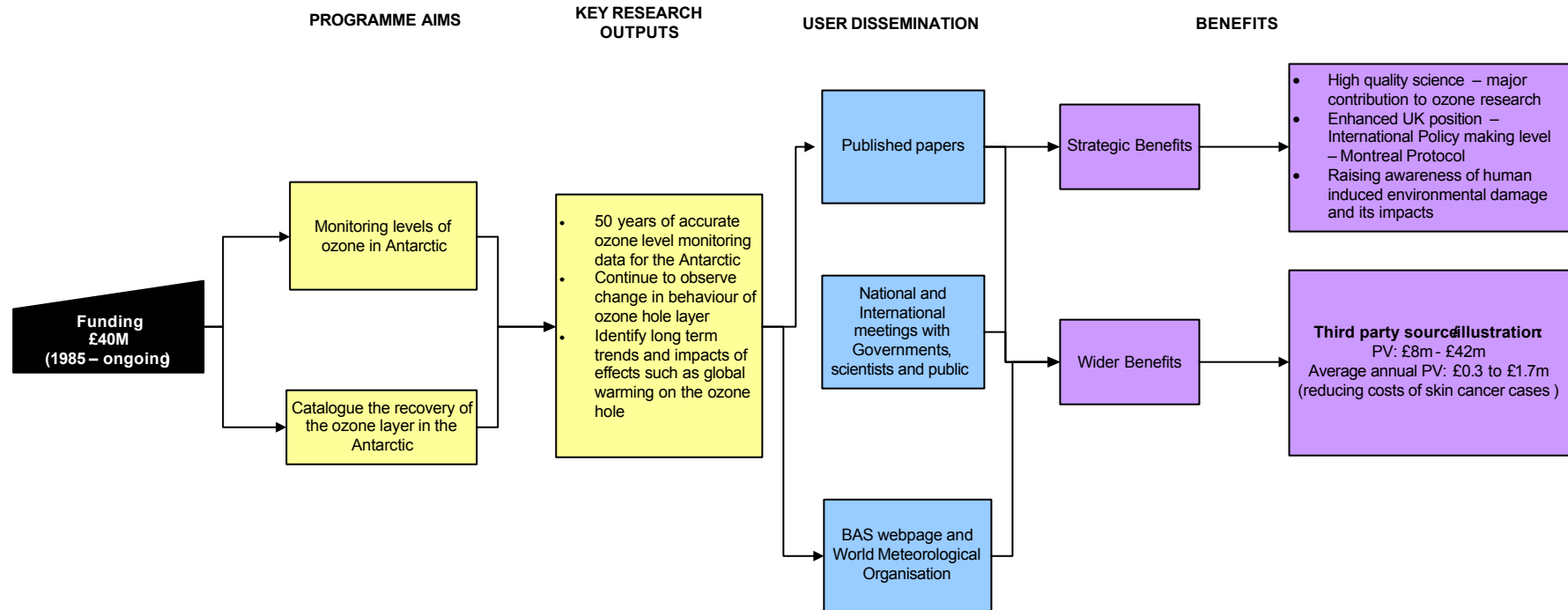
current costs of £300 million. This implies savings of around £836 million in present value terms or an average yearly present value of £33 million.

Only a portion of the benefits projected to the Montreal Protocol can be allocated to BAS work. However, stakeholders consulted did not feel able to provide views of the extent to which BAS work supported the Montreal Protocol.

For the purposes of illustration, a 1-5% portion of the savings allocated to the Montreal Protocol equates to around £8 million to £42 million in present value terms or an average annual present value of £0.3 million to £1.7 million.

Finally, it should be noted that this case study would have the potential of contributing to benefits also at the global level, which have not been modelled as this study focuses on the UK economy.

# BAS's Value Chain



## Annex A – Summary Methodology

The following section summarizes the methodology and approach used in this report.

### Socio-economic Benefit Assessment

This report summarises the results of a social and economic benefit assessment conducted on case studies of NERC-funded research. Such assessments are commonly conducted, usually by public sector bodies and organisations, on a wide range of infrastructure projects, policies and programmes. The methodological framework of this, and indeed the majority of socio-economic assessments, is prescriptive in nature and is described in detail below. However, before summarising the methodological approach, it is instructive to consider the broad parameters of this assessment.

