Annex 1: Areas for which selection of the available evidence will be made available to the tendering bodies .

This Annex contains the titles (in *Italics*) of the case studies/group of case studies available in the impact data base, and a short description of what they are about. It also proposes groupings (but alternative clusters are a possibility, as many belong to more than one category)

Air pollution

NERC's Impact Data Base contains a large number of case studies relevant to air pollution. Below, a non-exhaustive list is provided.

- *Air pollution – Indoor contamination flame retardants chemical Hexabromocyclododecane (HBCD):* Research from Birmingham (Harrad) contributed to the 2013 decision by the UN Environment Programme Convention on Persistent Organic Pollutants to ban Hexabromocyclododecane (HBCD), and informed Defra's stance on this matter. HBCD is a flame retardant of significant concern from a health perspective.
- *Air Pollution – Ozone- The role of Master Chemical Mechanism – University of Leeds*. Leeds generated a model that describes the chemical reactions that lead to the formation of ozone pollution in the lower atmosphere. The model started being built in 1993 and it is now the golden standard model against which simpler, operational models are assessed. The model allowed the UK to have a strong position in negotiations over air quality directives in the EU and avoid further restrictions being introduced under the 2004/42 Directive.
- *Air pollution and weather forecasting - University of Manchester*
  Research from Manchester (CEEREC) has investigated the damage done by nitrogen oxides, acid rain and ozone to semi-natural habitats, and the potential for habitat restoration. This has led to the application of the concept of critical loads. This research has also contributed to the UK Review of Transboundary Air Pollution.
- *Air Pollution Information System (APIS) & Ammonia emissions from livestock - SCAIL - a new model*
  Information on Nitrogen critical loads is also collected by CEH in its data base APIS. Decision makers use this data base to grant/not to grant permissions for specific industrial sites with significant emissions of reactive nitrogen (incinerators, large pig farms, etc), when these activities can affect Natura 2000 sites.
- *Air Pollution measurement with Spatial Light Scattering (SLS) -University of Hertfordshire.*
  Herfordshire university has developed spatial light scattering instruments that are used to monitor air pollution, in particular asbestos fibers and emissions from incinerators
- *Air Quality - Standardisation Measurement Instruments - NOx O3 PM -University of St Andrews.*
  St Andrew Univ. established reliable techniques to measure NO_2 for a national protocol and to quality the relationship between $PM_{2.5}$, O_3, and hospital admissions/deaths. Improvements in NO_2 measurements are taking place, while the research on $PM_{2.5}$ and O_3 is finding its way in government reports. Importantly, this research showed that a considerable part of $PM_{2.5}$ is not due to fossil fuel and this will be reflected in policies.
- *Air quality in extreme events - Natural emissions and ozone - York – REF*
  University of York has highlighted (in 2003) how extreme heat can lead to the release by plants of VOCs that can lead to peaks in O_3 during the summer. This mechanism has been incorporated into the Met Office forecast for O_3, helping those who suffer from high level of

O_3. This natural mechanism is also relevant to the assessment of the UK policies w.r.t. air pollution directives (that is: if the limits set in directives are exceeded because of extreme heat, this does not indicate that the policy is not working).

- *Air quality management improvements - University of the West of England - REF.* University of West England has engaged extensively into the evaluation of national and local policies for air quality management. This has led to the improvement and increased effectiveness/reduced costs of these policies. The research has also led to the creation of the Institute of Air Quality Management, dedicated to the improvement in training of air quality workforce.
- *Air quality network of sensors* (2010-2014) are also relevant (lower costs) but a bit early days.
- *Air Pollution - Long range Transboundary Air Pollution - CEH- Centre Eval*. CEH monitored long range air pollution issues and informed the UK policy on trans-boundary air pollution.
- *Fast isoprene sensors used on marine plants:* these sensors made identification of VOCs cheaper.
- *Time line – CEH and acid rain:* provides a time line description of the Air Pollution – Long range transboundary Air Pollution story
- *Health – Assessing urban air quality impact on lung tissue* gives some evidence of involvement of NERC researchers in the understanding of the physiological basis of health damage
- *Incinerators, nanoparticles and network*: provided evidence that allowed Defra to decide nanoparticles from incinerators were a non-issue.
- *Heavy metal - Mercury in the environment and policy - University of Oxford*. This and other case studies under the 'Heavy metals' title provide an overview of NERC's research on heavy metals and mercury
- *Heavy metals- Moss research proves that pollution drops as emissions fall*. Showed reductions in heavy metals pollution
- *Nitrogen* - Finding the most efficient and cost effective way of tackling local nitrogen pollution. There are a few case studies, but impact has never been described comprehensively. A potentially interesting story, but it would require some work to gather the evidence. This could be coupled with some of the case studies under the *Ozone* title (those not referring to the Ozone hole) but, again, this is likely to require addition work to understand the impact of the science, before evaluation is possible.
- *Human health - hay fever Worcester*: provides an overview of the contribution to the forecasting of pollens and to the benefits that improved forecasts have generated for Asthma sufferers.
- *Volcano Flouride Monitoring – CEH* illustrates the actions undertaken by CEH with regard to the monitoring of potentially toxic fluoride emitted by volcanoes.
- *Waste: managing bioaerosol emissions from commercial composting* – NERC helped identify issues with regards to emissions from composting.

