The Economic Case for Investment in Natural Capital in England

Final Report

For the Natural Capital Committee

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SUMMARY

This is the final report to the Natural Capital Committee on the economic case for investment to protect and improve natural capital in England. The purpose of this project is to develop the economic evidence for investments to protect and improve[1] England's natural capital in order to sustain (as a minimum) or enhance benefits for society. Natural capital is the elements of nature that directly and indirectly produce benefits (or value) to people. This project aimed to identify a set of ambitious natural capital protection and improvement investments that are likely to be most beneficial to society, and an economic case for why they should be undertaken. This report covers the methods deployed, analysis and results.

The review of potential natural capital investments revealed that different investment options have very different evidence bases. These differences were expected to some extent, as the existence of some natural capital investment strategies (e.g. for woodlands, as presented in State of Natural Capital 2) and visions (e.g. the Wetland Vision[2]) was already known. However, the variety of existing strategic-level assessment of natural capital (related) investments (e.g. the Environment Agency's Water Framework Directive investment options appraisal[3]) were initially under-appreciated by the project team. This led to the project focusing more on the interpretation of existing reviews and national-level evidence, using reviews of project or site based evidence as a way of providing complimentary evidence.

Potential investments in natural capital were prioritised based on criteria reflecting the strength of economic evidence for investment at scale across England. This identified ten natural capital investment options that were subsequently prioritised for detailed analysis in this project, which is reported in three appendices:

- Marine:
  - Shellfish
  - Demersal fish
- Urban and Air:
  - Air quality
  - Urban green space
- Land Use:
  - Saltmarsh
  - Freshwater wetland
  - Woodland
  - Peatland
  - Lowland farmland (low-input improved grassland, hedgerows, pollinator strips)
  - Catchments

The potential investments that do not appear in this priority list should not be interpreted as not worthwhile or important to society. In particular, some of those not included , (e.g. some agricultural habitats and 'Specialist' (i.e. scarce) wildlife habitats) are a significant part of England's natural capital and efforts to protect and improve it. Specialist wildlife habitats are relatively limited in extent (by definition) and have a weaker economic evidence base, particularly on benefits, compared to other options prioritised (e.g. wetlands), so are not analysed in detail in this work. However, within the creation of large areas of habitat in investment cases (e.g. for

[1] Overall the project relates to what can be described as 'restoration' of natural capital, but more specifically involves 'protecting and improving' natural capital. See Section 1.2.
[2] http://www.wetlandvision.org.uk/
[3] Obtained from Environment Agency on 10/10/14.

wetland), there would be opportunities to create areas of specific habitat types (e.g. a BAP priority habitat like reedbed).

Analysis of the potential investments produced a variety of results. For some, the work developed evidence that indicates the need for investment, but does not allow examination of a specific set of actions. This arises for a variety of reasons, but often because evidence is available at different scales. For example, benefits to human health may be estimated from national data, but the costs of actions are driven by local circumstances, and poorly understood. These analyses are presented as 'evidence bases' for air quality, urban green space, lowland farmland and catchments, in the respective Appendices.

For other potential investments, it was possible to identify costs and benefits for particular actions at a defined scale. These are presented as 'investment cases' for the two fisheries, saltmarsh, freshwater wetland, woodland and peatland. These cases have cost and benefit evidence for specific actions, and a basis for estimating their spatial extent. In some cases, this spatial analysis was already available (e.g. saltmarsh, woodland), whereas for other cases (e.g. wetland, peatland) GIS analysis was used to develop the investment case. This included examining the scale of investment possible in relation to factors affecting costs (e.g. taking action on lower grade agricultural land with lower opportunity costs) and benefits (e.g. targeting actions close to population centres for recreational benefit, or upstream of them for water regulating benefits).

The scale of the investments where a specific case has been identified are summarised in Table S1. Methods for scaling up of evidence, including through use of GIS analysis, are challenging at such a large scale. Further work is needed including on how the following factors behave at different scales:

- Type of impact: May be constant across scales (e.g. carbon); may increase (e.g. wildlife benefits, which can increase through complementarity of actions that increase habitat connectivity) and/or decrease as species become less scarce);
- The value of impacts: May also be constant across scales (e.g. unit value for carbon, and for local air quality improvements in different cities, or for water quality regulation in different catchments), or may diminish (e.g. the value of wildlife protection as species become less scarce), and
- Costs: May decrease due to economies of scale and/or increase if less-cost-effective locations need to be used or actions are undertaken on a very large scale too quickly.

A further large scale consideration is the existence of synergies and conflicts across the potential investments. Synergies are examined in detail under individual investments, particularly in the catchment management evidence base. This concludes that investment is needed in governance to coordinate existing actions, this cannot be left to goodwill or assumed to be covered in existing budgets. Such governance has potentially significant additional costs (of approx. 30%), but these can be outweighed by significant benefits.

The results in Table S1 allow consideration of synergies and conflicts between the investment options. The main issue is the potential trade-off with agricultural land-use. Clearly, this needs recognition, but the actual effect on agricultural output would be managed because many of the investments considered involve land with either very low (e.g. upland peatland), or lower than average (e.g. lower grade land used for wetlands, field margins) productivity. Some of the impact on agricultural output could be partly offset through greater yields of fish from recovered stocks, and enhanced pest control and pollination ecosystem services, for example.

Table S1: Overview of Impacts of Potential Natural Capital Investments in England

Land use change	Area of suggested land use change	Current area[4]	% Impact on existing area	Notes
Land that is largely permanently lost to agricultural production:				
Wetland	100,000 ha	1.5m ha	7% increase	Targeted to lower grade land
Woodland	150,000 ha[5]	1.25m ha	12% increase	Presumed partly targeted to lower grade land, but needs to be near towns
Peatland	140,000 ha[6]	(355,000)[7]	39% of current area improved	Opportunity cost of reduced grazing and grouse rearing capacity
Saltmarsh	22,000 ha	40,500[8]	54% increase	Land already vulnerable to climate change
Subtotal	**412,000 ha**	**2.79m**	**15%**	
Land lost to agricultural production, but easily reversible:				
Arable margins	200,000 ha	n/a[9]		Margins are often less productive land
Total	**612,000 ha**	**n/a**		
Broad and shallow interventions on farmland:				
Low-input improved grasslands	500,000 ha	2.8m ha	18%	Reduced grazing intensity
Hedgerows (/lines of trees)	154,000km	402,000km	38%	Possible land take for gapping up
Catchment actions & coordination		In 56% of catchments in England appraised by EA for WFD agricultural land management actions are part of a package of measures with a positive benefit cost ratio.		
Marine Improvements	**Investment Required**	**Current Level**	**% Increase of benefits**	**Notes**
Demersal Fish (Example: North Sea cod)	Decrease catch to allow stock recovery (ongoing investment)	Landings currently approx 33,000 tonnes/year	Landings at least 200% higher (3 times larger) after stock recovery	Different stock modelling approaches predict a large range of stock recovery levels
Shellfisheries: (Example: Lobster and Crab)	Landings decreased by 9,450 tonnes over 4 years	Landings currently approx 13,500 tonnes/yr	25% higher landings – an additional 122,000 tonnes over 50 years after stock recovery	Stock assessments uncertain: only recently completed, and do not enable stock modelling.

[4] For context: England land surface: 13 million ha; agricultural land: 9.3 million ha

[5] Assuming optimal area for new woodland is less than 250,000 ha examined by Forestry Panel and between 100,000 and 200,000 (midpoint of 150,000)

[6] Exact size of area unclear due to overlap in peatland condition categories

[7] Area is subset of wetland area, so not included in total.

[8] England and Wales

[9] Location and extent of margins can vary on short (annual or multi-annual) timescales.

The estimated present values over 50 years of the costs and net benefits of these investments are shown in Table S2. The cost of these potential investments is estimated to have a present value of approx. £4.4bn over 50 years. The total PV of the measured benefits from these investments range from £7.7bn to 13.6bn over 50 years. Both costs and benefits have significant uncertainties. The breakdown of Net Present Values (NPVs) for these investments are shown in Table S2. They are estimated to produce net benefits with a present value of £3.3bn - £9.2bn over 50 years. In other words, for the overall investment costs, society receives benefits that are between two and three times as large. However, it should be borne in mind that not all benefits are fully valued in all cases (e.g. biodiversity) and that realising positive returns on such investments requires careful targeting of actions to minimise costs and maximise benefits.

Table S2: Net Present Values (NPV) of Potential Natural Capital Investments in England

Natural Capital Asset	NPV 50 yrs, £million, 2014 prices	
	Low	High
Upland peatland	560	
Demersal fish (cod)	860	4,700
Shellfish (lobster & crab)	123	
Saltmarsh	730	730
Wetland	634	2,700
Woodland[i]	354[i]	
Total	3,260	9,170

[i] For 250,000 ha, potential investment case is for 150,000 ha

The above estimates are for England. While the investment cases can help guide potential strategies, they should not be used to justify specific actions at individual sites. There are significant uncertainties involved in reaching these figures, as reflected in the ranges of values involved. These uncertainties include many of the challenges faced in environmental economics and reflected in preceding Natural Capital Committee Work (2014), with further challenges in many cases to scale the impacts up to a national (England) level. For example, the costs will depend on the responses of land markets, and how benefits may potentially diminish with scale, including for non-use values across the population requires further research. They could also be informed by more research into natural capital investments already underway.

A comparison was made of these investment cases to a selection of other (non-natural) capital investments undertaken by Government. An overall conclusion is that several of the natural capital investment cases stand up well to typical average public sector benchmarks (e.g. benefit-cost ratios of 4:1 and 5:1 for the roads programme). This is because investment costs are reasonably certain, with some spatial analysis of the best investment opportunities available, and actions can be designed to target projects/programmes with higher benefits and/or lower costs.

The figures in Table S2 rely on estimating the full range of costs and benefits, including market and non-market values, from the natural capital. Ignoring these impacts allows competing investments to present a more favourable picture of themselves.

The sources of uncertainty reflected in the large ranges in the figures in Table S2 include that some key environmental costs and benefits that do not have market values. These costs and benefits tend to be excluded from conventional infrastructure and other investment analysis. The alternative to using these data and the resulting large ranges would be to effectively give no value these environmental impacts, resulting in less accurate information with smaller ranges of results that spuriously suggest greater accuracy.

1. INTRODUCTION

This is the final report to the Natural Capital Committee on the economic case for investment in natural capital in England. This report covers the methods deployed, analysis and results. After a discussion of the terminology used, this introduction is followed by a description of the methods in Section 2, including handling uncertainty, scaling up and value transfer, and the use of geographical information systems (GIS) analysis. Section 3 describes the baseline adopted for the analysis. Section 4 describes the development of evidence on natural capital investments, the results of which are presented in three separate appendices. The synergies and conflicts between investments are discussed in Section 5. The benefit cost ratios for the investment cases are summarised in Section 6, where they are compared to other capital investments. Conclusions are in Section 7.

Section 4 includes a process for identifying potential natural capital investment options that are subject to more detailed analysis in the remainder of the report. Ten issues were chosen, which are analysed in detail in 3 appendices:

Marine	Shellfish
	Demersal Fish
Urban and Air	Air
	Urban
Land Use	Saltmarsh
	Freshwater wetland
	Woodland
	Peatland
	Lowland farmland (low-input improved grassland, hedgerows, pollinator strips)
	Catchments

1.1 Purpose of the Project

The purpose of this project is to develop the economic evidence for investments to protect and improve[10] England's natural capital in order to sustain (as a minimum) or enhance benefits for society. Natural capital is the elements of nature that directly and indirectly produce value or benefits to people. This project aimed to identify a set of ambitious natural capital protection and improvement investments that are likely to be most beneficial to society. This required review and interpretation of a wide range of evidence, in a relatively short space of time, on the costs and benefits of actions that protect and improve natural capital.

Natural capital protection and improvement interventions can provide benefits to society in different ways and at different scales (geographically, economically and over time). For example, improving a drained and degraded peatland back to a healthy wet condition can have long term global benefits (by halting emissions of greenhouse gases), and shorter term local benefits (by improving the quality of water available for public supplies).

[10] Overall the project relates to what can be described as 'restoration' of natural capital, but more specifically involves 'protecting and improving' natural capital. See Section 1.2.

Ambition is defined in terms of the magnitude of benefits involved. This can be assessed through a combination of a potential investment's spatial extent, amount of natural capital improvement (in terms of its capacity to provide benefits) and/or number of beneficiaries. It therefore reflects the extent of existing actions to protect and improve natural capital assets, and the remaining capacity for additional action that is beneficial to society. Not prioritising particular investments should not be interpreted to indicate that they are not worthwhile; they just do not have the strongest case under this project's rapidly undertaken economic approach to assessing the evidence.

The analysis also aims to compare investments in natural capital to other investments society could choose to make, taking into account that natural capital protection and improvement:

- Can have benefits that impact on commercial activity (i.e. goods and service bought and sold in markets) and/or that are intangible in conventional economic impact terms;
- Needs to be feasible and beneficial at a significant scale (not just at a small number of specific sites);
- Can be compared to investments in other forms of capital (e.g. human capital – the workforce, or built capital - such as transport infrastructure) and the scale and nature of benefits these provide;
- Gives benefits that can sometimes only be increased after a lag of several years, therefore comparisons may require a longer timescale than some of society's other investment decisions, and
- Needs to be organised into a coherent set of initiatives to benefit from synergies and to avoid conflicts and unintended consequences of individual activities.

The findings of the project are intended to inform strategic policy decisions, rather than investments in specific locations, and to lead to more efficient use of resources by and for taxpayers, such as:

- Provide evidence for NCC's advice to the Government on the unsustainable use of natural capital;
- Assist the NCC in making recommendations to Government for a long-term strategy to manage natural capital, and
- Inform priorities for monitoring and reporting, including through national natural capital accounts.

1.2 Terminology and Definitions

It is important that a consistent set of terms and definitions are used in this wide ranging analysis of natural capital investments. The terminology and definitions proposed lead on from the NCC's second state of natural capital report (SoNC II). A glossary is included at the end of this report, and key terms are discussed here.

SoNC II, in turn, largely used the terminology of the UK National Ecosystem Assessment (NEA), but also incorporated the wider literature, including the UN System of Environmental-Economic Accounts - Experimental Ecosystem Accounts (SEEA-EEA, 2013[11]) process, to define candidate

[11] SEEA-EEA is an accounting framework for multi-disciplinary research and testing on ecosystems and their relationship to economic activity. It features a Central Framework, an international standard for environmental-economic accounting that applies the System of National Accounts model (which uses standard asset accounting model for produced assets) to the measurement of 'individual environmental assets' (e.g. timber resources) and expected flow of benefits in basic resource accounts (SEEA CF, 2012) and a framework for experimental ecosystem accounts (SEEA-EEA, 2013).

categories for natural capital assets, convenient 'major land use types', and the benefits delivered by the ecosystem services and goods they produce. The categories used in SoNC II were:

The major land use types (MLUTs), defined through the eight main UKNEA habitats: mountain, moors & heaths; enclosed farmland; semi-natural grasslands; woodlands; freshwaters; urban; coastal margins; marine. These are described further below.

The benefits provided by natural capital, defined through ecosystem services classifications terminology: food; fibre; energy; clean water; clean air; recreation; aesthetics; wildlife; protection from hazards; equable climate.

These benefits are provided by **the natural assets** that underlie the MLUTs: species; ecological communities; soils; freshwaters; land; atmosphere; minerals; sub-soil assets; oceans; coasts.

The major land use types, ecosystem services and natural capital asset categories listed above are described in more detail in subsequent sub-sections.

1.2.1 The purpose of natural capital investments

This project is concerned with investments in natural capital, which could be thought of as 'restoring' natural capital. Defining and categorising restoration can be complex. Some define restoration as the process of actively managing recovery of ecosystem services (CBD, 2011), whilst others define it as the return of an ecosystem to its original structure or function. The eftec-led report that informed SoNC II (eftec et al, 2014) found that the latter was rarely achieved because:

- Defining 'original' is difficult. As most MLUTs in the UK have been modified by a long history of human intervention. Reference to previous states relates also to previous socio-economic contexts and can therefore be controversial; and
- It is very difficult to restore all components of an ecosystem especially over short time scales, but it is possible to restore some components or functions.