- This study is concerned to reflect the broadest range of societal and economic benefits, which might be generated by selected case studies of NERC-funded research; these are termed ‘resource’ benefits.

In addition:

- The method is unconstrained in nature. As such, benefits should not arise which fall outside of the scope of this assessment – the method employed seeks to capture a range of societal, environmental and other economic applications and benefits that might arise through selected case studies of NERC-funded research.
- The assessment considers and expresses potential benefits in both quantitative and qualitative terms. In doing so, it employs a variety of economic valuation tools, and excludes others. In particular, the use of contingent valuation has been avoided (whereby benefits are expressed from the perspective of a societal willingness to pay for the benefit itself). Rather, a pragmatic market-based assessment of the benefits was adopted, whereby a wide number of informed stakeholders are asked to consider the magnitude of the application or contribution made by selected case studies of NERC-funded research. Thereafter, this contribution is valued with reference to respected published sources in the field of economic valuation. This approach is regarded as more robust and less subjective since it involves a process of ‘expert’ assessment, and
- Ultimately, projected economic resource<sup>130</sup> benefits will be monetised and expressed in present value terms where possible.

### Key approach features

The approach sought to identify and quantify the full range of benefits arising from the NERC case studies that were the subject of study. Benefits were expected to arise at a variety of levels, and were disaggregated as follows:

- **Strategic Benefits:** these arise for policy makers and regulators that use NERC’s data, information and advice to increase the effectiveness of public services and policy development, regulation and implementation. These may also include benefits arising out of the communication of research outputs and data to

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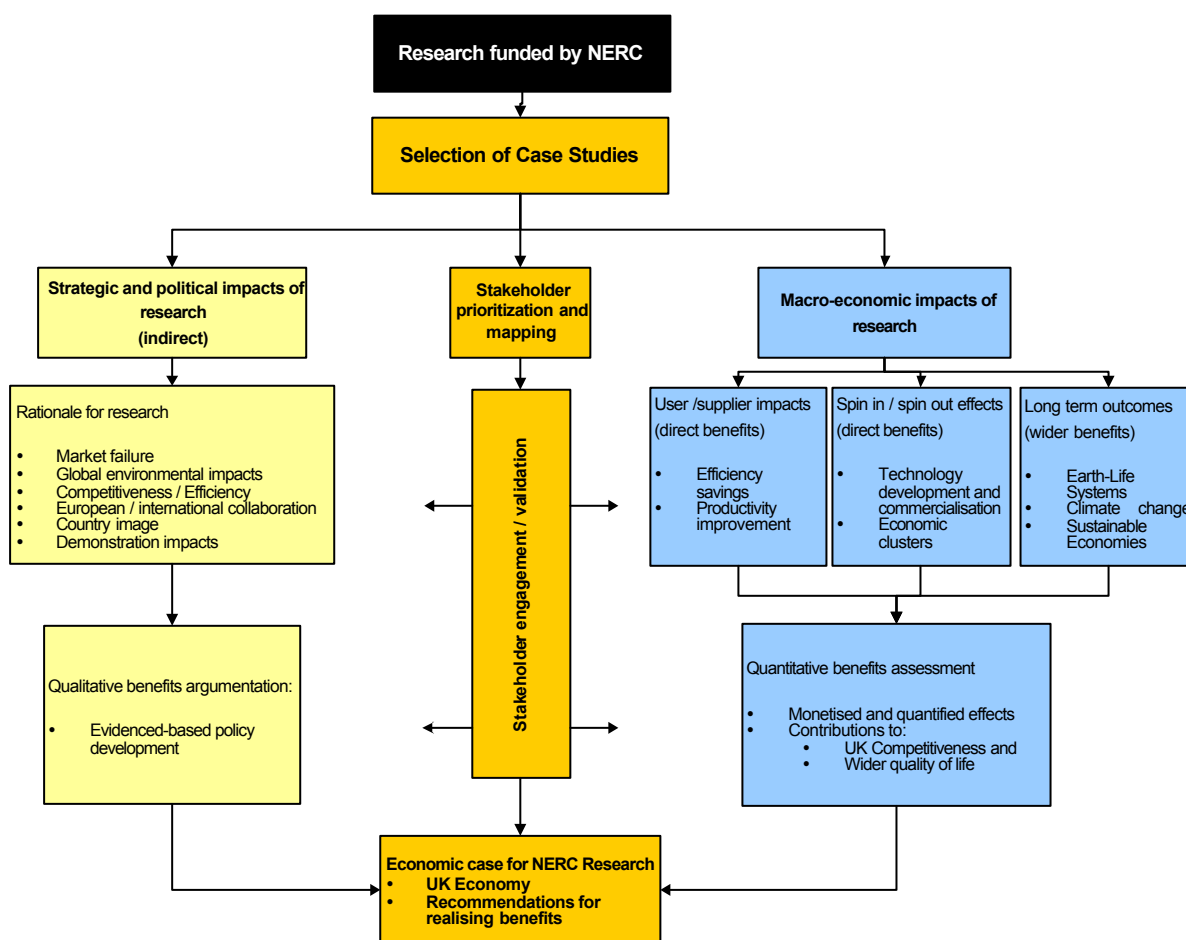
<sup>130</sup> (e.g. inclusive of societal, environmental and other economic benefits)