<u>Biodiversity & Conservation</u>

- *Agri-Environmental schemes monitoring – CEH – Centre Eval.* Demonstrates how CEH contributed to the shaping of the agri-environmental schemes.
- *Amphibian and reptile survey protocols- Kent*. Changes in the way the survey are undertaken led to results which carry more weight and lower costs.
- *Biodiversity – Heathland and moorland conservation land management – Univ. Liverpool*: illustrates the contribution that NERC funded research made to the management of moorland. It could possibly be linked either to case studies on water colouring or on habitat management (including agri-environmental schemes)

- *Biodiversity – influencing practice on floodplain meadow – Open university*; it influenced guidelines for nature conservation from the Environment Agency. A link could be perhaps made with the Agri-environmental schemes.
- *Biodiversity - Large Blue butterfly (various versions)*: NERC science allowed to re-introduced it after it went extinct despite a century of failed conservation efforts.
- *Biodiversity – Pollinator conservation – Government policy and Public Practice:* looks at how research on pollinators led to changes in the scientific paradigm within which pollinators conservation is undertaken, as well as to changes in biodiversity conservation, which were also implemented by gardeners (hence, it could be linked to the BUGS case study as well as to the Large Blue butterfly)
- *Bird conservation - conservation policy for red-billed choughs in Scotland* provides evidence of how research led to the creation of a protected area.
- *Citizen Science – CEH – Centre Evaluation:* shows the importance of data collected by citizens and, also, of the Biological Record Centre
- *Coastal management geodiversity and biodiversity:* influenced management of coastal habitat in Scotland
- *Conservation – Development of the landscape scale approach* Conservation effort and strategy influenced by the landscape approach developed by Univ of York personnel
- *Conservation – Model helps Balance Coastal bird conservation and needs of society*: the approach allows to avoid the Precationary Principle when this would lead to the decision not to go ahead despite no actual damages and allows to prevent projects which actually are harmful. This case study could perhaps be linked to the one on TBT, as both have application to shellfish farming & biodiversity.
- *Conservation – protection of grassland fungi:* research led to the institution of new SSI and new guidelines for the conservation of mushrooms
- *Invasive species (various case studies)*: biosecurity guidance issued to EA and Parks, making it more effective and less time consuming. Conker tree citizen science used to save money on data gathering. Mink eradication process based on citizen science and voluntary sector. Surveillance on INNS through DAISE reduces costs to the UK and leads EU policy (including the recent decision by the EU to use a list of INNS essentially produced through DAISE as the list for INNS)
- *Lake ecosystem protection case study – Liverpool –REF* Saltwater damage avoided in the area under the Broad Authorities. Possibly saving remediation costs
- *Lake restoration – CEH Centre Evaluation* (various versions). Provides evidence of research contributing to the avoidance of loss of tourism and fisheries' income
- *Monitoring Environmental Change – CEH Centre Evaluation /Land Cover Map – Details of UK habitats revealed*: these two case studies show how the Land Cover Map has been used for many decisions, including Making Space for Nature, Foresight Land Use Futures Project, UK National Ecosystem Assessment (NEA), the Review of Transboundary Air Pollutants (RoTAP) (2012), the UK Biodiversity Indicators for reporting on progress towards Convention of Biological Diversity Aichi Targets, the Natural Environment White Paper (2011) and the Climate Change Act.
- *Marine mammals:* there are a few case studies about disturbance and standards setting relevant to the renewable energy sector (this also includes the case study about SMRU)
- *Marine protected areas (various)* – thermal fronts have been used to save on costs of establishing marine reserves. Also, information on cold coral reef has contributed
- *Marine Strategy* (various versions): these case studies showed how NERC contributed to the development of the Marine Strategy (both in the UK and at a EU level). NERC science also contributed to information used to assess whether the UK is achieving the quality targets that have been set out.
- *Nanotechnologies safety in fisheries and aquaculture* – mainly about human health, but it provided a way to test whether nanotechnologies are safe or otherwise

- *New statistical tools for ecologist – Kent*: it illustrates the gains in efficiency brough about in conservation work by the availability of new survey methods and of new statistical approaches. It could be linked to the survey of amphibians and reptile or to case studies on software development (e.g. PRIMER-E, used to decide on infrastructure such as renewable or DEPOMOD, used to grant consent to fish farms)
- *Oestrogens – Water quality – Endocrine Disrupting Chemicals – Exeter*. This, together with other case studies listed under 'Oestrogens' provides an overview of the research that led to the discovery of adverse effects of oestrogens on ecosystems. However, as this will likely lead to increased costs for water companies, it's unlikely it will make a strong case study.
- *Peat code – Paying for Nature's Services* : provides evidence on the role of a NERC funded researcher in facilitating the adoption of the peat code, as the key example of payment for ecosystem services in the UK
- *Peatland and upland water – South West Water*: a list of research collaborations with South West Water on their Upland Thinking project
- *PES – Bolivian Reciprocal Watershed Agreement*: demonstrates the provision of an alternative scheme that was used by the Bolivian government to preserve ecosystems
- *PES Fowey Auction*: there are some examples of a payment for ecosystem services funded by NERC for SWW that was very successful, both with the company and with Defra
- *Pesticides impact of historic and recent work at NERC*. Shows how research done by NERC led to the ban on DDT and other pesticides, and this led to the recovery of the Peregrine Falcon population in the UK (it was affected through DDT causing egg thinning and failures)
- *Systematic reviews of environmental research in policy making*
- *Timeline – UK National Ecosystem Assessment:* provides an overview of the contributions to the UK Ecosystem Assessment that has been used in the White Paper on the Environment.
- *Water and Water Framework Directive:* filed under water or WFD are a host of case studies on water and ecosystems. These could sit either
- *Wildfire and water resources/Wildfire – Improved Hazard Assessment – Swansea/Wildfire management in the UK.* These case studies collectively show the role of NERC funded research in reducing wildfires and improving the effectiveness of the Fire Brigades.