Restoration of ecosystems is also a target within the EU's biodiversity strategy. Studies for the EC informing the achievement of this target have defined restoration in different ways. Lammerant et al (2013) defined four levels of ecosystem condition[12] and defined restoration as improvement of at least one level. IEEP-led analysis of the costs and benefits of achieving the EU ecosystem restoration target (Tucker et al, 2013) used a definition from the Society for Ecological Restoration (2004): that restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed".

Complete restoration of natural capital may not be a feasible nor desirable outcome from natural capital investments. Restoration, where it implies reversion to some historical condition, is

[12] The Arcadis study (2013) proposes a four stage approach ranging from level 4: highly modified abiotic conditions, reduced ecological processes and functions with declining native species to level 1: where abiotic conditions are satisfactory and key species, properties and processes of ecosystems and their functions are in good to excellent condition. Work to inform SoNC II set out with the intention to work with the definition of restoration as 'the return of a habitat/ecosystem to pristine condition' as in the European Commission definition. However, if this were the case then few of the previous studies would have been described as achieving restoration, as they did not demonstrate a return to 'pre-disturbance or pristine conditions'. In identifying the potential for restoration of a habitat a more flexible approach similar to Arcadis' was used, which considered that restoration represents a gradient from degraded to good condition (of abiotic conditions, species, functions and processes) and movement along this gradient needs to be demonstrated for some level of restoration (i.e. improvement) to have occurred. However, full restoration requires the return of key species, properties and processes of ecosystems as measured by comparing the target to the final state.

therefore not necessarily the best term for describing how we might make investments in natural capital. An alternative way of defining restoration is as an activity to improve ecological quality and condition in order to achieve a specific goal or target. However, such a definition is not particularly intuitive.

The NCC's remit refers to the 'protection and improvement' of natural capital, with one of the three parts of its terms of reference being:

- Advise the Government on how it should prioritise action to protect and improve natural capital, so that public and private activity is focused where it will have greatest impact on improving wellbeing in our society.

The focus of this project thus is described in terms of investments in initiatives *to protect and improve* natural capital. During subsequent analysis this is shortened to '**investments**' to refer to the resources required or '**actions**' to refer to the actions required. **Improvement** refers to the enhancement of natural capital to some target condition (e.g. good WFD status) or extent from a baseline. The **protection of natural capital** refers to its conservation or the avoidance of degradation.

The interventions may produce benefits by enhancing natural capital (e.g. fish stocks) to increase the goods and services they can provide (e.g. fish), or by halting declines in natural capital (e.g. pollinators) to avoid the expected loss of goods and services they provide (e.g. supporting crop production).

Either way, assessment of costs and benefits requires careful definition of a **baseline** to ensure the identified impacts are additional. This baseline must recognise that, unlike some other forms of capital, the impacts of not safeguarding natural capital can be severe ***and*** irreversible. For example, roads can be resurfaced, but once fish stocks have collapsed even strong conservation measures may not lead to their recovery for generations.

Developing a better understanding of which ecosystem service and which natural capital assets will benefit from protection and improvement activity is critical. However, given the limited time scale, this study uses a pragmatic output- or outcome-based approach to rapidly summarise cost and benefits. For example, for a managed realignment investment, the output is an increase in intertidal area and the outcome is how this benefits final ecosystem service delivery (e.g. carbon sequestration and hazard regulation services).

1.2.2 The major land use types (MLUT)

The eight Broad Habitat types in the UK NEA each contain a number of different habitat types. These types are considered too broad in many cases for analysis of protection and improvement of natural capital. Therefore, they have been sub-divided in some cases into functional units of natural capital (e.g. urban green space) or more narrowly defined sub-habitats within the broad habitat types (e.g. blanket bog). The selection of such units has been based on the following principles:

- Data on extent and quality should be available at the unit level (for water and marine habitats, units follow the Water and Marine Strategy Framework Directives);
- There should be a link between the unit and the benefits it provides;
- Habitats with important benefits or specific pressures should be separated out (e.g. blanket bog), and
- If information is not available at the proposed level, units can be combined.

In some cases, the meaningful unit of investment may be based on the more narrowly defined habitats. For example, the case for investing in wetlands is examined, but the case for investing in saltmarsh, a specific intertidal type of wetland, has a different set of costs and benefits and thus is analysed separately. Table 1.1 sets out the definition of broad habitats and sub-habitats.

Table 1.1: Definitions of broad and narrow habitats

UKNEA broad habitat	Associated sub-habitat	Scope
Mountains, Moorlands and Heaths	*Blanket Bog*	Rainfall-fed bog in upland environments
	Mountains, Moorlands and Upland Heaths	Upland heath, montane habitats and associated wetlands (flushes, fens). Also include rock and scree habitats such as limestone pavements
	Lowland Heath	Lowland habitats dominated by heather family or dwarf gorse species
Semi-natural grasslands	*Semi-natural grasslands*	All grasslands unimproved for agricultural purposes
Enclosed farmland	*Enclosed arable farmland*	Arable, horticultural land and improved grassland as well as associated boundary features e.g. hedgerows
Woodland	*Woodland*	Includes broadleaved and coniferous woodlands both natural woods and planted. (Wet woodland included here)
Freshwaters	*Standing open waters*	Lakes, ponds, reservoirs and canals
	Rivers and streams	Streams and rivers down to the tidal limit
	Groundwaters	Aquifers and significant quantities of below ground water
	Wetlands	Lowland fens, raised bogs, swamps, reedbeds and floodplain wetlands
Urban	*Built urban*	The built environment elements of urban space e.g. buildings, roads, industrial works
	Green space	The natural environment elements of built up areas e.g. parks, gardens, towpaths, urban trees
Coastal Margins	*Coastal dunes and sandy shores*	Dune systems and the upper zone of sandy shores
	Saltmarsh	The upper zone of vegetated intertidal habitat - transition into other intertidal habitats
	Transitional and coastal waters	Estuaries, coastal lagoons and other near shore waters (Water Framework Directive definition)
Marine	*Intertidal rock*	Bedrock, boulders and cobbles which occur in the intertidal zone. Colonised by mussels/barnacles and seaweeds depending on exposure
	Intertidal sediment	Shingle (mobile cobbles and pebbles), gravel, sand and mud in the intertidal zone
	Subtidal rock	Bedrock, boulders and cobbles in the subtidal zone colonised by seaweeds (infralittoral zone) or animal communities (circalittoral zone)
	Shallow subtidal sediment	Shingle (mobile cobbles and pebbles), gravel, sand and mud in the subtidal zone
	Deep sea bed	The sea bed beyond the continental shelf break
	Pelagic water column	The water column of shallow or deep sea; beyond the coastal waters

1.2.3 Natural capital assets

In some cases, the objective of an investment in natural capital may be to protect and/or improve a specific natural capital asset (e.g. species providing pollination, or peatland soils). As defined above, natural capital assets include species; ecological communities; soils; freshwaters; land; atmosphere; minerals; sub-soil assets; oceans; coasts. Table 1.2 sets out the relevant natural capital assets and their definitions.

Investments in natural capital assets need to be associated with narrow and/or broad habitats and subsequent ecosystem service provision so that the actions can be linked to the changes in benefits. In other words, the link between the actions and benefits need to be established so that a benefit-cost ratio can be calculated.

Table 1.2: Natural capital assets and their definitions

Natural capital asset	Definition
Species	All living organisms including plants, animals, fungi and micro-organisms. The product of ongoing evolutionary processes.
Ecological communities	A group of actually or potentially, interacting species living in the same place. A community is bound together by the network of influences that species have on one another. Groups of interacting species in form persistent and distinctive assemblages interacting with their physical environment (e.g. pollination).
Soils	The combination of weathered minerals, organic materials, and living organisms and the interactions between these.
Freshwaters	Freshwater bodies (rivers, lakes, ponds and ground-waters) and wetlands - includes water, sediments, living organisms and the interactions between these.
Land	The physical surface of the Earth and space for human activity - includes the various landforms and processes which shape these (weathering and erosion).
Atmosphere	The layer of gases surrounding the Earth including oxygen, carbon dioxide and nitrogen used by all living organisms, and the processes which give rise to climate, weather (wind, precipitation) and temperature regulation.
Minerals and sub-soil assets	Naturally occurring non-living substances in the Earth's crust with a specific chemical composition and those formed by geologic processes (e.g. stone, salt, sand, metals (gold, magnesium etc.), coal).
Oceans	Saline bodies of water that occupy the majority of the Earth's surface - includes water, sediments, living organisms and the interactions between these.
Coasts	The transitional zone between land and oceans - includes water, sediments, living organisms and the interactions between these.

1.2.4 Benefits from natural capital

The analysis of any project to protect or improve natural capital must consider both the costs of restoring the broad/sub- MLUT (habitat) and/or natural capital asset, and the subsequent benefits that are to be gained from the project in the future. The default approach to assessing these future benefits is to consider investments to take actions over a time period of up to 25 years, and then subsequent impacts for a further 25 years. Therefore, the present value (PV) of costs and benefits

is over 50 years[13]. However, these time periods may be varied depending on the investment case involved. Benefits, in this context, refer to those provided by ecosystem services for people. At least some of these benefits can be expressed in monetary terms. The present value of benefits is calculated using HM Treasury recommended discount rates.

Table 1.3 sets out the definition of the ecosystem service categories used to identify the benefits of protecting and improving natural capital in this project. It should be noted that some benefits are the product of a combination of natural and other capital inputs. For example, most food is harvested, prepared or processed using human capital (e.g. farming skills) and built capital (e.g. machinery) before being consumed.

Table 1.3: Benefits from natural capital and their definitions

Ecosystem service benefit	Definition
Food	Plant, animal and fungi consumed by people. Both wild and cultivated sources
Fibre	Plant and animal materials used by people for building, clothing and other objects, including timber
Energy	All sources of energy used by people (fossil fuels, wind, tidal, wave, hydro, biomass and solar)
Clean water	Water for human use (e.g. drinking, bathing, industrial processes); a combination of quality and quantity
Clean Air	Air quality that has no adverse impact upon human health or wellbeing
Recreation	Active enjoyment of the natural environment e.g. walking, fishing, canoeing
Aesthetics	Passive enjoyment of the natural environment e.g. landscape appreciation and views
Wildlife	Wild species diversity and abundance which have aesthetic and recreational value, and cultural and spiritual significance, including through the conservation priorities for species and habitats. This is distinct from the natural capital assets, species and ecological communities, in that these represent the species that are significant to England and that people care about.
Protection from hazards	Natural regulation of extreme events such as flooding, drought and landslides.
Equable climate	A comfortable climate that has no adverse impact upon human health or wellbeing. The result of both global scale and local scale effects (e.g. urban cooling by trees)

Source: Natural Capital Committee (2014)

1.2.5 Thresholds and targets

In line with previous NCC work, this project uses these terms as follows:

- A **threshold** relates to a property of system, such as an ecosystem, or some other functional relationship, whereby a change in one factor leads to a non-linear response in another factor and/or the recovery from the change in the future is compromised, and
- A **target** is a level defined by society as being desirable to achieve (or avoid falling below).

[13] For example, in the wetland investment case, wetland creation costs are spread over the first 10 years, and management then costs continue up to year 50. Benefits are obtained from when the wetland is created up to year 50.

Targets may be determined by society in different ways (through laws or in aspirational goals) and reflect a variety of factors. These factors can include the possibilities of crossing thresholds, with some targets reflecting 'safe limits' to avoid deterioration of natural capital reflecting what society may judge to be an acceptable risk of crossing thresholds, given the available evidence. In other cases, targets may be more 'aspirational'.

2. METHOD

This Section summarises the approach taken in this project. More detailed descriptions of the methods specific to each investment case are presented in relevant subsections.

2.1 Approach to Identifying Investment Cases

Given the short time available for the work, this study was organised in a series of tasks that were undertaken concurrently. It started with a review of evidence to identify potential natural capital investments. These were prioritised with input from the NCC (see Section 4). A complicating factor in identifying natural capital investment options was the extent to which site specific evidence can be scaled to contribute to a prioritised set of *national* natural capital protection and improvement initiatives. This issue is one of the significant technical challenges of this study and is discussed further in Section 7.

Work to develop 10 detailed investments was then undertaken, resulting in different types of outputs:

- For some, it was possible to identify costs and benefits for particular actions at a defined scale. These are presented as '**investment cases**'.
- For others, the work developed evidence that indicates the need for investment, but does not allow examination of a specific set of actions. These are presented as '**evidence bases**'.

In all cases consideration was given to both costs and benefits and how these would alter with scale (see Section 2.4 for further discussion of scaling). Unit costs for most cases were derived from market prices, but include some uncertainties. Benefit evidence used included qualitative, quantitative and monetary assessment of benefits. The interpretation of the evidence followed the Defra value transfer guidelines (eftec, 2010) in terms of judging the quality of evidence, reporting the evidence to ensure comparability and commentary on how transferable an estimate is from the original context to an investment option.

Throughout the study consideration was given to potential synergies and conflicts between the options for national investment initiatives. Synergies include the complementarity of improving adjacent habitats (e.g. wildlife provision in blocks/networks of habitat, as per the Lawton Review conclusions), and potential conflicts (e.g. competition for space between intertidal habitat creation, protected freshwater habitats, and farming on high-grade agricultural land). Synergies and conflicts are discussed further in Section 6.

A review of cost-benefit evidence for other forms of public sector investment in (non-natural) capital was also undertaken. This Task reviewed a shortlist of potential comparators and identified evidence on other national capital investment options (e.g. buildings, broadband, energy infrastructure) undertaken or promoted by Government. These investments were then compared to the natural capital investment initiatives, replicating comparisons that could be made in a public sector spending review or other policy appraisal context. The range of comparators drawn on covers built and social capital, long and short term investments and those providing private/public and market/non-market benefits. This comparison also provided evidence on the way investments in natural capital and other forms of capital are assessed within Government.

2.2 Types of Investment Evidence Identified

The research revealed that different potential investment options have very different evidence bases. These differences were expected to some extent, as the existence of conservation strategies and visions (e.g. the Wetland Vision[14]) for some natural capital assets was already known. However, the variety in the existing strategic-level assessment of natural capital (related) investments (e.g. the Environment Agency's Water Framework Directive investment options appraisal[15]), was under-appreciated, leading to an adjustment to the intended approach.

In general, three broad approaches were identified for drawing together information on natural capital investments:

- **Use existing large scale evidence**

For some potential investments in protecting and improving MLUTs or natural capital assets, national scale analysis of science and/or economics evidence had already been carried out. For example, this was the case for woodland area expansion, which had been subject to detailed and spatially explicit modelling by a team from UEA. The results of this work were presented in SoNC II. Other examples of evidence that was already summarised at the scale at which investment decisions in natural capital might be made, include the air quality strategy, and pelagic fisheries recovery targets defined by ICES. Where this is the case, the challenge is to relate this evidence to the wider benefits that could be associated with these actions to manage natural capital.

Where evidence already existed at this scale, the approach taken was to translate it to inform potential investments in natural capital. Where this is possible, reviews of several individual investment examples were not seen as necessary. However, in presenting the overall investment case, examples of site/project case studies were provided in order to illustrate how the beneficial outcomes are realised in practice (e.g. taking The National Forest as an example that illustrates the benefits of increased investment in woodland near population centres).

- **Existing reviews of natural capital investment evidence**

For some potential investments in protecting and improving MLUTs or natural capital assets, aspects of the literature had already been subject to evidence reviews (e.g. for improving the condition of blanket bogs and agri-env measures). However, the results have not been interpreted at macro-scale and/or made spatially explicit. The task with this type of evidence was to check its suitability to informing this study, and then interpret it into natural capital improvement data that could be applied in an investment case. Again site/project case studies were used to illustrate how the beneficial outcomes are realised in practice.

- **Evidence base exists, but no systematic review/summary**

In some investment areas, there was an evidence base and there may be some summaries of evidence, but these require further review to enable interpretation. In these cases effort was put into drawing on case studies and synthesising study evidence.