the academic and scientific communities. These benefits are strategic and/or political in nature and in some cases cannot be appropriately quantified. However, consultation with stakeholders and access to published sources was used to build a credible argumentation of the potential impacts of NERC's research in this area.

- **Wider Benefits:** these wider benefits are linked to quality of life improvements and arise as an outcome of NERC-funded research insofar as it facilitates improvements in decision-making or policy, which in turn delivers positive benefits to the UK economy and to society as a whole. These benefits are generated through the final use and implementation of NERC's research outcomes and solutions to pressing environmental problems.
- **Direct Benefits:** these arise as productivity and efficiency gains for public and private institutions or as increases in competitiveness of the UK economy particularly in the environmental goods and services industry (e.g. spin-out effects). These benefits are generated through NERC's commercialisation of techniques, tools and software.

Figure A.1 below summarises the main components of the methodology.

## METHODOLOGICAL APPROACH



### Figure A.1. Benefits assessment framework

Due to the scale and diversity of NERC's research agenda, it was necessary to select a sample of ten case studies to focus the assessment. Case studies were selected to ensure there was a fair representation of the diverse research that NERC funds. However, they also reflected the main areas of expenditure. It is important to note that the case studies were not selected with the view that they would generate the biggest economic impact.

#### NERC's value chain

As mentioned in NERC's mission<sup>131</sup>, NERC aims to meet users and beneficiaries' needs, thereby contributing to the economic competitiveness of the UK, the effectiveness of public services and policy, and quality of life.

In the context of this, and in preparing for the analysis of how each case study adds scientific value and achieves economic impacts, PwC developed a value chain, see below, which linked NERC-funded research and their outputs to strategic/policy and wider outcomes and/or macro-economic impacts (direct impacts).

Outcomes of research come at different levels and represent different types of strategic and economic benefits. Through funding scientific research and long-term survey work, key outputs are generated such as scientific knowledge and data. These outputs are disseminated for example to policy makers, the scientific and research community, the private sector and the public, or are turned into commercial applications or tools. These outputs then in turn have an impact on the effectiveness of public services and policy, and economic competitiveness, and hence quality of life. This process is encapsulated in the figure below.

As discussed above, different types of stakeholders were consulted to identify NERC's contribution at each stage of the value chain.

Figure A.2 below provides an overview of the generic value chain that PwC used to analyse each case study.

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<sup>131</sup> NERC (2002) Science for a Sustainable Future 2002-2007