Carbon Emissions & Carbon policy

- *Carbomap:* is a spin-out providing carbon maps. (Probably still too early & would need going back to PI, plus no public savings so far)
- *Carbon – cumulative emissions and policy – Oxford – Allen:* Oxford research contributed to the acknowledgement that it is cumulative emissions that matter, This went into the 5th IPCC Report and helped the UK government shape international policy.
- *Carbon Calculator over the Life Cycle of Industrial Activities*: the software allows life cycle analysis of carbon emissions, at minimum cost (joint with EPSRC)- it led companies to reduce emissions & was supported by TSB and Defra.
- *Carbon Sequestration (various case studies):* these case studies provide some initial evidence on work related to the carbon sequestration ability of forests: on the amount of carbon stored in forests, as well as on the key determinants of the release/sequestration of carbon within forests. Most case studies are early stages, but offer an interesting insight in what could be future impact. The case study which is more directly relevant to the UK is: *Carbon sequestration - Major review of how land use might affect the 90 per cent of UK land-based carbon held in soils*. Also relevant are the calculations NERC did in house on the benefits of LULUCF data, summarised in *Carbon Sequestration - CEH - LULUCF Impact.* The data behind LULUCF come, in turn, from the Countryside Survey. There are two documents in the data base that explain the impact of the countryside survey (both named *countryside survey*).
- *Peatland (various case studies)*: these are mainly about addressing water colouring issues that UK water companies have to address

Climate change

- *Climate change and biodiversity*: (2 case studies) long term data have informed the making space for nature policy & IPCC's 5th Assessment. Subsequently the research was used by NE to provide guidelines on conservation and gain in efficiency
- *Climate change impact on crops*: simulations at Reading guide adaptations to higher concentrations of CO2 and highest temperatures for farmers. It also informed DECC for negotiations.
- *Climate Change - Reducing Impact of Agriculture - Cool Farm Tool*: the tool allows farmers to reduce their emissions and to implement targets (often as a result of their customers, mainly in the retail sector)
- *Climate Change – IPCC (various)* there are a number of case studies illustrating the substantial impact of NERC research on IPCC. This also includes: *Climate Change – Carbon accounting.* However, we have never told this story in a complete way, tracking all the NERC contributions to IPCC, as this is quite challenging. Moreover, it's likely to result into international impact, rather than UK impact).
- *Climate change -LULUCF*: CEH's role in quantifying carbon captured by vegetation and soil
- *Climate change uncertainty and infrastructure* Research at Durham underpinned the quantification of uncertainty in the UKCP09

Contaminated land & Waste

- *Bioaccessibility testing of Contaminated Land DTZ*: an economic evaluation of the contribution for *Contaminated Land testing*

- *Bioremediation* – a smart molecule to understand what amount of pollution poses a threat to humans and hence tailor the remediation action. Impact needs updating before evaluation.
- *Contaminated land – Choosing natural attenuation saves millions*. Illustrates instances in which the natural environment can take care of itself. The adoption of the method means there is no need to carry out land remediation.
- *Contaminated Land Assessment Remediation Technology (CLARET) for monitoring brown field sites:* a visualisation technology developed by BGS to identify which areas are affected by subsurface contamination. Impact needs re-assessment
- *Contaminated land testing saves money for local authorities and industry*: Already evaluated in the Bioaccessibility testing of Contaminated Land – DTX case study.
- *G-BASE - Geochemical Baseline Survey Applied geoscience for decision-making in London and the Thames basin*: data showing the amount of contamination in land and whether it can be absorbed by people (hence whether remediation is needed)
- *Groundwater- new remote monitoring technology helps manage water supplies, pollution and hazards* – this case study illustrates how a technology developed by BGS can be used to monitor pollution in groundwater, helping remediation work. There are also other case studies which illustrate a variety of contributions to groundwater management from NERC science. Most are mainly focused on the science, rather than on science impact.
- *Heavy metals - Mercury in the environment and policy - University of Oxford.* Illustrates howa group in Oxford influenced UNEP's framework to deal with redundant mercury. This in turn influenced many countries' policies, including the UK stance on Minamata convention and EU policy.
- *Heavy metals (various case studies)*: there are a host of other case studies on heavy metal, but the best are *Heavy metal chemistry predictions in water and soil* and *Heavy metals – Moss research proves that pollution drops as emission falls*. Nonetheless, their focus is still on the science.
- *Incinerators, nanoparticles and networks.* Shows that incinerators nano-particles emissions are OK: no need to spend (see air pollution). What happened after this evidence was provided is not yet highlighted.
- *Waste: managing bio-aerosols from composting*: evidence for decision making, EPSRC and EA co-funding. Impact could be measured by looking at the amount of composting plants that operate in-door and at the total number of composting plans permitted before/after the guidance.