[14] http://www.wetlandvision.org.uk/

[15] Due to be released for consultation on 10/10/14 – Claire Johnstone, EA, pers com.

2.3 Uncertainty

This project involves interpretation of a complex and often incomplete evidence base in new and challenging ways. There is inevitably uncertainty in much of this evidence. The level of uncertainty can be defined in terms of the robustness of the available evidence and agreement across the field on the interpretation of the evidence. These two dimensions can be used to score the level of uncertainty as shown in Figure 2.2. This scoring puts greater weight on the level of agreement on the robustness of the evidence base – leading the high agreement/limited evidence being scored 2, above low agreement significant evidence (scored 3).

Figure 2.2: Evidence Uncertainty Scoring Matrix

		Agreement	
		High	*Low*
Robustness	*Significant evidence*	1	3
	Limited evidence	2	4

The investments examined involve a combination of evidence on many aspects of the protection and improvement of natural capital. The internal work of the team has considered uncertainty scores relating the evidence used in relation to each investment. This has influenced the way conclusions are presented – for example with larger ranges of results used to reflect greater uncertainty.

2.4 Scaling Up & Value Transfer

This Section considers the issue of scaling up the available evidence into natural capital investment options for England. Scaling up in this sense means applying actions to protect or improve natural capital over a significantly larger area. This can be done by increasing the number and /or size of the locations where the actions are taken, and which of these is undertaken may influence the outcomes.

In most of the investments examined, the extent of potential actions, costs and benefits are not worked out in the existing literature. Understanding the optimal size of potential investments has required some modelling. This has taken into account issues like technical feasibility, and likely areas of land with acceptable opportunity costs, or yielding certain types or levels of benefits. However, there is also an element of expert judgement involved due to the many uncertainties in the variety of variables involved.

The proposed scales of investments have been determined through the analysis of scientific and economic factors that could influence the scalability of actions to protect and improve natural capital. Three broad areas of evidence were considered:

- Science;
- Conservation practice, and
- Economic values.

Our current thinking on each of these areas is outlined in the following sub-sections.

2.4.1 Scientific Evidence

The science of scaling up is complex, being dependent on underlying biophysical factors at broad (soil type, geology, altitude, climate etc) and local scales (habitat context, species pools, hydrology, habitat connectivity etc). Depending on available data, GIS can be used to look at site suitability for investments. The linkage from site evidence to potential national initiatives is key to developing investment at a scale sufficient to make a difference to the UK's natural capital. For example, evidence generated on commercial farms run for research purposes (e.g. by RSPB, GCT, CEH) have demonstrated actions that restore goods and services (e.g. water regulation, farmland wildlife) without compromising farm profitability. These actions have subsequently been reflected in policy changes to agri-environment schemes which can deliver large scale 'investment'[16] in natural capital assets across similar farmland types.

This scientific evidence has input to consideration of the potential drivers through which investments can be motivated/enacted at a nationally significant scale. These include policy incentives (as for agri-environment, above), climate change adaptation or mitigation objectives, or the emergence of new understanding, technologies and techniques on ecosystems and their services. Such considerations are necessary to ensure that the output of the project is a set of practical restoration initiatives for the UK.

The review of restoration science conducted by CEH and eftec to inform SoNC II summarised evidence on the feasibility of restoration (see Table 1 in Maskell et al, 2013). It shows how it is possible to achieve some recovery in components of most habitats. However, full restoration of species, abiotic components, functions and processes is very difficult. Eliciting the degree of recovery from the literature was also a challenge: it is very dependent on how recovery is measured and what target/counterfactuals are set. Studies in the review for that paper used various definitions of restoration; from the improvement in ecosystem variables (without achieving pristine condition) to the application of restoration activity as an indicator of restoration (as in the CBD definition) even though no detailed analysis between initial and final states had taken place, to a return to pre-disturbance or pristine conditions.

A significant issue in using scientific information is the large complexity in the process of habitat restoration, to understand it fully, knowledge is needed of:

- The initial state of the habitat (the degree of degradation, species composition, abiotic variables and whether a threshold has been crossed);
- The actions taken to restore it (which can be very diverse);
- Sources for species colonisation (from nearby habitat or within soil);
- Ongoing management in addition to restoration facilitation;
- The final state;
- The target of restoration (which may be multiple from the same management actions), and
- How closely the final state matches the target.

All these factors influence the potential for restoration, its costs and benefits, and the rate of restoration.

[16] It should be noted that as an investment, agri-environment agreements purchase actions over a fixed time period (usually for 5 or 10 years of agreements) that lead to improvements in natural capital, but these may subsequently be unsecured and reversible.

2.4.2 Conservation practice and ambition

The scientific issues described above are often applied in nature conservation practices that protect and improve habitats in England. The extent of this activity, particularly over some habitat types (such as lowland heathland, reedbeds and saltmarsh) has created an evidence base which can inform this project. This is captured in a number of restoration strategies for habitats that are a conservation priority in England/The UK, including for:

- Lowland heathland;
- Reedbed;
- Freshwater wetlands, and
- Nature after minerals[17].

These documents were reviewed to understand the different constraints faced in determining the extent to which nature conservation benefits could be achieved over a larger area. Information was also drawn from the work to date in England's Nature Improvement Areas (these are discussed further in the catchment evidence base). The management of these areas is taking a landscape scale approach to improving areas of habitat, and in particular improving connectivity and resilience, thereby potentially achieving economies of scale in the biodiversity benefits realised, in line with the principles from the Lawton Review.

2.4.3 Economies of Scale in Conservation Land Management

There is well established evidence on the costs of managing land for nature conservation purposes (GHK, 2006) and of ecosystem restoration (IEEP et al, 2013). These sources note the potential influence of economies of scale. IEEP suggest that it can be expected that in many situations the cost curves for ecosystem restoration will be S-shaped, as a product of three factors. Firstly, costs will increase rapidly; secondly, the unit rate may decline as learning and economies of scale bring benefits; and thirdly, costs then start to rise more rapidly as suitable and low-cost restoration sites are used. The third factor may be more likely to be reflected in actions being regarded as technically unfeasible (within reasonable costs) rather than explicitly rejected for reasons of high costs.

For example, the analysis of sites managed by the Yorkshire Wildlife Trust identified that a combination of geographic, ecological and socioeconomic characteristics of sites explains 50% of the variation in management costs (Armsworth et al, 2010). Site area is the most important determinant of management costs, which demonstrate economies of scale; implementing conservation management on an additional hectare adjacent to a larger protected area would incur a lower cost than doing the same adjacent to a smaller site. The authors note that there may be no alternative to establishing small protected areas to conserve biodiversity in highly fragmented landscapes. But the decision to do so should take account of the greater cost burden that isolated small protected areas incur and that they may have only slightly higher unit costs if managed as part of a cluster of sites.

To obtain more detailed site-level information, contact was made with the RSPB's habitat management specialists (Malcolm Ausden, pers comm.)[18]. They have analysed costs across their conservation estate to understand economies of scale and other factors influencing habitat management costs. They drew data from 59 nature reserves (or clusters of nature reserves managed from the same work centre) of between 110 ha and 16,346 ha in area. They show large

[17] See: http://afterminerals.com/index.aspx
[18] Conservation Advice Department, Royal Society for the Protection of Birds.

economies of scale in the total costs of maintaining nature reserves, and the costs of staffing, land management operations, and maintaining work premises.

These economies of scale are sufficient to have significant implications for land management. They allow estimates of how differences in the size of nature reserves affected the total area of land of a conservation priority habitat type that could be restored to and maintained as high quality habitat for a given amount of money. If costs are considered over a 50-year period, then the estimated cost of acquiring, restoring and maintaining 600 ha distributed in five 120-ha blocks, is the same as acquiring, restoring and maintaining more than 1,200 ha distributed in two blocks. Furthermore, where additional blocks of land are managed as new sites (i.e. managed from different work centres) this is significantly more costly than additional blocks of land added to existing sites.

There are also 'economies of scale' in conservation outcomes from managing larger sites designated for nature conservation. As stated in the UK's Lawton Review[19], *"species confined to small, single, or only a few sites, are unlikely to be adequately protected"*. There is a wide evidence base which shows that small areas offer less effective protection for species, because small areas have[20]:

- Small populations, with more limited gene pools, therefore species could naturally fluctuate into extinction;
- Lower diversity in species due to low habitat diversity;
- Edge effects – the edges of protected areas are often affected by external environment pressures (pollution, noise, human interference); the smaller the protected area, the greater chance these external impacts will penetrate all of the area, therefore no area free from impacts area in the protected Zone, and
- 'Allee effects' – which mean that species do not breed successfully at low densities.

2.4.4 Economic Values

Economic values are known to vary significantly across different scales for a number of reasons. Analysis by Armsworth (2009) compared the outcomes for selected ecosystem services of investments in small protected areas to larger remote wilderness zones. It suggests that scaling up of investments in small protected areas can deliver high carbon storage and biodiversity benefits. In comparison returns from agri-environment payment schemes for these services and agricultural production are lower. Their modelling suggests that wilderness areas, small protected areas, and agri-environment payments strategies do not devote a sufficient proportion of land to providing recreational services to society. The trade-offs between these four ecosystem services (biodiversity protection, carbon storage, food production and recreation) show that scaling up benefits from investments in natural capital is likely to be non-linear. They suggest that a portfolio of conservation and sustainability investments will be needed to deliver both biodiversity and other ecosystem services demanded by society.

This is expected given that economic values can exhibit diminishing returns to scale and economies of scale. Key reasons for these variations with scale in relation the analysis in this study include:

[19] Lawton et al. 2010 - An Independent Review of England's wildlife and ecological network commission by the government chaired by Professor John Lawton.

[20] Abensperg-Traun and Smith (1999), Berger (1990), Berger (1999), Bulman et al. (2007), Franking (1980), Gilpin (1986), Groom, Meffe and Carroll (2006), Harris and Pimm (2008), MacArthur and Wilson (1967), Pardini et al. (2005), Shaffer (1981), Trail, Bradshaw and Brook (2007), Willi, Van Buskirk and Hoffmann (2006).

- The influence of substitutes on value. Substitutes are goods and services that provide the same (or sufficiently comparable) benefits. The value of most goods and services decrease with increasing availability of substitutes (e.g. recreational opportunities). This results in diminishing returns with scaling up. For example, as the area of a site increases, so does the availability of alternative recreational locations (i.e. substitutes). Also, as biodiversity conservation activities become more widespread, the value of additional activity may fall (this is why greater resources are devoted to conserving scarce species). On the other hand, the value of some goods and services does not vary at all with the availability of substitutes (e.g. carbon sequestration and storage).
- The influence of complements on value. A complement is a good or service that facilitates the enjoyment of another. Many natural or human-made capital assets are complements to natural capital goods and services (e.g. transport is a complement for recreational opportunities). The value could increase with increasing availability (or lower cost) of complements. This results in increasing benefits as an investment is scaled up, if with scaling up, availability of complements also increase (e.g. biodiversity networks).
- Displacement. This refers to the case where benefits from a given investment in a given location are not new or a net increase but simply displaced from elsewhere. For example, in recreational benefits, investment in green infrastructure would attract visitors to the investment area. But these benefits should only be counted if the visitors are shown to be making new trips (and not coming to the area instead of somewhere else they would have gone). For an appraisal within a smaller geographical area, the level of potential displacement is likely to be lower. For scaling up, as the area of investment (and analysis) increase, with previously existing substitutes increasing, so would the proportion of benefits displaced. This would mean with scaling up net benefits could be declining.

These factors create an extra layer of complication in trying to apply value transfer (eftec, 2010) to evidence from small (in number and size) study sites to much larger policy sites. Table 2.1 shows how the key variables to consider in a value transfer could alter with a significant increase in scale. This analysis applies to an increase in scale of investment which could be due to an increase in the size of sites invested in and/or the number of sites invested in.

Several of the locational factors that influence value have been scrutinised using GIS, for selected cases, in the investment cases where they are most relevant. Investments were also prioritised for GIS analysis where the optimal scale of the investments was uncertain and/or spatial factors were more likely to influence their costs and benefits (see Section 2.5).

Scaling up is found to have greater influence on costs and benefits:

- On costs when the factors influencing the technical feasibility and/or opportunity costs of natural capital protection and improvement actions are more sensitive to spatial factors (e.g. soil type) and scale (e.g. due to economies of scale in site management).
- On benefit valuations when the parameters influencing unit values (£ per beneficiary), or the number of beneficiaries, are more sensitive to spatial factors (e.g. proximity of substitutes influencing distance decay rates for recreational values) and scale (e.g. increasing width of saltmarsh has diminishing hazard regulation benefits).

There is also a temporal aspect to scalability, as returns to previous investments will be realised over time, raising environmental quality and therefore resulting in diminishing returns to investments. For example, an investment in natural capital may have generated high benefits in the past, but could now face diminishing returns as the most serious aspects of a problem have been dealt with. This is arguably the case with bathing waters, for example, with the

approximately 90% of waters in England now at good status, the marginal benefit of cleaning up further beaches diminishes.

Table 2.1: Influence of Scale on Key Value Transfer Factors

Value Transfer Factor	Influence of scaling up the benefits of investment (more and/or larger sites)
Type of good	Scaling up may increase the benefit. Larger investments may offer enhanced services, (e.g. in terms of resilience to change)
Type of change	Scaling up may not have a significant impact on the benefit. The value here is dependent on the nature rather than size of sites/ investments.
Whose values?	Scaling up may increase or decrease the benefit. Larger sites are likely to provide benefits to larger and more varied beneficiaries. This applies to both users and non-users. However, larger sites may also increase the availability of substitutes and the displacement effect for some of the benefits. The effect depends on the type of natural capital asset and ecosystem goods and services and local characteristics.
Data limitations	Scaling up may increase uncertainty about benefits. Data on the impact of investments, but also other factors like beneficiary population, displacement, substitutes and complements are likely to be less at larger scales. This necessitates assumptions to be made which inevitably increases uncertainty.
Timing of the valuation exercise	Scaling up may decrease discounted benefits by postponing them into the future. Larger investments are likely to take longer to implement.
Time and financial budget limitations	Scaling up may influence the choice of value transfer approach. Larger scales may provide benefits further from the marginal choices in beneficiaries financial and time budgets, and therefore may have greater influence due to time and financial limitations.
Level of acceptable uncertainty or error	Larger investments cost more (in total and/or per unit area). Therefore, scaling up may require higher certainty of benefit estimates to obtain investment approval. Larger investments may provide a spread of risks on individual actions, resulting in greater certainty of overall outcomes.

2.5 Role of GIS Analysis

The method for this project utilised GIS to analyse the potential impacts of land use change in specific natural capital investment cases. This includes establishing the costs and benefits of potential natural capital investments across England. This has included the following where spatially explicit (geo-coded) datasets exist:

- The extent, distribution and condition of natural capital stocks (major land use types, natural capital assets);

- The quantity and quality of flows (ecosystem services);
- Environmental pressures, and
- Proximity to population (e.g. for recreation and flood protection value).

Existing NCC analysis using GIS (SoNC II, 2013) included the market and non-market benefits of changes in land use, specifically woodland coverage and the intensity of agricultural production. For woodland a 50 year planting of 750,000 ha of new woodland in Britain (250,000ha in England) was assessed by the NCC, with an estimated net benefit of +£546m/yr. However, SoNC II noted that the case for investment across Britain varies substantially and ranges from strongly positive in one area to highly negative in another. This means that whilst the case is made for change through a positive net benefit, this analysis could be refined to be more targeted towards those areas with only positive net benefits, leading to an even stronger investment case. The suggestion is that such targeting might be pursued through a payment for ecosystem services mechanism (Bateman et al, 2013).

GIS has been used in this project to build on this existing NCC work using GIS which makes the investment case for woodland and agriculture. It is used to answer questions on the costs and benefits of the prioritised investment cases identified. There were two broad steps to this process:

i. Choosing which investment cases to apply GIS in?
ii. Choosing which issues to analyse with GIS in the investment cases chosen?

i. GIS in Which Investment Cases?

The cases for GIS analysis were chosen based on the following criteria in order of importance:

a. No currently available spatial results on potential investments;
b. Highest potential NPV (as this will reflect best returns on investment and greater ambition);
c. Benefits and costs that are more spatially (location and or scale) sensitive;
d. Data availability/quality to inform the GIS analysis.