# NERC's Value Chain

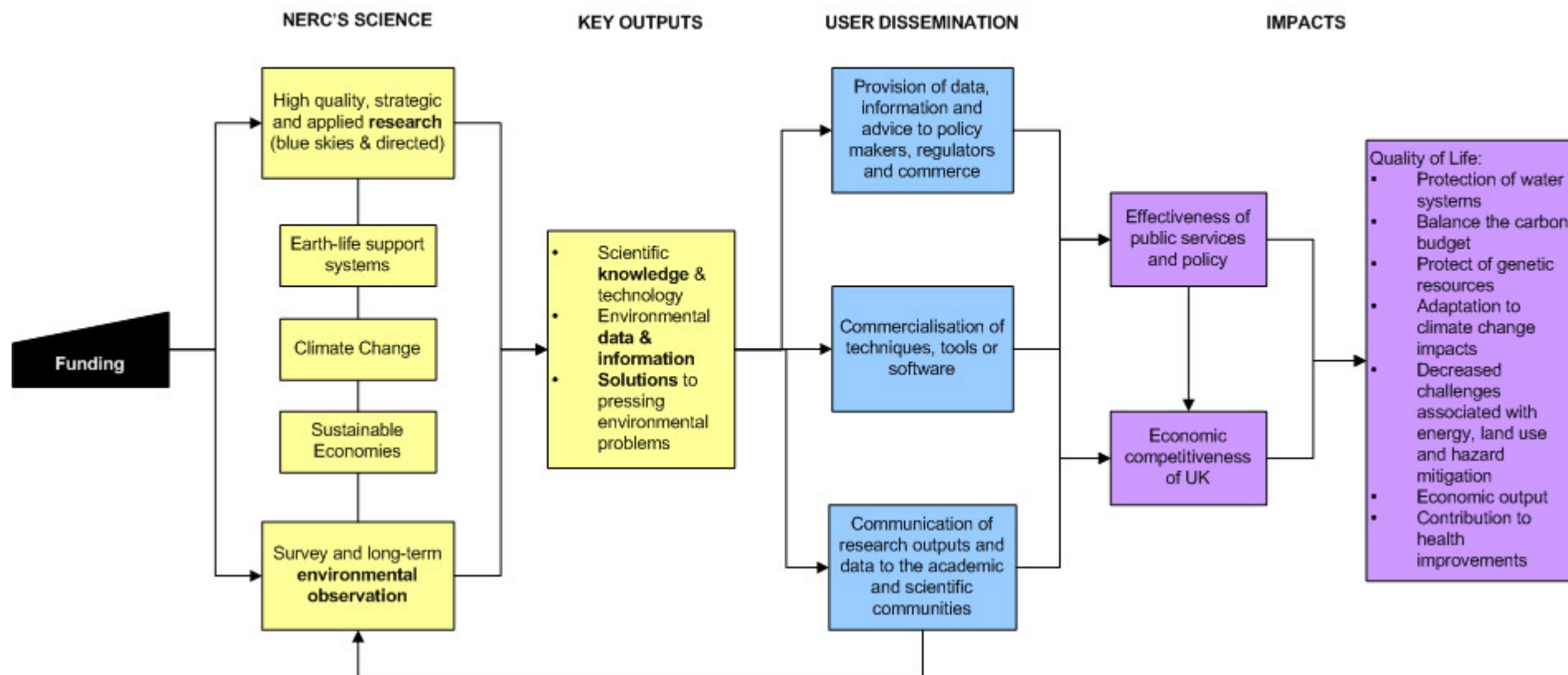


Figure A.2 NERC's Value Chain

## Assessment of economic benefits

In each case study, and where practical, the economic benefits associated with each case study were quantified in monetary (present value) terms. To estimate the wider and direct economic benefits of selected case studies of NERC-funded research PwC developed a NERC economic model. Calculations in the NERC model involve a series of inputs, assumptions and formulae. Many of these perform arithmetical functions to collect and summarise data for use in later steps in the calculations or to provide output statistics.

The NERC model uses a logically coherent family of equations in its core calculations. In each case study, and where practical, PwC has projected the economic benefits associated with each case study in monetary (present value) terms. The key assumptions that were used in this process include:

- **A discount rate of 3.5% real**, which is used in the evaluation of the effectiveness of projects or programmes which receive public sector funding, for the purpose of expressing the present value of benefits generated by NERC expenditure.