<u>Defence</u>

- *Defence Applications NOC Centre Evaluation*: NOC contributied to the development of Unmanned Marine Vehicles, modelling of the ocean used for Nuclear Submergibles, etc
- *DSTL case studies*: various: Air particles, bio-luminescence, depleted uranium, magnetism and mine clearances
- *Earthquakes*- monitoring and seismic hazards: the monitoring of earthquakes can also be used to monitor nuclear experiments
- *Lab on a chip* – New generation of micro sensors for monitoring ocean acidification: could have defence applications but very early days/should be checked with scientist.
- *Technologies NOC Centre Evaluation* includes information on NOC technologies with applications in defence
- *Unmanned marine systems*: provides further information on NOC technologies

<u>Energy (renewable, CCS and Nuclear)</u>

- *Bioenergy/biofuel:* there are a few case studies but none is actually very strong.

- *Carbon Capture and Storage*: various scientific contributions reflected in a number of case studies, demonstrating it is feasible/safe, but little that has been applied, as it's still too early.
- *Conservation – Model helps balance coastal bird conservation and needs of society*. This case study shows application to off-shore energy and other infrastructure, with regards to the risk
- *Data – the value of NERC's data*: an internal analysis of a large number of case studies relevant to data trying to put a value on them.
- *De-risking the Growth of Tidal Data*. Illustrates and evaluates in economic terms the activity undertaken by SMRU to facilitate the approval of tidal energy project
- *Eavesdropping device protects whales and dolphins during seismic surveys*. A very short description of scientific work relevant to mammals' interaction with noise sources.
- *Energy Atlas for the UK launched online* (for renewables)
- *Energy modelling informs decarbonisation policy – UCL.* The MARKAL model has influenced a number of policy decisions
- *Environmental Outreach to Business and Community – Keele* presents some business engagement and some development in renewable/unconventional energy
- *Geothermal – Geoenergy Durham*: a spin-out working in the geothermal energy space.
- *Geothermal Energy East Africa- Biggs*: provides evidence on work prof. Biggs did that is benefitting geothermal development in Africa. (see also: *Volcanoes risk Bristol Biggs*)
- *Geothermal write up – BGS IRETHERM*: mainly potential impact for geothermal development in Glasgow.
- *Marine mammals* (*Marine mammals and offshore renewables/Marine Mammals disturbance – changing management)* two related case studies on marine mammals and energy. Probably best coupled with case studies such as those on SMRU.
- *Marine Renewables – CSR Final tides*: the case study illustrates the role of science in assessing a tidal barrage in the Mersey estuary that did not go ahead on economic grounds.
- *Marine renewables – Turbolence Research Aids Resource Exploitation*: the case study illustrates how research on turbulence has made it less expensive to locate renewable farms
- *Noise and marine renewable* – Bristol: gives evidence on work relevant to noise disturbance on marine mammals
- *Nuclear energy – enhancing public understanding of nuclear safety issues*
- *Nuclear Energy - Keeping the nuclear option open*: illustrates activities to make sure the nuclear energy option was not completely lost from the UK energy system.
- *Pilio Ltd – NERC supported spin-out provides software to help reduce and control energy use* (could perhaps be coupled with the Carbon Calculator over the Life Cycle of Industrial Activities case study)
- *Primer-E* a software that has been used to grant consent to off-shore renewable energy sites.
- *Radiation and radioactive waste (various)*: there are a number of case studies relating to the protection of animal and human from the risk of radiation and on the management of radioactive waste (noting though that a repository is yet to be identified)
- *Renewables; Carbon Calculating Tool/ Renewables – land management – biomass renewable energies and carbon sequestration.* Shows what are the carbon costs associated with renewables, helping the decision process
- *Renewables – Test Protocols for Tidal Current Energy Converters – Edinburgh:* test protocols enable the diffusion of renewables
- *Sea bed resources – BGS*: an understanding of the sea bed is necessary to decide what gets where on the sea
- *Seafloor Mapping NOC Centre Evaluation*: similar to the sea bed resources from BGS (the two worked together)
- *SMRU (various)*: SMRU demonstrated how marine mammals were not significantly affected by marine currents turbine and this research was crucial to getting approval

- *Tidal data uses NOC Centre Evaluation* NOC's measurement of tides are key to tidal energy and infrastructure developments.
- *Weather forecasting for medium term and energy* – weather forecasting has been used to predict the demand for energy and optimise the supply
- *Wind farm do not cause coastal erosion* – NOC research showed that wind farms do not cause erosion, saving companies from the need to monitor erosion and, hence, saving them money.
- *Wind farm science contribution to policy* – not a case study, but a EU document about permitting wind farm development in protected areas. It would be interesting to look at which papers are NERC funded, amongst those listed in the bibliography.