Point (c) above is linked closely to the discussion under (ii) below.

ii. GIS to Analyse Which Issues in an Investment Case?

The value of costs and benefits from investment in natural capital vary spatially for all investment cases, but these variations will be different depending on the goods and services a given natural capital investment produces. GIS can be used to understand more about certain aspects of an investment case that determine this variation. It thus informs the estimation of costs and benefits, including through the process of economic value transfer. Specifically, where detailed examples exist, the scale over which it is relevant to transfer the evidence from these examples across England to get a national restoration plan can be established through identifying:

- **The extent (ha) of natural capital in a specific condition/subject to same pressures** which might be defined by the condition/extent of specific natural capital assets. Evidence to inform the definition of natural capital condition through a specific state of degradation should come from the technical science work in each potential investment;

- **The extent (ha) of natural capital where a certain investment can be carried out** (i.e. in the same condition/subject to the same pressures) **across England**. Extent could be

determined through one or both of: minimum size either in a single block (i.e. size of site), or minimum part of a functional unit such as a catchment (this is important because there may be a minimum extent required for ecosystem services to be provided (e.g. specific % of peatland in a catchment)). Size of sites can also be important as there may be diminishing returns to restoring natural capital beyond a certain size (ha) meaning that further restoration does not deliver significant additional benefits (e.g. water regulating services), and/or there may be economies of scale meaning that marginal costs reduce as scale of restoration increases (see related note on scaling of values).

- **The extent (ha) of natural capital in a specific location where it is able to provide a given ecosystem service.** For example, for peatland, this may be whether it is located in a catchment upstream of a significant population. Or it may be the distribution/proximity of natural capital relative to population to establish how many people are in catchments where peatland could be restored and therefore enjoy the benefits of improved water regulating ecosystem services.

The investment cases that used GIS are described further in Section 4.4.

3. THE BASELINE

Any investment, including into natural capital, needs to be appraised relative to a baseline. The baseline should be 'dynamic' so that it includes both the current situation at the time of the investment and also reflect future trends. Such a dynamic baseline allows for the estimation of costs and benefits both when the supply (or quality) of goods and services are increased relative to current baseline, and when a deterioration of natural capital is halted.

3.1 Baseline Assumptions

This study adopts a default business as usual baseline assumption, which is defined through knowledge of the current state of the natural capital assets, taking into account any known trends where possible. The status and trends in natural capital in England are a complex issue. Current evidence was used in the risk register of natural capital assets in the NCC's second report (SoNC II). In that study trends were assessed relative to policy targets for the assets covered in the report.

In reality the future baseline could vary dramatically in terms of both the supply of and demand for goods and services from natural capital. These could vary due to factors such as resource scarcity, population growth and distribution, climate and changes of future consumer preferences. These and many other factors are not incorporated systematically into the analysis. Doing so would require considerable effort to construct detailed scenarios, and would give results that are sensitive to the assumptions used. Nevertheless, it is borne in mind, with reference to previous analyses of risks and understanding of trends (e.g. in SoNC II), that these baseline issues are an important influence on the value of investments in natural capital.

3.2 Climate Change Risks

Taking potential future trends into account is crucial in particular for climate change risks[21]. The main influence of climate change in the UK (within the 25 year timescale for protection and improvement actions in this study) are expected to be on coastal margins and in temperatures (with the latter having observable impacts on species distribution). Other climate risks, such as the effects of floods and droughts on wetland ecosystems, also exist, and may become more significant beyond 25 years. They could also affect the impacts (effectiveness) of the protection and improvement actions.

In considering interactions between climate change and investments in natural capital, some key strategic issues have been identified in this study:

i. The analysis should consider climate change risks beyond the next 25 years, that investing in natural capital in the next 25 years can help mitigate against. Given the high uncertainties involved, it is useful to identify 'no regret' actions that address strategic environmental risks to England (e.g. on flood mitigation, will be useful even if flooding regimes are stable), and

ii. The need to avoid short-term mal-adaptation, whereby decisions taken on a particular timescale are not optimal to address impacts or risks on a longer timescale.

[21] Links have been made with Committee on Climate Change (CCC) Secretariat who commissioned a study on risks to natural capital assets from climate change. That study (led by URS) is working on a longer timescale than this study (reporting in May 2015). Method notes were exchanged between the studies, with the aim of identifying key interactions between climate change risks to natural capital and returns on natural capital investments.

A further issue is the presence of spatial hot-spots in England, where there are greater risks that climate change will result in the reduction of a range of goods and services from natural capital. Formal identification of these hotspots is beyond the scope of this study, but the analysis of natural capital investment options can input to future considerations of hot-spots.

More detailed analysis of the interactions between climate change risks to natural capital, and options for protecting and improving natural capital may be needed based on future adaptation scenarios. These scenarios can be informed by the ongoing revision of the UK climate change risk assessment, which the current URS-led work for the CCC is part of the evidence base for.

In the analysis to prioritise natural capital investments in this study, "strategic climate risks" was used as a prioritisation criterion to reflect climate change risks. This considers mitigation of long-term climate risk, and avoidance of short-term mal-adaptation, and any other relevant evidence. More detailed site-specific or investment-action specific analysis of climate change risks was not generally feasible in the context of this project.

4. DEVELOPMENT OF EVIDENCE

This Section describes the development of evidence used in the analysis. It explains the differences in analytical approaches needed to handle the evidence available on the impacts of different natural capital investments. The natural capital investment options analysed in subsequent Sections are also defined.

In order to collate information from diverse sources in a structured and comparable way, a series of separate templates were developed for the scientific evidence, economic evidence and summary of this evidence in an 'investment' template. The three templates are shown in Annex 1. Investment options are also summarised visually in value chain diagrams.

4.1 Identifying Natural Capital Investment Options

This Section contains a list of the natural capital protection and improvement investment options considered in this analysis. It is also noted that there are a wide range of management actions that can be taken to improve natural capital. For example, Sutherland et al (2014) identify a candidate list of 296 possible interventions to maintain and enhance the main regulating services of air quality regulation, climate regulation, water flow regulation, erosion regulation, water purification and waste treatment, disease regulation, pest regulation, pollination and natural hazard regulation. The range of interventions they identified differed greatly between habitats and services depending upon the ease of habitat manipulation and the level of research intensity.

The investments considered for prioritisation for detailed analysis are defined below. This list was intended to cover the main natural capital investment options of significance in England. However, the list is not exhaustive. Other options include analysing urban soil improvement (i.e. contaminated land remediation), or separating analysis of specific environmental features (e.g. analysis of different types of grassland, as only one type is considered within the work on agricultural habitats).

Demersal Fish Stocks: Actions to restore fish stocks are based around adjusting fishing effort to reduce overall mortality, including of juvenile fish, in order to allow stock biomass to recover to what are understood to be maximum levels that can be supported by the marine ecosystem. There are uncertainties in such models as most assessments are for individual species, and thus do not take into account species interactions (such as predation). Also not all commercial pelagic species have stock assessments. Analysis is based on ICES stock assessments, using Cod landings as an example.

Shellfish Stocks: Actions to restore shellfish stocks are based around adjusting fishing effort to reduce overall mortality, including of juvenile shellfish and the most reproductive adults, in order to allow populations to recover to what are understood to be maximum levels that can be supported by the marine ecosystem. There are uncertainties in such models as most shellfish species do not have stock assessments. However, there are examples of management measures (e.g. minimum and/or maximum landing sizes) and how management of particular shellfisheries (e.g. Lundy) has shown improvements in stocks following protective management.

Inshore Fin Fish Stocks: Actions to restore inshore fin fish stocks are based around adjusting fishing effort to reduce overall mortality, including of juvenile fish, in order to allow stock biomass to recover to what are understood to be maximum levels that can be supported by the marine ecosystem. There are uncertainties in such models as most assessments are for individual species,

and thus do not take into account species interactions (such as predation). Also not all commercial fin fish species have stock assessments.

Bathing Water: Actions can be taken to deal with point sources and diffuse water pollution in order to comply with the revised Bathing Water Directive standards. The majority of UK beaches do not require further investments to meet the revised standards.

Saltmarsh: Actions can be taken to protect, enhance or create saltmarsh habitat. Protection and enhancement can include sediment feeding and other stabilisation techniques. Creating saltmarsh habitat can be through managed realignment or regulated tidal exchange. Managed realignment refers to the reorganisation of flood risk management embankments to create a larger intertidal area, much of which will be colonised by saltmarsh vegetation. Examples include Freiston Shore in Lincolnshire, and Medmerry in West Sussex.

Biogenic Reef: Actions to re-establish benthic species (such as mussels, sabellaria worms) that form reef structures on the seabed. Such reefs are typically productive and biodiversity habitats. Some protection and improvements of biogenic reefs can be achieved through relief of pressures restricting their extent on the seabed. However, the response to such measures and over what extent of seabed is very poorly known. Understanding of the history of changes to seabed features and their reversibility is poor.

Peat Bogs: Primary action is re-wetting of peat by blocking artificial drainage ditches. Example projects include Exmoor mires, Life Active blanket Bog in Wales, Moors for the Future partnership, North Pennines Peatland programme and Pumlumon. There can be various protection/improvement activities taking place on a site including; grip blocking, preventing overgrazing, reseeding bare peat (e.g. with sphagnum), stabilising bare peat (e.g.spreading brash on peat surface), gully blocking, cessation of moorland burning, removing forestry, removing non-native species. The degradation of the site and the level of action/ subsequent management required will affect the cost:benefit ratio.

Enclosed Arable Farmland: There are numerous actions relevant to both cropping and non-cropped habitats, but here the focus is on arable land (grasslands are considered separately). Cropping actions include those to address soil structure and function (carbon storage, fertility, biodiversity and water capacity), inclusion of leys, fertility building leys (including legumes), cover/catch crops, fallow, rotations, minimal tillage, agroforestry, organic farming etc. Non-cropped actions include hedge creation/ improvement, hedge management, field margin management (including conservation headlands, nectar strips, wildflower and game strips), detention ponds for sediment, wildlife ponds, wetland creation, planting farm woodlands, planting individual trees, setting aside marginal farming areas for wildlife, beetle banks etc. (Chalara and loss of ash from farmlands will particularly affect hedgerow trees, small copses and hedgerows). Examples drawn on include agri-environment scheme measures and specific farm scale projects such as those at Hope Farm, Loddington and Hillesden.

Woodland: UKNEA follow on project work package on planning Britain's forests (Bateman et al., 2013) includes detailed modules on agriculture, timber, GHG, recreation, water quality and biodiversity. Important factors include the location of new woodlands, improvement of existing woodlands including actions required to deal with impacts of tree diseases (e.g. Chalara and loss of ash species from woodlands and in the wider landscape) and interactions with climate change.

Diverse Specialist Habitats: Investments in a wide variety of specific habitats can be identified in line with the priorities identified in the UK BAP (e.g. Can re-creating lowland heathland by removing conifers from afforested heathland?). Many of these habitats are a specific part of the

broad investment options identified here. These investments are primarily framed in terms of biodiversity objectives, even though they are recognised to enhance a range of ecosystem services (Armsworth, et al 2009). These investments are regarded as a special case, and so have not been analysed in detail, but are discussed further in Section 4.5.3.

Freshwater Wetlands: Focus is on habitat conservation and improvement for biodiversity. Actions include re-wetting historic wetland areas, taking land out of intensive agricultural production and restoring to more extensive use and allowing inundation, linking up current wetland areas to benefit dispersal of wetland species, and site management restoration removing unwanted species. Action may also include provision of visitor facilities, educational resources. Example projects include the Great Fen project, Little Ouse headwaters project, possibly Nature Improvement Areas (e.g. Morecambe Bay).

Freshwater (protection by water treatment – for water supplies, recreation, aesthetics): Mainly investments in water treatment capacity by water utilities, but also includes actions to address other point source and diffuse source pollution. Latter overlaps with 'catchments'.

Semi-natural Grassland: Actions to achieve more species rich assemblages with higher levels of ecosystem function may require active intervention through seeding of desirable species, beneficial grazing and/or cutting practices and reductions in fertiliser and (where applicable) pesticide inputs. Active management of competitive species may also be required. See also non-cropped actions for enclosed farmland.

Grasslands, Intensive Livestock: Improvement may require nutrient stripping (to remove phosphorus) as well as seeding of desirable species, beneficial grazing and/or cutting practices and reductions in fertiliser and (where applicable) pesticide inputs. Active management of competitive species may also be required. See also non-cropped actions for enclosed farmland.

Air: Actions to improve air quality by reducing pollution loads, in particular of NOx, Ammonia, $PM_{10/2.5}$, VOCs and other pollutants. Many of the actions required relate to restriction of point sources from buildings and transport. Measures can include use of vegetation and tree belts to recapture ammonia from agricultural activities in rural areas, reduce pollution impacts on surrounding ecosystems and also long-range air pollution. Example evidence includes CEH research on ecosystems for Defra. This action links to tree planting in urban areas as part of urban green infrastructure, but may be confounded by increased VOC's and ozone.

Urban Green Infrastructure: Improvement of urban habitats to provide multiple benefits, in particular to facilitate recreation and access to greenspace, with associated mental and physical health benefits and well-being. Projects may be quite diverse from creating community woodland on brownfield sites (Ingrebourne Hill), to river restoration (e.g. Mayesbrook park, River Quaggy), creation of roof top gardens/living walls or other increases in quality and/or quantity of green infrastructure.

Catchments: Catchment Initiatives encompass a broad range of activities many of which fall under the individual habitats which comprise the catchment (as above, dependent on specific catchment). Other activities are likely to incorporate specific actions to improve the water-body within the catchment. For lakes and rivers this may include re-vegetating margins, dredging to remove sediment, removing species (fish, geese, invasive non-natives), manipulating the water body through addition of phoslock (to lock up sediments). In rivers, options include re-naturalising channels, reconnecting channels, re-establishing flood plains, removing artificial barriers, adding material. Examples of projects include Catchment Restoration Fund initiatives, Loch Leven, Reform (river projects), Rivers Trust catchment Initiatives etc.

4.2 Priorities for the Analysis

The objective of the analysis was to establish an evidence base for the costs and benefits of natural capital improvements and the scale at which beneficial investments can be undertaken. A key aspect of this work was to prioritise the natural capital investments which have the strongest case in terms of potential economic returns to society. This sub-Section describes the prioritisation criteria used to select natural capital investment options. It then applies the prioritisation criteria to select those investments to be taken forward for more detailed analysis.

The criteria relate to the extent to which the evidence available is sufficient to conclude on the cost and benefits of natural capital investments at the scale of England. It is noted that uncertainty will influence the prioritisation on numerous levels – benefits, costs, scaling up, etc. The criteria developed by the project team for prioritising for the initiatives to be taken forward for further analysis are listed in Table 4.1.

Table 4.1: Prioritisation criteria

	Criteria	The higher priority investments are those with…
1	Scale of (net) economic benefits	…greater scale of net economic benefits evidence. *Site/project level evidence is of lower priority than larger scale natural capital investment benefits analysis. This includes SoNC II on the potential value of meeting existing targets for natural capital. Benefits are assessed as total economic benefits (i.e. total contribution to human welfare) whether or not this contribution has a market value.* *The intention is to assess benefits net of costs, but costs are not always known reliably so this uses both calculated net benefit evidence, and expert judgement on benefits exceeding costs.*
2	Monetised benefits	…greater proportion monetised benefits. *Meaning a lower reliance on non-monetary measures of welfare. There is also greater weight placed on market values, in most cases. It is recognised that this can introduce bias against investments whose benefits are harder to monetise (e.g. biodiversity conservation).*
3	Scalability	…greater scalable potential / ambition. *See Section 2.3*
4	Chance of success	…greater chance of success (or lower risk of failure). *This criterion addresses another aspect of evidence uncertainty (formally classified using established approaches based on strength of evidence base and consensus on interpretation).*
5	Equity	…more equitable impacts in terms of temporal, social and other distributional aspects. *This criterion relates to the social acceptability of the distribution of costs and benefits.*
6	Balanced natural capital investments	…greater contribution to a balanced set of investments across a range of natural capital assets (and/or goods/ services), geographical locations, social groups. *An initial assessment of this factor is noted for application later in the study.*

7	SoNC II risk register rating	…higher risk register rating. *This covers most relevant MLUTs and ecosystem services. The criterion includes the confidence level and whether the risks relate to the quantity, quality or spatial location of the MLUTs.*
8	Strategic climate risk	…higher contribution to mitigation of long-term climate risk and avoidance of short-term mal-adaptation.