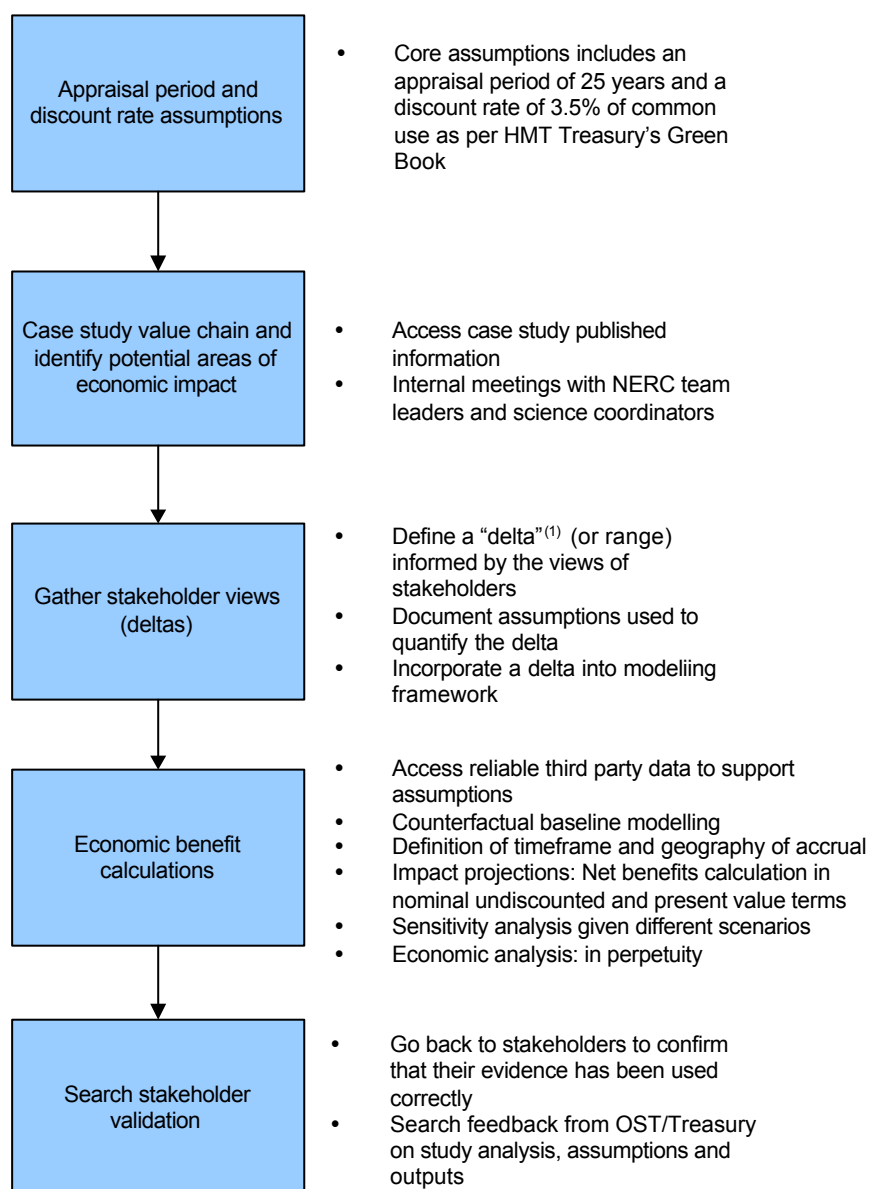
The methodological approach adopted in the course of this study conformed to HM Treasury appraisal standards and protocols. These are set out in the HM Treasury 'Green Book'.<sup>132</sup> The Green Book sets out comprehensive guidance on the methodological approach, which must underpin any robust appraisal. The Green Book specifies a discount rate of 3.5% real for use in evaluating the effectiveness of projects or programmes which receive public sector funding. As such, for the purposes of expressing the present value of benefits generated by NERC expenditure 3.5% was adopted. The Green Book recognises a tendency for projects to be overly optimistic in the quantification of benefits. To redress this tendency, PwC aimed to make an explicit adjustment to the NERC benefit case to reflect any potential bias by using ranges, if suggested by stakeholders due to different assumptions, to identify conservative and optimistic views of NERC's research benefits.

- A key feature is the economic 'return' (or projected benefit) over the **core appraisal period** (assumed to be 2006 through 2030). No terminal values were used in this study to analyse the benefits of case studies in perpetuity given the uncertainty of the impacts of case studies expressed by stakeholders consulted.
- The appraisal of economic benefits is net in relation to a **counterfactual baseline** that assumes the non-existence of NERC-funded research in each case study  
baselines ('counterfactuals') were developed to provide a point of reference against which to measure the net additional economic benefits arising from NERC-funded research. These counterfactuals effectively represent a view of the world without NERC (a 'do-nothing' position).