<u>Food</u>

- *Agriculture – reducing footrot in sheep- Warwick*
- *Agri-environmental schemes monitoring (CEH)*: it informed their development over a long time period. It links with the Country Side Survey, which was recently reviewed by Defra.
- *Agrifood metastudy*: a meta-analysis of case studies available to NERC, done before the REFs and the Impact Award case studies were filed.
- *Air Pollution and acidification – protecting and restoring ecosystems – Manchester*: relevant to the permissioning of activities, including animal farming (see APIS and Ammonia)
- *Air Pollution Information System- APIS:* used to inform permission on activities including animal farming
- *Ammonia emissions from livestock*: used by SEPA to decide on permitting (see also Air Pollution Information System- APIS)
- *Animal health and welfare – parasite management – Bristol*
- *Aquaculture – balanced harvest model underpin new sustainable fisheries policy*
- *Aquaculture - Harmful Algal Bloom Monitoring Programmes - University of the Highlands and Islands* (it could also be linked to the nitrogen and water pollution case studies that cause algal bloom)
- *Aquaculture - Impact of fish farming on wild populations*
- *Aquaculture - Satellite monitoring of Harmul Algal Blooms.* Monitoring of harmful algal blooms allows farmers to save money by not losing stock
- *Aquaculture -Regulating Standards and Growth in Scottish Fish Farming (DTZ)*
- *Aquaculture/DEPOMODE (various versions)*: as it saves SEPA money and effort in permitting
- *Bee-plants interactions* (but possibly better as agri-env schemes or as biodiversity: there is little food component) (there are also other case studies on bees)
- *Biodiversity – Gardeners help understanding nature in the garden (BUGS) (various versions)*
- *Biodiversity and food production, is organic farming the answer?* Advice used in the Common Agricultural Policy
- *Biofresh*: a spin-off that found a way of using O3 to preserve food
- Bio-pesticide: RELU/BBSRC/NERC Research facilitated the regulation
- *Biopesticides – Jasmonic Acid – increased yields from improved pest control.* Seed treatment with Jasmonic acid provides crops with pest protection
- *Biopesticides (various)*
- *Blowfly (various versions):* NERC contributed to analyses demonstrating that blowfly are not just transported by prevailing winds, but are quite capable of flying in certain directions. However, their range is more limited than previously thought.
- *Bluetongue and modelling of Midge behaviour (various versions)*
- *Climate change and biodiversity*
- Climate change impact on crops (climate change and crop modelling): understanding what adaptation is need translates in cutting costs

- *Climate change impact on crops (various versions)*
- Combating environmental and food chain viruses
- *Conservation – Model helps balance coastal bird conservation and needs of society*: this model has been used in shellfish farming.
- *Conservation – protection of wild bumblebees against imported parasites* relevant to pollination issues; this research changed guidance from Natural England on imports
- *Cool Farm Tool - Climate change Reducing Impact for Agriculture (plus other versions)*
- *Country Side Survey* - policy assessment by Defra (also relevant to air pollution, planning and biodiversity)
- *Data the value of NERC's data:* an internal report for a number of areas
- *Diffuse Pollution risk mapping for targeting mitigation measure;* an early impact case study on SCIMAP. A later one is offered by the REF case study: *Diffuse Pollution and Flooding - SCIMAP - University of Durham*
- *Drought monitoring – Food security _ Remte sensing*
- *Ecosystem approach – improving agri-environmental schemes - Exeter*
- *Examining ancient organic residues* (various versions relevant to food fraud prevention) – to be developed
- *Fences help clean up livestock pollution of rivers*: a shallow case study, but it can be linked to the Diffuse Pollution topic
- *Fertilisers fingerprinting* (to detect organic and non-organic food)
- *Fisheries and bird monitoring* (protecting fisheries and birds before they collapse)
- *Fisheries –fish stock monitoring*
- *Food - John's Ingram analysis* for an in depth analysis of NERC relevant activities (but less focused on the impact)
- *Food fraud detection – seafood fisheries forensics*: a DNA barcoding test allows to reveal fraud in fish labelling (pre-processed cheaper fish sold as if it were higher quality fish)
- *Food fraud detection in meat – University of York*: a technique used in archaeology has allowed the Food Standard Agency to detect fraud in frozen meat.
- *Food quality assurance*
- *Food security and sustainable agriculture – Leeds* (needs to be followed up on the actual impact, as it currently presents only outcomes)
- *Food security- Impact of agriculture on the way crop plants interact with fungi – Bulmers*
- *Foot and Mouth*: BGS advised on how to safely dispose of the animals that had to be culled during the foot and mouth epidemic in 2001
- *Isle of May (various versions)* these data allowed to close the sand eel fisheries and prevent the collapse of other fisheries as well as of the bird population
- *Millet considered by Unilever for climate adaptation*
- *Nanoparticles* (two case studies): research shows they are no threat to aquaculture or human health and this research has influenced the regulation
- *Nitrogen (various versions):* these could be linked to the ones on ammonia, as there are overlaps.
- *Ozone and vegetation*
- *Peat code – paying for Nature's Services – Reed - Birmingham/PES Fowey (various versions)* illustrates how research helped develop and implement payment for ecosystems in the UK, which are part of the White Paper on the Environment.
- *Pesticide*: research on the Peregrine falcon leads to the withdrawal of DDT for agriculture
- *PhD Case Study _ James Bullok ecosystem services*: another case study on payment for ecosystem services
- *Phytoplankton productivity – New technology for estimating*: is a case study relevant/linked to harmful algal bloom and phytoplankton work that was used to demonstrate the UK sea is not

in breach of water quality directive (case study: *Water pollution – Phytoplankton research defines sustainability*)