There is a possibility for economic/monetary criteria creating bias against biodiversity benefits. However, SoNC II risk register included a large selection of wildlife risks, so this creates a balance at least to some extent.

4.3 Prioritisation of Investment Options

The criteria in Section 4.2 were applied to the list of potential investments described in Section 4.1. Table 4.2 presents a shallow initial review of the investment options against the prioritisation criteria described above. For all these criteria the assessment is summarised qualitatively as: very high, high, medium, low or nil. Each criterion is defined such that a higher score is better. For example, for the criterion 'lower risks/higher chances of success...', a high rating indicates that risks are lower and the investment should therefore have a higher priority.

This results in the majority of initiatives being included or rejected from the list for analysis. It leaves a small number of 'borderline' choices regarding investment options, and these were then reviewed in more detail against the criteria, as shown in Annex 2.

The conclusions from applying these criteria are indicated in the table by shading on the first cell of each row as follows:

Include in further analysis of natural capital investments.
Not a priority for further analysis.

The details are provided in the text following the table.

Table 4.2: Initial review of natural capital investments against prioritisation criteria

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Demersal fish stocks (fish for food)	**High** – possible benefits of £1.4bn/yr additional landings significantly greater than costs (e.g. recovery of North Sea cod stock to MSY could generate £0.4bn in value of landings over 10 years)	**High,** but further non-market benefits of conserving non-target species. Also ecosystem benefits and resilience are not monetised.	**High** – many stocks in North Sea, English Channel and Irish Sea are not exploited at MSY levels.	**Medium/High** – actions known & the UK is committed to fish stock recovery policies. Uncertainty due to previous policy failures & transboundary nature requires cooperation by other countries. MSY cannot be achieved for all stocks simultaneously	**Medium**: Short-term costs of reduced catches represent deferred future benefits from stock recovery. Transitionary support may be required to adjust to short-term costs on some coastal communities	**High** – should cover marine environment, of which fisheries are a major component.	**High** risk (quality, low confidence)	**High** – up to £1.4bn/yr	**High** – healthy fish & shellfish stocks, and marine ecosystem, more likely to be resilient to climate change
Inshore shellfish (fish for food)	**Medium** – benefits significantly greater than costs, inshore shellfish stocks are over-exploited in many areas and could yield higher catches if enhanced, but moderate value	**High**, but further non-market benefits of conserving non-target species. Also ecosystem benefits and resilience are not monetised.	**High** – important shellfish fisheries for crab and lobster all around England	**Medium** - actions required are understood. Restocking can increase yields.			**High** risk (quality, low confidence)	Not Assessed	
Inshore fin-fish (fish for food)	**Medium** – benefits significantly greater than costs, inshore finfish stocks are over-exploited in many areas and could yield higher catches if enhanced, but moderate value	**High**. Further non-market benefits of conserving non-target species.	**High** – across most inshore waters	**Medium** - actions required are understood but requires cooperation of larger vessels and countries that fish same stocks offshore.			**High** risk (quality, low confidence)	Not Assessed	

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Bathing Water (recreation)	**Medium** – benefits understood to be greater than costs for meeting revised bathing water directive 'sufficient' status in ¾ of 70 English bathing waters at risk of failure.	**High** – but benefits are non-market for recreational access and use. Excludes avoided illness & biodiversity benefits.	**Low** - Analysis only applies to 70 (out of approx. 400) bathing waters in England. Diminishing returns to scaling up from this.	**High** - actions required are understood	**High** – costs in line with polluter pays for those shared by water (sewerage) bill payers, local authorities and those with private sewerage. Taxpayers subsidise part of measures in agriculture. Benefits to users.	Possible	**Low** risk/ not assessed	Not Assessed	**Low** – although risk of storm-related pollution incidents may increase
Saltmarsh (hazard regulation, etc)	**High** — provides a range of benefits: hazard regulation; carbon sequestration; fisheries production; recreation opportunities; biodiversity.	**Medium** – avoided flood protection/ flooding costs, but current figures may not fully capture some non-market benefits (e.g. fish nursery grounds, aesthetics)	**Medium** – current saltmarsh area 40,522ha (England & Wales). Coverage is around 1/2 of historic area (Roman times)[22]. Net loss estimate up to 100ha/yr[23]. Potential sites for large-scale managed realignment are known. Also potential for advancing the line.	**High** – techniques for stabilising and improving quality of saltmarsh well established.	**Medium** – costs mainly borne by taxpayer, but opportunity costs to existing land uses/users through short-term loss of agricultural land and potential change in public access.	**High** – should cover coastal margins	**High** risk (quantity - high confidence; quality – low confidence)	**Medium/ High -** Coastal Margins: Aesthetics up to £10m/yr; Hazard protection up to £50m/yr; Equable climate up to £40m/yr	**High** – coastal margins are one of UK's most vulnerable assets. Dampens increased costs of sea-level rise to flood defences

[22] Davidson, N.C., Laffoley, D.d'A., Doody, J.P., Way, L.S., Gordon, J., Key, R., Pienkowski, M.W., Mitchell, R. & Duff, K.L. 1991. Nature conservation and estuaries in Great Britain. Peterborough: Nature Conservancy Council. 422 pages.
[23] Phelan, N., Shaw, A., Baylis, A. 2011. The extent of saltmarsh in England and Wales: 2006–2009. Bristol: Environment Agency. 47 pages.

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Biogenic reef (wildlife, water regulation)	**Low/Moderate** – include some valuable biodiversity and ecosystem services, e.g. supporting commercial fish sps	**Low** – limited understanding of enhancement makes valuation limited and highly uncertain.	**Low/Moderate** – large former extent, but potential enhancement unclear: depends on local conditions. Requires suitable habitat, water quality, currents and larval supply. Mussel beds often measure a few hectares or less.	**Low** – best method is removal of pressures, but some biogenic reefs have very slow recovery. Interventionist techniques poorly understood.	**Medium** – investment returns could take decades to be realised. Enhancement would require restriction of fishing pressure, causing short term cost.	**Medium**, marine already covered	For marine wildlife: **High** risk (quality, low confidence))	Not assessed	**High** – healthy fish stocks/marine ecosystem less vulnerable to climate change but shellfish and maerl growth may be affected by acidification.
Peat Bogs (carbon, wildlife, water)	**Moderate/High** – avoided costs of water treatment, biodiversity benefits, increased carbon storage (costed using carbon trading price and estimates of emission reductions NE report NE257)	**Medium** – savings in avoided water treatment costs uncertain and non-market values not fully measured & valued except for carbon	**High** – extensive areas of peatland in England, many in densely populated catchments	**Medium** – techniques extensively used, but timing of returns unclear and variation in cost: benefit ratios dependent upon degree of site degradation/ actions required	**Medium** – water company investments = beneficiary pays. Most successful projects are partnerships of farmers, NGOs, water companies, agencies	**High** – possibly main issue in uplands	**(Very/)High** risk for several services, high confidence (mainly quality)	**High** - Mountain, moors and heaths: Hazard protection £50m - £80m/yr; Equable climate £70m- £210m/yr	**High** – peat bogs condition vulnerable to lower summer rainfall; negative feedback that this reduces potential to store and sequester carbon, resulting in carbon source
Enclosed arable farmland (food, wildlife)	**High** – potential to reverse large wildlife losses possible for low opportunity cost. Potential to impact on water (see catchments) and many other services.	**Medium** – value of wildlife recovery and other ES uncertain	**High** – large proportion of England, arable land use covers ~ 30% of England	**Medium/High** – techniques understood, may be restricted by cultural barriers in farming with respect to wildlife friendly methods	**High** – zero/low cost way of increasing returns on CAP payments	**High** – large area, links to catchments	**Very high** risk, high confidence for wildlife (quality).	**Medium – High,** Enclosed farmland: Wildlife benefits £20m - £80m/yr	**Medium** – uncertain and variable across different locations/ services. Vulnerable to rainfall variations - may be changes in cropping regime with climate change.

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Woodland	**High** – see work in SoNC II and Science paper led by IJB	**Medium/High** – but reliance on non-market benefits (recreation, carbon). Some benefits (biodiversity, aesthetics) may not be fully captured	**High** – increase in urban-edge woodland cover on several % of England land area may be beneficial	**Medium** – very long term investment and challenge to overcome opportunity costs	**Medium** – carbon and recreation benefits spread widely, but long time period for returns on investment	**High** – woodland is key MLUT	**High** risk, mainly low confidence for fibre (quality & quantity); wildlife, recreation, water regulation (mainly spatial)	**Medium** – Woodland: Wildlife £20m - £210m/yr	**Medium** – vulnerability of woodland to climate change uncertain ~ some attempts at modelling climate change impacts
'Diverse/sps rich' Specialist Habitats	**Potential high**, but uncertain additionality of wider services	**Low** – conservation and regeneration benefits poorly valued	**Low/Medium** – generally small areas of land, but could involve 100 or more sites. Investment case/ opportunity varies by location	**High** – actions well understood	**Medium** – benefits vary depending on proximity/ accessibility. Some habitats enhancement takes decades.	**Medium** – uncertain how large a role this can play	Not assessed	Not assessed	**Medium/High** – potential contribution to Lawton objective of resilient network of habitats
Freshwater wetlands	**Medium/High** - potentially high covering a wide range of benefits, but very location dependent.	**Medium** – non-market use and non-use values are significant part of benefits, and may be significantly under-measured	**Medium/High** – wetland vision identifies large areas for creation/ improvement, but feasibility varies by location	**High** – techniques understood for several habitats (e.g. reedbed, wet grassland)	**Medium** – range of beneficiaries, including from mitigation of flood risk, recreation, but opportunity cost to farming may be barrier at larger scale.	**Medium** – depends on other actions on farmland	**Very high** – wildlife very high risk, 6 other services high risk, from freshwater assets (mainly quality)	**High** - Freshwater: Aesthetics up to £410m/yr; Recreation up to £400m/yr; Wildlife up to £440m; Hazard protection up to £50m/yr; Equable climate up to £40m/yr	**High** – habitats, esp. smaller sites vulnerable to variability in rainfall & wetlands regulate impact of extreme weather events

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Freshwater (protection by water treatment – for water supplies, recreation, aesthetics)	**Medium** – water supplies are reliable, benefits of river water quality	**Medium** – water supplies and WFD objectives have valuation evidence. Local variations in some benefits (e.g. biodiversity) less well measured	**Medium** – limits to what can be achieved cost-effectively without wider catchment interventions	**High** – techniques well understood	**Medium** – costs borne by water bill payers, but issue of affordability of short-term costs for benefits that are long-term	**Low** – catchments and wetlands are more balanced natural capital investments	**High risk**, high confidence for clean water (quality) from freshwater assets		**Low** – energy intensive approach and does not address water quantity variability due to climate change
Semi-natural grassland (SNG)	**High** – potential to reverse large wildlife losses for low opportunity cost, and reduced management intensity can increase soil quality and soil carbon	**Medium** – value of wildlife recovery and other ecosystem services uncertain	**Medium/Large** – large areas of semi-natural grassland (~16% of GB), multiple services could benefit from improvements in condition, but existing coverage by agri-env schemes	**Medium/High** – techniques understood, may be restricted by cultural barriers in farming	**High** – zero/low cost way of increasing returns on CAP payments	**Medium** – large extent, but limited market benefits	**Very high** risk, high confidence for wildlife (quality)	**Medium** - Semi-natural grassland: Wildlife £20m to £40m	**Medium** – uncertain and variable across different locations/ services, can contribute to resilience from reversing habitat fragmentation
Grasslands - intensive livestock	**Medium** – potential to reverse large wildlife losses possible. Costs higher than SNG as losses for farmers de-intensifying production- benefits from lowering runoffs to water quality	**Medium** – value of wildlife recovery and other ecosystem services uncertain	**High** – large proportion of England, improved grassland covers ~20% of England	**Medium/High** – techniques understood, may be restricted by cultural barriers in farming and costs to farmers	**High** – zero/low cost way of increasing returns on CAP payments	**High** – large area, links to catchments (measures that reduce outputs from intensive grassland beneficial to water quality)			**Low** – not a high-risk habitat
Air	**High** - reduced ecosystem damage (pollutants, nitrogen, ozone, human health)	**Medium/High** - see Jones et al.	**High** - can be applied to many different urban areas	**Medium** - limited actions, but these have high confidence	**High –** affects many sub sections of society, benefits arise rapidly after actions	**High** – based on view that air is a key natural capital asset	**High** risk, low confidence in urban (quality & quantity)	**High** – Urban: Clean air £9bn to £20bn	Climatic changes significantly linked to air quality, e.g. temperature and NH3, CH4 and O2 emissions
Urban green infrastructure	**Medium/high** - Potential to improve health and well-being through relatively low cost methods	**Medium**- difficult to establish cost/benefits of well-being but some work has been done in this area	**High** - can be applied to many different urban areas	**Medium** - fairly simple techniques, some evidence on health outcomes emerging	**High** - benefits for larger populations	**Medium/High** - multiple actions can be applied in many locations	**High** risk, low confidence for urban aesthetics (quantity)	Not assessed	**Low** - not a high priority for climate change action, although other urban issues (e.g. heat, a concern)

Natural capital investment	Scale of economic benefits		Scalability	Chance of success	Equity	Balanced NC investments	SoNC II Risk Register		Addresses strategic climate risk
	Overall benefits	Proportion of monetised benefits					Risk register rating	Benefits of targets	
Catchments (water regulation)	**High** – water quality, quantity and hazard regulation, plus potential co-benefits (e.g. wildlife)	**Medium** – some cases value improvements, but values location-specific to uncertain	**High** – potentially the majority of England	**Medium** – techniques understood for some types of catchments, but outcomes complex to model	**Medium** – taxpayer interventions and wide benefits, but opportunity cost to land uses may be barrier at larger scale.	**High** – involves variety of land uses and large scale	**Very high** – Farmland, freshwaters, MMH (quality) & woodland (quantity, spatial), all high risk for 'clean water' services	Not assessed	**High** – water resources and significant strategic risk to UK.

4.3.1 Discussion of Prioritisation of Investment Options

The analysis in Table 4.2 results in the following priority investment cases (see Table 4.3):

Table 4.3: Summary of Prioritisation of Investment Cases for Detailed analysis

Include in further analysis of natural capital investments.	Demersal fish stocks Inshore shellfish Saltmarsh Peat Bogs Catchments Freshwater wetlands	Urban (health) Woodland Air quality Lowland farmland (low-input improved grassland, hedgerows and pollinator strips).
Not a priority for further analysis.	Inshore fin-fish Bathing waters Biogenic reef Grasslands – intensive livestock	Specialist Habitats (see Section 4.5.3) Freshwater resources

Inshore shellfish and fin-fish both have strong investment cases, but shellfish were preferred for analysis for two reasons: firstly they support a high proportion of inshore fisheries activity, and in terms of employment in small coastal communities and ports. Secondly, fin-fish investments would be vulnerable to a lack of cooperation from other countries' fleets pursuing the same stocks when they are in offshore waters. Demersal fish are vulnerable in a similar way, but are of higher value. Pursuing both demersal and fin-fish investments would create greater exposure to risks related to international fisheries policy cooperation.

Investments to improve bathing water quality have been investigated for the implementation of the revised Bathing Water Directive (eftec, in prep.). This shows that investments to achieve standards for the majority of currently failing waters have benefits that outweigh costs. However, this conclusion relates to a relatively small number of bathing waters (approximately 70 out of over 400 in England). Therefore, although investment in individual bathing waters may be worthwhile, overall this is not considered a sufficiently beneficial investment to be part of national natural capital priorities.