Figure A.3. summarises the key steps of the assessment process. PwC aimed to follow this process in each of the case studies analysed.

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<sup>132</sup> HM Treasury (2003), Appraisal and Evaluation in Government, HMSO



**Figure A.3. Benefits assessment process**

(1) The extent to which stakeholders interviewed in the course of this study believe that NERC-funded research can contribute towards improvements in policy or practice, which ultimately could deliver an economic benefit.

## Annex B - Abbreviations

AO – Announcement of Opportunity  
BADC – British Atmospheric Data Centre  
BAS – British Antarctic Survey  
BBSRC – Biotechnology and Biological Sciences Research Council  
BCC – Birmingham City Council  
BGS – British Geological Survey  
BODC – British Oceanographic Data Centre  
CCW – Countryside Council for Wales  
CEH – Centre for Ecology and Hydrology  
CFCs – Chlorofluorocarbons  
CH<sub>4</sub> – Methane  
COAPEC – Coupled Ocean Atmosphere Processes and European Climate'  
COMEAP – Committee on the Medical effects of Air Pollutants  
COMET – Centre for the Observation and Modelling of Earthquakes and Tectonics  
CO<sub>2</sub> – Carbon Dioxide  
DGVMs – Dynamic Global Vegetation Models  
DEFRA – Department for Environment, Food and Rural Affairs  
DTI – Department of Trade and Industry  
EA – Environment Agency  
EFTEC – Economics for the Environment Consultancy  
EHH – Environment and Human Health  
EIS – Economic Impact Study  
EPSRC – Engineering and Physical Sciences Research Council  
ERFF – Environment Research Funders' Forum  
EU – European Union  
FEH – Flood Estimation Handbook  
FRA – Flood Risk Assessment  
FREE – Flood Risk from Extreme Events  
FSR – Flood Studies Report  
GANe – Global Nitrogen Enrichment  
GIS – Geographical Information System  
G8 – Group of eight industrialised countries; UK, US, Canada, France, Italy, Germany, Japan, Russia  
GCM – General Circulation Models  
GCTE – Global Change and Terrestrial Ecosystem  
IGBP – International Geosphere-Biosphere Programme  
IPCC – Intergovernmental Panel on Climate Change  
JIF – Joint Infrastructure Fund  
JNCC – Joint Nature Conservation Committee  
LOCAR – Lowland Catchment Research  
MAFF – Ministry of Agriculture, Fisheries and Food  
MET – Meteorological Office  
M&FMB – Marine and Freshwater Microbial Biodiversity  
MOD – Meridional overturning circulation  
MRC – Medical Research Council  
MRSA – Methicillin-resistant Staphylococcus Aureus  
NERC – Natural Environment Research Council  
NOAA - National Oceanic & Atmospheric Administration

N<sub>2</sub>O – Nitrous Oxide  
NSF – National Science Foundation  
ODPM – Office of the Deputy Prime Minister  
O<sub>3</sub> – Ozone  
PMG – Programme Management Group  
PM<sub>10</sub> – Particles smaller than 10µm in diameter  
POST – Parliamentary Office of Science and Technology  
PwC – PricewaterhouseCoopers  
QUEST – Quantifying and Understanding the Earth System  
RAPID – Rapid Climate Change  
RDC – RAPID Data Centre  
RSPB – Royal Society for the Protection of Birds  
SAC – Science Advisory Committee  
SBRI – Small Business Research Institute  
SEPA – Scottish Environment Protection Agency  
SERAD – Scottish Executive Environment and Rural Affairs Department  
SMURF – Sustainable Management of Urban Rivers and Floodplains  
SNH – Scottish Natural Heritage  
TCD – Terrestrial Carbon Dynamics group  
THC – Thermohaline circulation  
TIGER – Terrestrial Initiative in Global Environmental Research  
UKCIP – UK Climate Impacts Programme  
UKWIR – UK Water Industry Research  
UNFCCC – United Nations Framework Convention on Climate Change  
URGENT – Urban Regeneration and the Environment  
UV – Ultra Violet  
WFD – Water Framework Directive  
WMO – World Meteorological Organisation  
WTP – Willingness to pay