- *Primer-E* a statistical software that has been used to assess water quality by EA, so could link to other similar software.
- *Sheep scab risk factors* research identifying the factors behind the risk of scab in sheep (but actual impact to be checked)
- *Shellfish Aquaculture and antifoulant*: research allowed the take-off of shellfish industry (oysters) which were the subject of public investment but depressed by TBT
- *Soil erosion – land and water management University of Exeter (various versions)*: research used by Defra for catchment management
- *UK NEA diagram of impact* provides a summary of the research that went into the UK NEA and of its impacts
- *Upland sustainability – stakeholder academic co-learning* related to peat conservation, water catchment management and food production
- *Water pollution – developing modelling tool for integrated water catchment*:
- *Weather forecasting for livestock disease*
- *Volcanoes fluoride monitoring*: fluoride could make pastures poisonous. Monitoring during Icelandic explosion revealed no issue.

Health (human and of the ecosystems)

- *Agriculture – preventing infectious livestock diseases*
- *Air pollution/air quality (various case studies)*
- *Algal blooms in rivers*
- *Amphibian pathogens*
- *Animal health and welfare – parasite management*
- *Aquaculture – Harmful Algal Bloom*
- *Aquaculture – Salmon farming – using behaviour modifying chemicals to control sea lice*
- *Bioaccessibility testing of contaminated land*
- *Bluetongue and modelling of Midge behaviour*
- *Climate change – Adapting to Impact on Birmingham's urban heat island.*
- *Combating environmental and food chain viruses* (weak)
- *Contaminated land testing saves money for local authorities*
- *Disaster – improving resilience through disaster and development research*
- *Drinking water – improving security of supply* (weak)
- *Electronic nose* (quite week)
- *Food fraud detection*
- *Food quality assurance*
- *Food security and sustainable agriculture*
- *Foot and mouth*
- *Fracking safety and groundwater*
- *G-BASE* (two case studies, neither very strong)
- *Genetic for Saving Species and Infectious Diseases*
- *Geological disposal of radioactive waste*
- *Health* (various case studies)
- *Heat waves and climate change adaptation*
- *Heavy metals (various case studies)*
- *Human health – hay fever*
- *Incinerators, nanoparticles and networks*
- *Information products from BGS*
- *Microalgae for biotechnologu*

- *Monsoon in Africa – AMMA*
- *Nanoparticles- CEH*
- *Nonoparticles – Exeter*
- *National River Flow Archive*
- *Nematodes as novel vector nad reservoirs of human pathogens*
- *Oestrogen* (various case studies, but a bit early days)
- *Ozone and vegetation CEH*
- *Ozone Hole* (various case studies)
- *Pesticides impact of historic and recent work at NERC*
- *Radiation – Depleted Uranium assessment*
- *Radiation Recovery Handbook*
- *Radiation risk assessment to wildlife*
- *Radioactive waste BGS* (two versions)
- *Radon gas risk*
- *Tsunami modelling/Tsunami risk from very large volcanic*
- *Volcanos* (various case studies – best summary: *Volcanos – high level – final v(2))*
- *War veterans test negative for depleted uranium*
- *Waste – managing bioaerosols*
- *Waste – reduced bioaerosols emissions*
- *Water pollution – INCA modelling tools for integrated catchment*
- *Water pollution – Phytoplankton data inform marine policy*
- *Water pollution Phytoplankton research defines sustainability and saves £6bn*
- *Water pollution monitoring – fish gills work with Environment agency*
- *Water quality- Influencing International Health Policy to reduce Waterbourne Diseases*
- *Water colour carbon peat*

Ozone hole

- *Ozone – measuring chlorine isotopers in the high atmosphere could help track use of illegal CFC*
- *Ozone – Montreal protocol has protected the ozone layer*
- *Ozone Hole – An account from the NERC scientist who discovered it*: the first discovery of the Ozone Hole was achieved by a researcher working at NERC's British Antarctic Researcher, Joe Farman
- *Ozone Hole – monitoring of octofluorocyclobutane in the troposphere*
- *Ozone Hole – Ozone Depleting Alogens in the atmosphere and infrastructure – York*: research by York has used satellite to identify natural sources of production of bromide, helping reconcile the observed data with the emissions
- *Ozone Hole – research and international policies to control ODS – Cambridge – Pyle* (three versions, including the NCAS one): research contributed to changes in the Montreal Protocol, to achieve the more rapid phase out of a range of Ozone Depleting Substances. The case study 'Ozone Depletion- Scientific assessment – NCAS – Pyle' covers approximately the same topic.
- *Ozone Hole – Use of CARIBIC data to determine the source of trace gases and aerosols in the UTLS region*
- *Ozone Hole and Global warming – Halocarbon impact – University of East Anglia*: research has led to further restriction being put on bromide from halons and of methyl-bromide, leading to a decrease in their atmospheric concentration

- *Ozone Hole and Greenhouse gases – Bristol:* work carried out by Bristol helps DECC to monitor UK and word-wide emissions of climate altering and ozone depleting gases.(here, however, NERC only contributed in recent years, so had limited impact)
- *Ozone IOP case study*: this case study provides time-lines on the discovery of the Ozone hole and on the policies that ensued.