Catchments are considered the key investment option in relation to water resources. This is because they are the functional unit across which investments in different MLUTs influencing water resources are complementary. The actions required in catchments are mainly covered in other investment cases (e.g. actions under the lowland farmland, peatland and woodland investments all can improve water regulating services). However, investment in catchments can coordinate these actions to increase their cost-effectiveness in improving these services). Practically, they are also subject to an investment appraisal being consulted (consultation launched October 2014, Claire Johnstone, EA, pers comm.) which helped inform the analysis of this investment options.

A choice needed to be made between freshwater wetlands or freshwater (resources). Freshwater (resources) will overlap more significantly with catchments analysis, and wetlands offer a wider range of services (e.g. hazard regulation and recreation) and contribution to climate change adaptation. Therefore, freshwater wetlands were prioritised, and freshwater resources were not considered further.

The choice of whether to analyse freshwater wetlands, semi-natural grasslands and intensive grasslands in more detail was less clear-cut. These options were subject to a detailed review against the prioritisation criteria, as shown in Annex 3. This resulted in the inclusion in further analysis of freshwater wetlands, but exclusion of intensive livestock grasslands. Semi-natural

grasslands were included in a wider analysis of lowland farmland, which also considered hedgerow management and creation of pollinator strips.

4.4 Use of GIS Analysis

The use of GIS analysis was made on two investment options (peat bogs and freshwater wetlands). The selection of these investments was based on applying the factors described in Section 2.5.

The choice for undertaking GIS work on peatland was based on the following:

- There are no currently available spatial results on potential investments in peatland;
- Investments in improving peatland have a potentially high NPV (based on their value for water and carbon regulating services).
- These benefits, and the costs of peatland improvement, are spatially sensitive (mainly driven by location). For carbon, although the unit value is not spatially sensitive, the quantity of carbon that can be stored as a result of improvements in peatlands varies significantly according to the existing condition of peat bogs in different locations.
- There is data available to use in a GIS analysis.

Peatland seemed like a suitable case for analysis provided there is spatial data on peatland extent and condition of sufficient quality to support analysis and provide results without too large a range.

The key question which the GIS was used to answer was how much peatland, and in what condition, can be improved. This is a key variable in both the costs and amount of ecosystem services benefits of the improvement.

The choice for undertaking GIS work on freshwater wetlands was based on the following:

- There are currently available spatial results on potential areas for investments in freshwater wetlands through the wetland vision. This provides a starting point of data, but does not take into account key socio-economic variables for an investment case.
- Investments in improving freshwater wetland have a potentially high NPV (based on their value for recreation, and water and carbon regulating services).
- These benefits, and the costs of wetland improvement, are spatially sensitive (mainly driven by location). Key spatial variables include the agricultural grade (and hence opportunity costs) of land that could be converted to wetlands, and the proximate population that could obtain recreational benefits from the site.

Data layers from the Wetland Vision were obtained through the RSPB, and analysis to link this to other socio-economic variables was undertaken.

4.5 Study Outputs

This Section summarises the outputs from the work. It discusses the implications of these investments for land use in the UK, and for the underlying natural capital assets.

4.5.1 Overview of Investment Evidence

The main outputs of the study are 10 papers examining different potential natural capital investments, presented in three appendices:

- Marine: describing potential investments in improving demersal fish and shellfish stocks, and a brief discussion of the benefits to the marine environment of such measures;
- Urban Green Space and Air: describing evidence on the need to protect and improve urban green space and air quality, mainly in order to support improved human health, but also considering other impacts (e.g. on ecosystems), and
- Land Use: This describes potential investments in increasing the extent of woodlands, saltmarsh and freshwater wetlands, and in improving the condition of upland peatlands. It also presents evidence on three examples of protection and improvement of natural capital on lowland agricultural land: for hedgerows, low-input improved grasslands, and pollinator strips. Finally it considers potential to invest in coordination of such actions with catchments to improve catchment management.

Table 4.4 gives an overview of the scale of potential investments and evidence involved in these 10 cases. The different options are identified in italics in the table. For air and urban green space, no specific investment case is defined. To do so, more work is required to interpret the evidence on these issues.

As Table 4.4. shows, the potential investments would result in trade-offs with current land-uses but the actual effect on agricultural productivity would be much lower because:

- The area of land involved includes are large area of upland peatland, which has very low productivity compared to most agricultural land in the UK;
- The investments can be targeted towards lower-productivity land; this is explicitly considered for wetlands , and is also likely to be possible for woodlands ;
- A large part of the investment is in field margins, which would be readily reversible, which can occupy less productive areas of fields (due to shading from hedgerows and soil compaction from machinery), and which can contribute to productivity by supporting pollinators and natural predators of crop pests, and
- The area on which saltmarsh is created is land already vulnerable to sea level rise, and arguably is uneconomic to protect from flooding, or will become so during the next 50 years as a result of sea level rise.

The benefit:cost ratios (BCRs) for the potential investments are summarised in Section 6.2, where they are compared to the BCRs for other capital investments.

Table 4.4: Overview of Impacts of Potential Natural Capital Investments

1. Land use change	Area of suggested land use change	Current area	% Impact on existing	Notes
England land surface	13m ha	-		
England agricultural land (upland and lowland)	9.3m ha	-		
Land that is largely permanently lost to agricultural production:				
Wetland	100,000 ha	1.5m ha	6.7% increase	Targeted to lower grade land
Woodland	150,000 ha[24]	1.25m ha	12% increase	Presumed partly targeted to lower grade land, but needs to be near towns
Peatland	200,000 ha[25]	(355,000)[26]	39% of current area improved	Opportunity cost of reduced grazing and grouse rearing capacity
Saltmarsh	22,000 ha	40,500[27]	54% increase	Land already vulnerable to climate change
Subtotal	**472,000 ha**	**3.15m**	**14%**	
Land temporarily lost of agricultural production:				
Arable margins	200,000 ha	n/a[28]		Margins are often less productive land
Total	**672,000 ha**	**n/a**		

[24] Assuming optimal area is less than 250,000 ha examined by Forestry Panel, between 100,000 and 200,000, taking a midpoint of 150,000
[25] Exact area unclear due to overlap in peatland condition categories
[26] Area is subset of wetland area, so not included in total.
[27] England and Wales
[28] Location and extent of margins can vary on short (annual or multi-annual) timescales.

2. Incremental: Broad and shallow interventions on farmland.	Land use change area	Current area	% Impact on existing	Notes
Low-input improved grasslands	500,000 ha	2.8m ha	18%	Reduced grazing intensity
Hedgerows	154,000km (lines of trees)	402,000km	38%	Possible land take for gapping up
Catchment actions & coordination	In 56% of catchments in England appraised by EA for WFD agricultural land management actions are part of a package of measures with a positive benefit cost ratio.			

3. Marine improvements	Current Landings	Investment Required	Investment as % of current	Estimated Benefits	% Increase of benefits	Notes
Demersal Fish Example: North Sea cod	Approx 33,000 tonnes per year	Landings currently being forgone to allow stock recovery is ongoing– investment	N/a	Lower bound estimate of 2.6 million tonnes of additional landings	Landings at least 200% higher (3 times larger)	Different stock modelling approaches give large range of predicted stock recovery levels
Shellfisheries: Lobster and Crab	Approx 13,500 tonnes/yr in 2012 and 2013	Forgone landings of 9,450 tonnes over 4 years.	20% reduction for 4 years	Additional landings of 122,000 tonnes over 50 years	Landings 25% higher	Stock assessments uncertain: only recently completed, and do not enable stock modelling.

4.5.2 Analysis of Impacts on Natural Capital Assets

The investments considered generally relate to major land use types (MLUTs) or other environmental resources (e.g. fish stocks). This is because these units are generally the most practical to use to measure natural capital (as described in Section 1.2) and they are also more practical management units (e.g. farmland, woodland) on which to organise investments.

Table 4.5 gives a brief review of how the potential investments relate directly to the Natural Capital assets defined by the Natural Capital Committee.

Table 4.5: Natural capital assets and their definitions

Natural capital asset	Overview of Impact of Potential Investments
Species ***Ecological communities***	Significant improvements for species and ecological supported by some habitats (woodland, upland peatlands, saltmarsh, freshwater wetlands), by measures under the lowland farmland evidence base (e.g. pollinators), and in waterbodies due to improved catchment management. Also benefits to many species groups through increased habitat connectivity (e.g. due to improvement in condition of hedgerows). Increases in numbers of fish and of marine food webs.
Soils	Some investments explicitly involve improvements in soil condition (e.g. upland peat, low-input improved grassland), whereas others (e.g. woodland) would be likely to do so.
Freshwaters	Investments in freshwater wetlands and catchment management would both be designed to significantly improve the state of freshwaters.
Land	A number of the investments would involve explicit choices to change land use (see Table 4.4).
Atmosphere	The air evidence base considered measures to improve the condition of the atmosphere.
Minerals and sub-soil assets	No major impacts identified.
Oceans	Improvement through Increases in numbers of fish and of marine food webs.
Coasts	Increase in extent of intertidal habitat under saltmarsh investment case. Increase in resilience of coastal ecosystems to climate change.

The review in Table 4.5 suggests that the investments would significantly improve the condition of all the main natural capital assets in England, except for minerals and subsoil assets.

4.5.3 Impacts on Biodiversity and Specialist Habitats

Biodiversity is a key part of natural capital and features strongly (as 'wildlife') amongst the natural capital assets at risk in NCC (2014). However, the investment cases do not generally target biodiversity protection and improvement directly. The investment cases are mainly based on broadly defined assets such as major land use types. A major part of the benefits of these investments would be to enhance wildlife, but specific actions for biodiversity, in particular for specialist habitats that contain scarce species, are not generally examined in detail.

These habitats are generally particular ecological communities that have relatively limited extent, but are known to be important for specific species (e.g. reedbed, purple moor grass and rush

pasture and others covered by the UK Biodiversity Action Plan Priorities[29]). These habitats are an important part of England's natural capital for a number of reasons, including:

- Culturally, for their non-use value, which can be significant;
- Financially through the value for nature-based tourism which can be a significant part of local economies (e.g. Dickie, Esteban and Hughes, 2005), and
- For the diversity and resilience they provide (e.g. in maintaining resilience in the face of tree diseases, maintaining a diverse set of woodland habitats).

These specialist habitats have not been prioritised in this work due to:

- Their generally limited spatial extent (by definition of being scarce/ limited in extent), and
- A lack of relevant economic data, particularly on the benefits of protecting and improving them. While a few economic valuation studies exist (e.g. Christie et al (2011), Jobsvogt et al, 2013), there is a general lack of knowledge of the benefits of conserving them (e.g. compared to the Brander (2008, 2011) valuation function for wetlands, which still retains significant uncertainties and gives broad range of results).

Lack of coverage in this work should not be taken as an indication of their low importance to society or as part of natural capital in England. Within the creation of large areas of habitat in investment cases for wetland and other habitats, there would be opportunities to create areas of specific habitat types (e.g. a BAP priority habitat like reedbed), and this should be examined as part of the objectives taken forward from the work.

[29] http://jncc.defra.gov.uk/page-5718

5. SYNERGIES AND CONFLICTS

This Section assesses synergies and conflicts between the natural capital investment options prioritised for detailed analysis in this project. Note that synergies and conflicts with investments in other (non-natural) forms of capital are not considered in this Section (See Section 6). This Section presents a high-level analysis of synergies and conflicts across the potential investment areas investigated. A more detailed analysis of synergies has been developed in the catchment evidence base (see Appendix: Land Use).

5.1 Approach

The potential natural capital investments analysed in this project, if implemented, would not exist in isolation to each other. Consideration needs to be given to how they could be organised to benefit from synergies, and to avoid conflicts and unintended consequences of individual activities. The objective is to identify the most productive package of investments (defined in the context of the study). The following lays out the approach to considering synergies and conflicts.

5.1.1 Synergies

Potential synergies between natural capital investment options include the following, which can act as a checklist for the analysis:

- Management costs and economies of scale of adjacent restored natural capital;
- The overlap of actions (i.e. types of actions in the same locations) taken under the investments;
- Overlaps in management of natural capital to support different ecosystem services. To assess this for each pair of potential investment cases:
    - Identify where the cases share a contribution to an ecosystem service as a significant part of their investment case (e.g. potential investments in peat bog improvements and in catchment management are both partly justified by water quality regulation benefits).
    - For these shared services, assess the extent of spatial (/temporal?) overlap in the investment to provide the service (e.g. what proportion of catchment management water quality regulation improvements are delivered by peat bogs). This may be qualitative.
    - Investments that support biodiversity outcomes of restoring adjacent habitats of all types are assumed to have some complementarity to creation of larger blocks of habitat that will be less vulnerable to external pressures such as disturbance, pollution and climate change (as per the Lawton Review conclusions).

5.1.2 Conflicts

Potential conflicts between natural capital investment options include the following, which can act as a checklist for the analysis:

- Diminishing returns to benefits from shared, but spatially distinct, ecosystem services (e.g. both freshwater wetlands and woodlands can provide recreational/ amenity benefits – but the value of the service is highly dependent on substitutes, so investing in both within a certain proximity could reduce the value of the benefits from each of them).
- Conflicts between management changes to a land use type and existing commercial activities – this should be reflected in the opportunity costs of the investment.

- Competition for space between investment in a change in land use type (e.g. woodland creation on arable and grassland habitats) and other human activities (e.g. arable and livestock farming) – this is also reflected in the opportunity costs (e.g. of utilising high-grade agricultural land to create alternative habitats).
- Competition for space between investment in a potential change in land use types and existing land use types which are the subject of other proposed investments (e.g. improving the condition of a floodplain agricultural land, or freshwater wetland habitat creation).
- Socio-political conflicts due to uneven distribution of costs and benefits (e.g. fisheries stock recovery, for which short-term costs of reduced catches for coastal communities represent deferred future benefits from stock recovery to coastal communities and society. Transitional support may be required to adjust to short-term costs on some coastal communities).

5.2 Analysis of Synergies and Conflicts

An initial review of the synergies and conflicts, discussed above, is reflected in the matrix in Table 5.1. This matches all potential investments prioritised for detailed analysis against each other. On the vertical axis the investment is the driver of actions, whereas on the horizontal axis the investment is the recipient of consequences of those actions. Synergies are highlighted green and conflicts in red. Areas with significant uncertainty are shaded more lightly and identified with a '?'.

The matrix indicates a significantly greater number of synergies, and potential synergies, than conflicts. The main conflicts relate to competition for space between:

- Woodland and enclosed arable farmland /semi-natural grassland, which may arise due to the one possible location for woodland creation being on arable land close to population centres who can benefit from recreational opportunities and enhanced regulating ecosystem services from each investment. Note that because investments in arable land tend not to involve land use change, this does not create a conflict with woodland. Therefore, this conflict is identified in the cell where woodland is the driver and arable land the recipient, but not vice-versa, and
- Freshwater wetlands and saltmarsh, both of which can be created on coastal floodplains. However, over the long term (50 year plus) time horizon of this study, this conflict may be mitigated by the influence of climate change on sea level rise: Saltmarsh creation is most viable and beneficial on land below mean high water, for which sea level rise will exacerbate risks of flooding (or costs of maintaining flood protection levels) into the future. Such locations are not optimal for freshwater wetland creation due to these long term risks from climate change.
- Freshwater wetland and enclosed arable farmland/semi-natural grassland - creation of new freshwater wetlands may require land to be taken out of agricultural production, potentially resulting in conflict for space.
- Peatland and woodland – restoration of peat bogs can involve removal of forestry activities and reversal of associated drainage.

The synergies from each investment option to the others are described in detail in the list following the table.

Table 5.1: Initial Analysis of Synergies and Conflicts

RECIPIENT

DRIVER

Investment cases	Air	Catchments	Enclosed Farmland	Inshore shellfish	Peatland	Pelagic fish stocks	Salt marsh	Semi-natural grassland	Urban GI	Freshwater Wetland	Woodland
Air		?									
Catchments	?										
Enclosed Farmland	?	?						?			
Inshore shellfish											
Peatland	?										
Pelagic fish stocks											
Salt marsh				?						?	
Semi-natural grassland											
Urban GI		?									
Freshwater Wetland							?		?		?
Woodland										?	

The following provides the rationale for the synergies and conflicts for each land-use/natural capital investment option. The investments linked to in each case are highlighted to enable assessment of the range of synergies identified.

Air

Synergies relate to improved air quality which reduces 'pollutant' deposition (e.g. PM10, carbon monoxide, nitrogen at high levels) and therefore improves the quality outcomes of other potential natural capital investments (as many habitats in England are currently negatively impacted by air pollution (Jones et al, 2012)):

- The regulation of water quality in **catchments**, as atmospheric deposition of pollution affects water quality;
- The crop provisioning potential **enclosed farmland**;
- Species important for **peatland** health and function (e.g. sphagnum moss);
- The health and functions of **saltmarsh**;
- The health of trees and grasses (parklands) in **urban areas** (GI);
- The health and functions of **freshwater wetland** habitats, and
- The health and functions of **woodland** habitats.

Catchments

Synergies relate to improved functions of catchments through actions that enhance water regulation ecosystem services which require investments to improve the quality of other habitats in the catchment, including:

- **Enclosed farmland**;
- **Upland peat bogs**;
- **Semi-natural grassland**;
- Planting of **woodland** in specific locations (e.g. to stabilised soils on steep slopes);
- **Air quality**- where nutrient management is part of catchment management plans, and
- **Freshwater wetlands** - creation of wetlands is likely to be part of catchment management plan benefits for water management.

Enclosed arable farmland

Synergies relate to expansion of measures taken in agri-environment schemes, specifically actions on field margins, such as hedgerow and buffer strip restoration, which will contribute to outcomes under other potential investments:

- **Air**: increased variety of vegetation structure will lead to greater absorption of airborne pollutants, but this effect may be minor in relation to the scale of air quality problems;
- **Catchments**: if appropriately located, actions on enclosed farmland will contribute to improved management of catchment, and
- For land that is close to **semi-natural grassland** through creation of an enhanced species pool, available sources for dispersal, and resources for pollinators.

Inshore shellfish and Pelagic fish stocks

These actions are taken in the marine environment and therefore will not contribute to the outcomes of the other terrestrial investments. It is possible that by increasing the health and resilience of marine food webs, improvement in inshore shellfish populations will contribute to the

recovery and maintenance of pelagic fish stocks. However, the evidence for such a link is highly uncertain at present.

Peat Bogs

Synergies relate to the improved functions of **catchments** through actions that enhance water quantity and quality regulating ecosystem services from upland peat bogs.

Saltmarsh

Synergies relate to the contribution from healthy saltmarsh to the health and resilience of marine food webs. For example, saltmarsh is known to be an important nursery environment for juveniles of commercial fish species in England (Colclough et al., 2010). As such, investments in saltmarsh will contribute to **demersal fish** and **shellfish** stock recovery investments, but current scientific understand of this link is insufficient to allow its quantification.

Semi-natural grassland

Improvement of semi-natural grassland in England, can contribute, in the right locations, to water quantity and quality regulating services, which are the target for investments in **catchments**.

Urban Green Infrastructure

Synergies relate to actions that will increase the extent and/or quality of urban green infrastructure, particularly trees:

- **Air**: vegetation, particularly trees, absorbs airborne pollutants, thereby complementing other investments to improve air quality;
- **Woodland**: expanding woodland within urban areas provides an opportunity to deliver the woodland investment option in close proximity to people. Similarly, urban areas may provide opportunities to enhance **semi-natural grassland** and **freshwater wetlands**, and
- Improvements in the quality of these habitats can contribute to **catchment management**.

Freshwater Wetlands

Synergies relate to ecosystem services of water quantity and quality regulation, and flood hazard protection, provided by floodplain freshwater wetlands. Enhancement of these services overlaps with or complements actions taken through investments in **catchments**, including in **urban** areas as part of the creation of **green infrastructure**.

Woodland

Synergies from expansion of the woodland area in England, particularly in locations close to large populations who can benefit from recreational opportunities, relate to:

- **Air**: woodlands absorb air pollutants which complements investments to control air pollution at source;
- **Catchments**: locating woodland expansion in appropriate parts of catchments can contribute to water quantity and quality regulating services, and
- **Urban green infrastructure**: expanding woodland within urban areas provides accessible green space.

6. COMPARISONS TO OTHER CAPITAL INVESTMENTS

This Section compares the evidence developed on potential natural capital investments, contained in the reports appendices as in preceding Sections, to other (non-natural) capital investments made by the public sector in the UK. Firstly evidence on non-natural capital investments is described, secondly, the natural capital investment evidence is summarised, and finally comparisons between the two are discussed.

6.1 The evidence base on non-natural capital investments

This research briefly explored the existing evidence base on the benefit cost ratios (BCRs) from public sector investment in the UK in a number of areas that potentially have some comparability to natural capital investment.

The scope of this review was limited by the quality of the ex-ante and ex-post evidence that is in the public domain. This is reflective of the fact that there is generally much more rigorous scrutiny of investment within each departmental or sub-departmental area of expenditure than across different areas of expenditure. So for instance there is systematic assessment of the value for money of competing national road capital investment projects but not between new roads and new hospital building projects. A further and related limitation is the scope of costs and benefits valued and indeed, in some respects, the methods of valuation differ across areas of public expenditure[30]. Finally, for the investments reviewed, the initial capital investment costs are generally known but future streams of annual benefits and costs are only estimated: therefore the BCRs quoted are generally taken from the initial investment appraisal stage (ex-ante), rather than ex-post after actual costs and benefits have been established.

Nevertheless, we have been able to explore the BCR evidence for four areas of public sector investment: flood defence; transport; broadband; and regeneration (encompassing physical investment in housing, in industrial/commercial property and in environmental improvements and some revenue investment in skills/worklessness reduction). The key findings of the work which are set out in Annex 3 in more detail are summarised in the table below. **Great caution should be placed on the use of these BCRs for the reasons set out above**. Some of the apparently very high BCRs in particular need to be treated with great caution as they are invariably ex-ante estimates that have yet to be rigorously evaluated.

[30] The assessment of BCRs in government is supposed to adopt best practice in HM Treasury Green Book valuation techniques, but in practice the degree to which the valuation (as opposed to quantification) is comprehensive varies across areas of spending and valuation methods tend to be applied in different ways

Table 6.1: Non-natural capital investments considered

Investment area	Notes	Progress
Roads Rail	Webtag guidance very detailed with set values to use. DfT publishes guidance on value for money ranges.	Complete: in Annex 3 Good evidence available from Eddington Review and other sources.
Walking and cycling	Uses Webtag plus monetisation of other benefits (e.g. health impacts)	Complete: in Annex 3 Some evidence available from Sustrans, Cycling England and other sources.
Flood defences	Environment Agency has detailed appraisal guidance for flood and coastal erosion risk management (FCERM) strategies and project appraisals[31].	Complete: in Annex 3 Some BCR evidence from periodic reviews by Environment Agency. However, there is limited detail available on underlying evidence.
Regeneration: physical investment Regeneration: Other investment (business support, skills and training) Housing	DCLG has published high level guidance on valuing the benefits of regeneration[32]. It also covers valuing environmental benefits of amenities. HCA tend to adopt these values and require Green Book style appraisals of schemes.	Complete: in Annex 3 Most recent and comprehensive source remains the DCLG review.
Business support in resource efficiency	Range of activities funded via ERDF, EAGGF, via agencies such as WRAP.	Historic BCR evidence is available from WRAP, but this is restricted (WRAP is in the process of updating their BCR evidence). Final report will review the methodology used for WRAP's forthcoming review, but no BCRs may be quoted.
Broadband	Largely delivered by market without public intervention. However, BDUK set up to invest in acceleration of super-fast broadband delivery in rural areas in particular.	Complete: in Annex 3 Most recent and comprehensive source is a UK level impact study in 2013. Other ex-ante evidence is available from business cases.

Source: See analysis in Annex 3.

6.2 Summary of the evidence from the Investment Cases for Natural Capital Investment

Gathering evidence on a consistent basis on BCRs for restoration projects is inevitably challenging and the study has had to draw on a wide range of sources from cases studies to macro-assessments and modelling. The key points from this evidence base are:

Forestry: there is a reasonably firm evidence base of an average BCR of at least 5:1 in England for a major woodland restoration/planting programme (the benefits rely largely on carbon and recreation benefits and provide few direct GVA benefits). The average returns are likely to be even higher for a somewhat smaller programme than assessed.

[31] http://webarchive.nationalarchives.gov.uk/20131108051347/http:/www.environment-agency.gov.uk/research/planning/116705.aspx.

[32] https://www.gov.uk/government/publications/valuing-the-benefits-of-regeneration

Catchments: it is very hard to generalise based on the very limited evidence base available and also BCRs are river catchment specific. The main case study reviewed (Cornwall Rivers project) suggested a BCR of over 4:1, with the benefits being largely market-economic (within farm businesses and the water sector).

Saltmarsh: there is more clustering of BCRs in the case studies reviewed, although they are relatively modest for the Alkborough (2:1 to 3:1) and Medmerry projects (over 3:1 where the main benefits valued were the economic benefits from enhanced protection of infrastructure, which account for around 80% of benefits).

Peat bogs: the evidence here results in a case for improvement based mainly on carbon benefits (BCR 1.5:1). Factoring in other benefits and targeting actions (e.g. to maximise benefits on deep peat, and where water regulating benefits are greatest) strengthens the case for investment.

Lowland farmland – restoration of grasslands, hedgerows and pollinator strips: the investment case for three strands combined is modest. The overall assessed BCR for a high level overview of this investment case is very modest at around 1.3:1 (PV costs c. £9bn, PV benefits £12bn). The conclusion is that a much more targeted approach would be needed to ensure better value for money.

Shellfish and Demersal fish: there are strong investment cases, with a BCR of approximately 6:1 for shellfish. However, demersal fish is amenable to traditional BCR analysis.

Inland wetlands: this is an area with a particularly wide range of BCRs assessed depending on the costs and benefit assumptions made. The investment case is targeted on restoring 100,000ha wetland on a range of sites with an average size of 100ha to maximise ecosystem service value and minimise opportunity costs. On this basis estimated overall BCRs range from a minimum of 2.6:1 up to 9:1. As with lowland farming the conclusion is that careful targeting needed to ensure best value for money and impact.

Urban greenspace: the evidence here is inconclusive, there is not a very useable evidence base as the ecosystems services approach has not been applied systematically to appraise the local impacts of changes in provision of green infrastructure.

Air quality: the evidence here is also inconclusive. Benefits are mainly assessed at a national scale, whereas many costs arise locally and are poorly understood.

6.3 Comparing natural capital and other capital investments

What can we conclude from the comparison across the evidence on the investment cases for natural capital investments and other public sector capital investment?

- First, the range in evidence on BCRs within most natural capital investment cases is far greater than that between types of natural capital investments and between natural capital investment and other public investment areas reviewed. This is due to several factors which means estimated BCRs (including for conventional infrastructure investments) need to be treated very cautiously:

    - There is no consistency in what is and is not valued and how;
    - The lack of market values for some environmental costs and benefits mean that some key impacts tend to be excluded from conventional infrastructure analysis;

  - Key environmental parameters that tend to be included in such analysis, such as carbon values, value of recreation etc., vary within and across investment areas, geographical locations and valuation methods used;
  - The actual case studies sometimes can be very location and project specific (e.g. catchments and saltmarshes) so it is hard to generalise from these.

- Second, the same issue, but perhaps to a lesser degree, applies to non-natural capital restoration public investment. A very wide range of BCRs exist on average for programme areas (and then within programme areas).

- Third, it is difficult from the evidence reviewed for this work relating to different investments, to separate out the economic and wider societal elements of benefits from ecosystem services. In the case of non-natural capital investment BCRs the majority of benefits appear to be economic (although it is not always possible to see the disaggregation of these).

- Fourth, there is a general point that much of the evidence based on forecasts of benefits and costs rather than firm evaluation (ex-post) evidence, both for natural capital restoration and other investments.

- Fifth, given the variation within investment areas it is reasonable to conclude that careful prioritisation and investment appraisal could ensure BCRs towards the higher end of the scale for restoration investments.

- Sixth, a reasonable overall conclusion is that several of the overall natural capital restoration investment cases appear to stand up well to some average public sector benchmarks (eg 4:1 and 5:1 for the roads programme). This is because:

  - Investment costs are known and reasonably certain;
  - There can be and has been a spatial analysis of the best investment opportunities available;
  - Investment cases can be designed to target projects/programmes with higher benefits and/or lower costs, and
  - In many cases there is a still developing but already well established body of benefits valuation evidence to link the assessment of spatial differentiation of costs and benefits.

- Finally, the evidence collated supports the argument that, if the right projects and investment strategies are made in several of the natural capital investment cases, the benefit cost ratios would readily stand up to or even exceed those in non-natural capital investment area.

7. Conclusions

This work has sought to make an economic case for a range of natural capital investments in England. It has prioritised potential investments according to economic criteria reflecting a range of decision criteria (e.g. highest net benefit, highest benefit:cost ratio).

10 potential investments were examined in detail. The evidence available was variable and resulted in some clearly defined investment cases, with comparable costs and benefits. For other issues (e.g. air pollution) where evidence was not sufficient to present a case for specific action, an evidence base is presented which highlights potential investments. The evidence collated supports the argument if the right projects and investment strategies are made, natural capital investments can have benefit-cost ratios that stand up to or even exceed those in other capital investment areas.

The investment cases where the scale of action could be defined are summarised in Table 7.2 below. The estimated costs and benefits of each investment all have some uncertainty, but offer potentially sizable benefits to society. The Net Present Values for the investments that could be calculated are shown in Table 7.1. This suggests potential returns from investments in natural capital of up to £9bn over the next 50 years. However, this figure is a very approximate estimate of potential the value.

Table 7.1: Net Present Values (NPV) of Potential Natural Capital Investments in England

Natural Capital Asset	NPV 50 yrs, £million, 2014 prices	
	Low	High
Upland peatland	560	
Demersal fish (cod)	860	4,700
Shellfish (lobster & crab)	123	
Saltmarsh	730	730
Wetland	634	2,700
Woodland[i]	354[i]	
Total	3,260	9,170

[i] For 250,000 ha, potential investment case is for 150,000 ha

An overall conclusion is that several of the natural capital investment cases stand up well to typical average public sector benchmarks (e.g. benefit-cost ratios of 4:1 and 5:1 for the roads programme). This is because investment costs are reasonably certain, with some spatial analysis of the best investment opportunities available, and actions can be designed to target projects/programmes with higher benefits and/or lower costs. The cases also utilised the developing, but already well established body of benefits valuation evidence. However, this evidence is still a source of uncertainty in the conclusions.

The uncertainty reflected in the large ranges in the figures in Table 7.1 needs to be put in context of other capital investments made by society. The figures in Table 7.1 include some key environmental costs and benefits that do not have market values. As discussed in Section 6.3 these costs and benefits tend to be excluded from conventional infrastructure and other investment analysis.

Including these values in the figures in Table 7.1 does introduce significant uncertainty, and the results for the investment cases often have very large ranges. However, the alternative would be to

effectively give no value to these environmental impacts in economic analysis, resulting in less accurate information with smaller ranges of results that spuriously suggest greater accuracy. The range in the benefit-cost ratios within most investment cases is just as large as the ranges between different types of natural capital investments, and across other public investment areas reviewed in Section 6. This is not necessarily a weakness – the narrower ranges, and hence the implied accuracy, in appraisals of other public investments may be spurious due to the exclusion of some environmental impacts.

One challenge in assessing the impacts of natural capital investments in England is scaling site or unit-cost level evidence to the national level actions. This has involved detailed consideration of diminishing returns and other factors, and is an area that would benefit from further research. Insights gained within the work include:

- That different environmental benefits vary with scale in different ways, for example due to diminishing returns operating for both the impacts of actions and the values of those impacts:
    - The benefits of avoiding loss of stored carbon and benefits of water regulation are specific to individual catchments so their impact and value do not diminish over a larger scale (i.e. multiple catchments).
    - The beneficial impacts to biodiversity could be expected to be constant across actions at large scales, or even increase with scale as ecological networks are enhanced. However, we would expect the monetary value of these impacts to have diminishing returns to scale[33] over the large areas involved.
    - There may be limitations to investments that can be made in natural capital at large scale as this may increase the costs of carrying out actions on a very large scale too quickly (100,000 ha plus per year).