Risks management (both for the financial sector and the public sector, excluding flooding)

- *African farmers and Insurers benefit from satellite data*
- *Agriculture – Preventing Infectious Livestock Diseases*
- *Aquaculture – Depomod case study*
- *Aquaculture – Harmful Algal Bloom*
- *Climate change- adapting to Impact on Birmingham's urban heat island*
- *Climate change – concept of tipping points*
- *Climate change – cutting uncertainty in regional climate predictions*
- *Climate change – Improved policy and planning via Evaluation of Models*
- *Climate change – IPCC – NERC data influence negotiations*
- *Climate change – risks – insurance Lloyds- Daron*
- *Climate change – supporting policy through the assessment of the consequences of climate change*
- *Coastal management geodiversity and biodiversity- Univ of Glasgow*
- *Conservation – Model helps balance coastal birds conservation and the needs of society*
- *Deliberation in science governance – public engagement*
- *Diffuse pollution and flooding*
- *Drought monitoring – Food security – remote sensing of rainfall*
- *Earth observation – Fire radiative power – Wildfires and quantification of smoke emissions*
- *Earth observation – models enables use of EO to monitor climate change and land management*
- *Earthquakes – improved hazard mapping (monitoring of L'Aquila, overseas earthquakes monitoring BGS,)*
- *Entice (on salting and transport risks: it could sit under transport)*
- *Extreme events management - Oxford*
- *Extreme weather – Windstorms and sting jets*
- *Extreme weather- Hurricanes in the US and Windstorms in the EU (but this is more for industry, mainly financial: the case studies' focus is on Plcs, not the public sector. The exception here is the sting weather example)*
- *Extreme weather services benefitting industry and humanitarian relief*
- *Fishereries – recovery of cod stocks*
- *Flooding: (various but suggest to leave out, or develop as a specific theme, but see Annex 2)*
- *Fracking safety and groundwater*
- *Improved seasonal forecasting for the UK*
- *Invasive species – citizen science to record wildlife*
- *Marine – Coral Reefs – Cost effective restoration strategies*
- *Marine mammals disturbance – changing management*
- *Ocean Acidification – consequences and natural analogues – CCS leakage*
- *Radioactivity management and monitoring*
- *Risks to woodland and heathland form ramorum blight*
- *Sea level change and coastal planning*
- *Seismology – Microseismic Monitoring for Environmental and Geotechnical Applications*
- *Shale das baseline for water - BGS*
- *Shale gas and CCS*

- *Space weather: Horne's work at BAS (Lloyds runner up for risk)*
- *Tsunami modelling*
- *Volcanic eruptions (many case studies, summaries best in Volcanos- high level – final v(2))*
- *Volcanoes: (see Health section)*
- *Waste –reduced bioaerosols emissions*
- *Weather forecasting – route based forecasting in winter*
- *Wild fires- Manchester*
- *Wildfire – Improved Hazard Assessmetn*
- *Wildfire management*

Sea Storms (including Thames barrier)

- *Extreme weather services benefitting industry and humanitarian relief*
- *Flooding – clouds to cost prediction of flood risk*
- *Flooding - Coastal flooding and cliff erosion*
- *Flooding – coastal flooding_NOC_Centre_Evaluation*
- *Flooding – Improved Extreme Sea Level Forecasting*
- *Flooding – Improved extreme sea level forecasting:* the case study shows how improvement in NOC forecasting (and the use of sea-defences informed by these forecasts) led to no loss of lives, while the storm surge in 1953 led to a large number of deaths.
- *Flooding – risk to London*
- Protecting people and property from storm surges and sea-level rise: provides a timeline of flooding, but does not include the most recent storm surges.
- *Sea level change and coastal planning*
- *Storm Surge Prediction – model performance in 2013.*
- *Storm Surge Prediction (DTZ report)*
- *Timeline Storm Surge Thames barrier*
- *Weather Forecasting – ocean and climate forecasting improved by data assimilation*

Water

- See case studies on peatland for discolouring issues.
- *Acidification and recovery of surface water:* no recovery despite SO2 emission coming down (as a result to changes in the dynamic of ecosystems)
- *Algal blooms in rivers*
- *Biodiversity – Heathland and moorland conservation* (could be linked with case studies on peatland/updland management)
- *Climate change – demonstrating the vulnerability of upland peat ecosystems*
- *Climate change – uncertainty and infrastructure – Durham* deals with UKCP-09, which have been used by the water industry
- *Data the value of NERC's data*
- *Diffuse pollution and flooding – SCIMAP*: helping to understand where the problem actually comes from
- *Drinking water – improvement security in Africa*
- *Droughts – past European droughts suggest ways to forecast droughts in the UK*
- *Fences help clean up livestock pollution of rivers*
- *Groundwater – new remove monitoring technology helps manage water supplies*

- *Groundwater – Understanding underground flow*
- *Groundwater Arsenic pollution*
- *Groundwater Management Manchester and Liverpool*
- *Groundwater pollution following depot explosion modelled by BGS*
- *Groundwater science – BGS – Centre evaluation*
- *Groundwater surface water interfaces – Sheffield*
- *Groundwater at higher risk of pollution from surface – Leeds and Lancaster*
- *Health- Assessing the environmental risks of treating a flue pandemic with Tamiflu*
- *Heavy metals in water (WHAM*): EU legislation influenced and set higher than it would otherwise had been, to take into account nature's self-cleaning abilities
- *Heavy metals chemical prediction in water and soil*
- *Heavy metals Moss research proves that pollution drops as emissions fall*
- *Lake restoration – restoration of Loch Leven (various versions)*
- *Lake Restoration – CEH centre evaluation*
- *Nanoparticle waste from consumer waste management*
- *Nanoparticles – CEH*
- *Nanoparticles safety in Fisheries and Aquaculture*
- *Nanoparticles Exeter*
- *National River Flow Archive (various versions)* this informs a lot of water management activities
- *Nitrogen improved measurements*
- *Oestrogens*: there are a number of case studies and it's getting traction in terms of policy implementation (but it translates in more costs: much of the research is on how to test for oestrogen damage/test whether oestrogens are present in water at damaging concentrations)
- *Peatland:* research from a variety of institutions has shown that peatland restoration is cost-effective for water functions and avoids water coloration, saving costs.
- *PES River Fowey Auction*: one of the first demonstrators for Defra introduction of Payment for Ecosystem Servicesbut implemented by South West Water
- *PhD – Andy Young – Wallingford – Hydrosolutions*
- *PhD – Jill Crossman – hydroecologist*
- *PhD Simon Quinn – Hydrogeologist*
- *Rivers – interaction sediments hydropower and climate change on Mekong*
- *Salamander (various versions)* developed a technology adopted by the water industry
- *Soil erosion (two versions)*: demonstrates improvement in the water pollution from agriculture
- *SUDS evaluation Envecon/SUDS Sustainable drainage* provide a value of the SUDS system developed by research
- *Systematic reviews of environmental research in policy making*: this was
- Phytoplankton work by SAMS and Edinburgh on marine pollution (saving £6bn in fines/costs)
- WHAM allowed the UK water industry to cut down on expenditure for the treatment of other heavy metals, by demonstrating that these treatment were unnecessary.

Annex 2: example of a case study summary

Flooding: NERC science saves £billions in lives, homes, business

Sustained NERC investment provides the 'big data' to improve flood forecasting and response

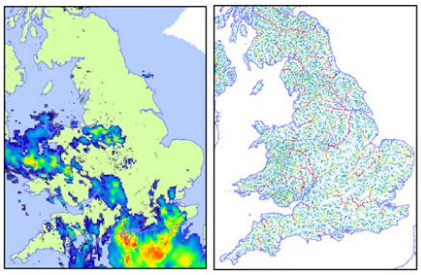
Extreme weather events are increasing in frequency and severity. The winter storms of 2013/14 set a host of new records. Apart from the human misery and insurance costs, flooding costs the UK £2.2 billion each year in building defences and restoring damage.

NERC invests £58 million a year in world-leading weather and climate research. Fifty years of funding has given us a wealth of scientific data and expertise for atmosphere and climate, river and groundwater flows, tides and storm surges.

We work with the Met Office, Environment Agency, Defra and emergency responders to translate this 'big data' into vital prediction tools. Examples include:

- NERC environmental science and data are essential for the Met Office's world-leading weather and climate prediction models.
- NERC data are used by the UK Flood Forecasting Centre and Cabinet Office Civil Contingencies Unit to give earlier and more accurate flood warnings.
- Cobra uses NERC data and expertise to coordinate the nationwide emergency response and brief the media.
- NERC tide and storm surge information is used by the Thames Barrier control centre to safeguard the London flood plain.

Flood forecasting with the NERC Centre for Hydrology's Grid-to-Grid model



Rainfall River flow

NERC science protects people, homes and business, saving £billions

NERC data enables increasingly accurate and earlier predictions, giving more time for Government, Environment Agency, local authorities and citizens to take the right action to protect lives, homes and businesses. Early warning avoids or reduces clean-up and rebuilding costs.

Costs avoided due to NERC science

Winter 2013/14 floods:

- More than 1 million properties protected, 50,000 fewer flooded.
- £2 billion less insurance pay-outs.

Loss of life is now rare. The winter 2013/14 floods were more severe than the 2007 floods. Yet more properties were protected and fewer homes were flooded (just one-tenth of the number in 2007). The Association of British Insurers estimates that the 2013/14 floods will cost £1.1bn, compared to the £3bn bill in 2007. The Thames Barrier protects around 1.25 million Londoners, £200 billion property and £230 billion annual economy. The barrier was closed 28 times between 6th December and 12th February, protecting the city and saving £2.6 billion (£94 million each day) in lost working. NERC climate science is used by infrastructure planners – such as Crossrail and HS2 rail networks, and the Thames Estuary 2100 Partnership – to build resilience to future flood threats. NERC data now suggests the Thames Barrier can continue protecting London until 2070.	• £2.6 billion of lost working saved in London alone. Rebuilding the Thames barrier: • £ billions saved by avoiding premature replacement.