- That in utilising the Brander (2008) function for wetland (freshwater wetlands and saltmarsh) values, the size of individual wetland sites was a very sensitive variable. However, the availability of substitutes (the area of other wetlands within a certain distance of the site being valued) was not as sensitive.

A further large scale consideration is the existence of synergies and conflicts across the potential investments. Synergies are examined in detail under the potential investments, in particular in the catchment management evidence base. This concludes that investment is needed in governance to coordinate existing actions, this cannot be left to goodwill or assumed to be covered in existing budgets. Such governance has potentially significant additional costs (of approx 30%), but these can be outweighed by significant benefits.

The main potential trade-off is with agricultural land-use. Clearly, as Table 7.2 shows, this needs recognition, but the actual effect on agricultural output would be managed because many of the investments considered involve land with either very low (e.g. upland peatland), or lower than average (e.g. lower grade land used for wetlands, field margins) productivity. Some of the impact on agricultural output could be partly offset through greater yields of fish from recovered stocks, and enhanced pest control and pollination ecosystem services, for example.

[33] i.e. the incremental benefit of an extra ha would decrease as the total area increases.

Table 7.2: Overview of Impacts of Potential Natural Capital Investments

Land use change	Area of suggested land use change	Current area[34]	% Impact on existing area	Notes
Land that is largely permanently lost to agricultural production:				
Wetland	100,000 ha	1.5m ha	7% increase	Targeted to lower grade land
Woodland	150,000 ha[35]	1.25m ha	12% increase	Presumed partly targeted to lower grade land, but needs to be near towns
Peatland	140,000 ha[36]	(355,000)[37]	39% of current area improved	Opportunity cost of reduced grazing and grouse rearing capacity
Saltmarsh	22,000 ha	40,500[38]	54% increase	Land already vulnerable to climate change
Subtotal	**412,000 ha**	**2.79m**	**15%**	
Land lost to agricultural production, but easily reversible:				
Arable margins	200,000 ha	n/a[39]		Margins are often less productive land
Total	**612,000 ha**	**n/a**		
Broad and shallow interventions on farmland:				
Low-input improved grasslands	500,000 ha	2.8m ha	18%	Reduced grazing intensity
Hedgerows (/lines of trees)	154,000km	402,000km	38%	Possible land take for gapping up
Catchment actions & coordination		In 56% of catchments in England appraised by EA for WFD agricultural land management actions are part of a package of measures with a positive benefit cost ratio.		
Marine Improvements	**Investment Required**	**Current Level**	**% Increase of benefits**	**Notes**
Demersal Fish (Example: North Sea cod)	Decrease catch to allow stock recovery (ongoing investment)	Landings currently approx 33,000 tonnes/year	Landings at least 200% higher (3 times larger) after stock recovery	Different stock modelling approaches predict a large range of stock recovery levels
Shellfisheries: (Example: Lobster and Crab)	Landings decreased by 9,450 tonnes over 4 years	Landings currently approx 13,500 tonnes/yr	25% higher landings – an additional 122,000 tonnes over 50 years after stock recovery	Stock assessments uncertain: only recently completed, and do not enable stock modelling.

[34] For context: England land surface: 13 million ha; agricultural land: 9.3 million ha

[35] Assuming optimal area for new woodland is less than 250,000 ha examined by Forestry Panel and between 100,000 and 200,000 (midpoint of 150,000)

[36] Exact size of area unclear due to overlap in peatland condition categories

[37] Area is subset of wetland area, so not included in total.

[38] England and Wales

[39] Location and extent of margins can vary on short (annual or multi-annual) timescales.

GLOSSARY

Benefit: Benefits reflect the goods and services that are ultimately used and enjoyed by people and which contribute to individual and societal well-being. Benefits are distinguished from ecosystem services (which contribute to the generation of benefits) and from well-being (to which benefits contribute).

Biodiversity (a contraction of biological diversity): The variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part. Biodiversity includes diversity within species, between species, and between ecosystems.

Biological resources: Biological resources include timber and aquatic resources and a range of other animal and plant resources (such as livestock, orchards, crops and wild animals), fungi and bacteria.

Carbon sequestration: The process of increasing the carbon content of a reservoir other than the atmosphere.

Cultural services: Cultural services relate to the intellectual and symbolic benefits that people obtain from ecosystems through recreation, knowledge development, relaxation, and spiritual reflection.

Defensive/ avertive expenditure: this method can be applied in cases where an environmental good can be substituted by a form of defensive expenditure incurred in avoiding damages from reduced environmental quality (e.g. expenditure on water filters and bottled water which is indicative of the value people place on clean water).

Discount rate: The discount rate is a rate of interest used to adjust the value of a stream of future flows of revenue, costs or income to account for time preferences and attitudes to risk.

Economic benefits: Economic benefits reflect a gain or positive utility arising from economic production, consumption or accumulation.

Ecosystems: Ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit

Ecosystem assets: Ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together.

Ecosystem condition: Ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics. Measures of ecosystem condition are generally combined with measures of ecosystem extent to provide an overall measure of the state of an ecosystem asset. Ecosystem condition also underpins the capacity of an ecosystem asset to generate ecosystem services and hence changes in ecosystem condition will impact on expected ecosystem service flows.

Ecosystem extent: Ecosystem extent refers to the size of an ecosystem asset, commonly in terms of spatial area.

Ecosystem services: Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. There is a distinction between (i) the ecosystem services, (ii)

the benefits to which they contribute, and (iii) the well-being which is ultimately affected. Ecosystem services should also be distinguished from the ecosystem characteristics of ecosystem assets.

Exchange value: Exchange values are observed market prices which reflect actual transactions. The concept of using exchange values/prices for accounting purposes assumes that all consumers pay the same price for a good. This means that exchange prices exclude consumer surplus.

Final ecosystem service: Are the outcomes from ecosystems that directly lead to good(s) that are valued by people.

Goods – something used or consumed by humans, such as food, timber or clean water that delivers benefits or is of 'value'. Often goods are produced through the input of different forms of capital e.g. food may require inputs of both natural (soils, water or species to pollinate and control other pests) and manufactured capital (fertilisers, farm machinery or processing).

Habitat: Is an ecological or environmental area that is inhabited by a particular animal or plant species. 'Broad Habitats' are used to classify different ecosystems for reporting.

Hedonic pricing method: this economic valuation method estimates implicit prices for environmental goods based on market transactions, where the environmental good is an attribute (i.e. feature) of a market good. The typical example is the demand for local environmental quality as reflected in house/property market exchange prices.

Improvement of natural capital: enhancement of natural capital to some target condition (e.g. good WFD status) or extent from a baseline

Intermediate ecosystem services: Those whose ecological processes and functions support all life, and, by definition all other services

Land cover: Land cover refers to the observed physical and biological cover of the Earth's surface and includes natural vegetation and abiotic (non-living) surfaces. Related to, but not synonymous with, land use.

Land use: Land use reflects both (i) the activities undertaken and (ii) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. Influenced by, but not synonymous with, land cover.

Major land use type – units of land that encompass areas of land and seas with broadly similar features and use.

Market price: See **'exchange value'**.

Natural asset: a distinctive component of natural capital as determined by the functions it performs, e.g. soils, freshwater, species.

Natural capital: the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions.

Net present value (NPV): Net present value is the value of an asset determined by estimating the stream of income expected to be earned in the future and then discounting the future income back to the present accounting period.

Provisioning services: Provisioning services reflect contributions to the benefits produced by or in the ecosystem, for example a fish, or a plant with pharmaceutical properties. The associated benefits may be provided in agricultural systems, as well as within semi-natural and natural ecosystems.

Protection of natural capital : the conservation of natural capital or the avoidance of degradation.

Regulating services: Regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, earth surface processes, and a variety of biological processes.

Replacement cost method: this approach approximates the value of an ecosystem service from the cost of mitigating actions required if the service is lost or if its productivity decreases.

Resilience: The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on ecological dynamics as well as the organisational and institutional capacity to understand, manage, and respond to these dynamics.

Resource rent: Resource rent refers to the contribution of natural capital to a final good in isolation of the contribution of other factors of production.

Restoration: an activity to improve ecological quality and condition in order to achieve a specific goal or target

Species: An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term species is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity, that once described and accepted is associated with a unique scientific name

Stated preference methods: Stated preference methods can be used for environmental goods which are 'final' non-market goods. Stated preference methods include (i) contingent valuation (CV) and (ii) choice modelling. The CV approach entails the construction of a hypothetical, or 'simulated', market via a questionnaire methodology where respondents answer questions concerning their willingness to pay (or willingness to accept) for a specified environmental change. The principal outputs from CV studies are estimates of willingness to pay (WTP) or willingness to accept (WTA) for changes in the provision of non-market goods and services. In the choice modelling approach respondents are presented with a hypothetical, or 'simulated', market via a questionnaire (or 'survey instrument') for a specified non-market good which is described in terms of its 'attributes' (or characteristics). Choice experiments (CE) may be used as a stand-alone study or combined with a contingent valuation (CV) question, particularly in cases where packaging effects are investigated. CEs can also be used in conjunction with travel cost methods in relation to valuing benefits of environmental improvements that result in recreation and amenity benefits.

Supporting services: Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

Target – a set level of benefit or status for natural capital determined by society.

Travel cost methods: these approaches are revealed preference methods. They use information on costs and time spent by individuals travelling to reach sites, and costs and time spent at sites, to estimate the value of recreation benefits. Different approaches can be used to analyse different aspects of individuals' decisions concerning recreation sites including (i) the demand for recreation visits and (ii) the choice of which site to visit.

Threshold: A threshold is a point at which going beyond will cause benefits from the environment to fall irreversibly (e.g. fish stock collapse). Thresholds are approached as the condition and extent of natural capital declines. They can arise from tipping points or chronic changes, and may be evident in increasing losses of productivity as the condition of natural capital declines, or as a restriction on the ability of natural capital to recover.

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g. of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on).

Value: The contribution of an action or object to user specified goals, objectives, or conditions.

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ANNEX 1: Templates

Science Template

Where summarising individual studies, include reference information (reference to the study, ID number in study google drive).

a) Contextual data

- Project/case study/action:
- Natural Capital Asset(s)/Subasset(s)/Boundar(ies)
- Source(s) of data:
- Year(s) data produced:

b) Baseline (Current) Conditions of Natural Capital Asset

- Geographical extent:
- Size of study area:
- Spatial configuration:
- Pressure/driver impacting asset:

c) Actions

- Initial state (habitat type and/or level of degradation) and trend (improving/stable/declining) (for natural capital asset and ecosystem services provision) NB: pre-protection/improvement action
- Actions taken to restore: (NOTE: representative of potential large scale actions to improve)?
- Other management information:
- Final state:
- Target (community type/ ecosystem function):

d) Outcome

- Timescale of recovery:
- Rate/type of recovery of state (linear/non-linear):
- Change in goods and services provided and/or resilience as a result of recovery:
- Factors affecting success?
- Evidence of threshold:

e) Economic Information

- Cost evidence: examples of costs (pass to economic analysts)
- Is cost evidence linked to the extent of restoration? (Yes/No):
- Scalability (expert judgement on whether example is 1-off or repeatable on larger scale (more similar sites and/or large sites):
- Constraints on scaling up these actions (e.g. environmental, such as soil type/hydrology; or socio-economic, such as existing land uses):
- Knowledge gaps/Research needs:

Economic Template

Where summarising individual studies, include reference information (reference to the study, ID number in study google drive).

a) Method

- Approach taken (1. using existing macro-modelling; 2. Using existing review evidence; 3. Undertaking a review) See investment case template, below.

b) Costs

- The costs of both the restoration actions and the subsequent management
- Scalability: The feasibility of undertaking natural capital restoration at a large scale (more sites and/or larger sites) nationally (across England), by transferring actions from exemplar sites to larger and/or more sites.

c) Benefits

- The improvement in ecosystem service provision (benefit) associated with restoration and any evidence on the change in the profile of these flows over time (qualitative, quantitative and monetary evidence)
- Other parameters that facilitate value transfer, as identified in the Defra value transfer guidelines (eftec, 2010):
    - Type of good
    - Type of change
    - Whose values?
    - Data limitations
    - Timing of the valuation exercise
    - Time and budget limitations
    - Level of 'acceptable uncertainty or error'
- Scalability: The feasibility of undertaking natural capital restoration at a large scale (more sites and/or larger sites) nationally (across England), by transferring actions from exemplar sites to larger and/or more sites.

Investment Case Template

Investment case evidence base involves a combination of science (S) and economic (E) information:

a) Description

- The natural capital (MLUT or asset) and ecosystem service of concern for restoration and how restoration is measured (S)
- The current status and trend of the natural capital and ecosystem service provision (S)
- The nature of the threat/driver leading to the current degraded condition of natural capital (S)
- The restoration actions and the subsequent management regime (S)

b) Benefits

- The timescale for restoration – including whether change is linear (gradual) or non-linear (step-change or threshold) (S)
- The improvement in ecosystem service provision (benefit) associated with restoration and the change in the profile of these flows over time (qualitative, quantitative and monetary evidence) (S, E)
- Other parameters that facilitate value transfer, as identified in the Defra value transfer guidelines (eftec, 2010), and their influence on the scaling up (E)

c) Costs

- Costs of restoration actions and the subsequent management regime (S and E), and

d) Feasibility

- Factors affecting the success of restoration actions (S)
- The feasibility of undertaking natural capital restoration nationally, by transferring actions from exemplar sites to larger and/or more sites (S, E).

Summary of investment case into value chain:

- Intervention over 25 years
- Change in value of NC (changes to levels of ecosystem service flows as a result of actions over 25 years - capitalised flows over 25 years from actions, or longer as appropriate)
- Time, spatial and socio-economic distribution of changes
- Returns to funders/representatives of beneficiaries

ANNEX 2: Detailed Review of Borderline Investment Cases

Detailed review of Grassland (intensive livestock); Freshwater wetlands; and Semi-improved grasslands natural capital investment options against prioritisation criteria.

Natural capital investment: *Grassland- Intensive(livestock)*		**Initial rating (from Table 4.2)**	**More detailed discussion/rating**
Scale of economic benefits	**Overall economic benefits**	High	Potential to reverse large wildlife losses possible for low opportunity cost where farmers are re-seeding pasture and producing hay rather than silage (can choose high diversity rather than low diversity mix). Net loss to farmers from de-intensification (and non-application of fertiliser) in terms of stocking densities but benefits from lowering runoffs to water quality and potentially water quantity (deeper rooted species), pollination, soil condition. Numerous options for non-cropped habitats/actions associated with Improved Grassland with potential benefits for a range of ES. Various catchment management initiatives (e.g. south west rivers trust) suggest opportunity costs to farmers can be low.
	Proportion of monetised benefits	Medium	Value of wildlife recovery in terms of plant species and impacts on forage quality quantified in some experimental cases (Bullock et al. 2007), other ES less certain.
Scalability		High	Countryside Survey estimates 22% of England to be Improved Grassland, but restoration of species rich grassland from Improved Grassland will impact on forage quantity and stocking numbers.
Chance of success		Medium/High	Techniques understood, may be restricted by cultural barriers in farming and costs to farmers due to reduced stocking and higher initial re-seeding costs.
Equity		High	Potential low opportunity cost way of increasing returns to society of CAP payments from taxpayers to farmers. May be changed under new agri-environment schemes (NELMS) and focus on funding availability (i.e. may be high quality areas only).
Balanced NC investments		High	Large area, links to catchments (measures that reduce inputs to intensive grassland beneficial to water quality and quantity), reduced stocking = reduced soil compaction and run-off, (also improved by increased soil porosity from deep rooted herbs), reductions in GHG from livestock presence and waste, increased food sources for pollinators, improved soil quality and carbon storage.
SoNC II Risk register	**Risk rating**	Very high risk	High confidence for wildlife (under the assumption that Improved Grassland is included under enclosed farmland)
	Economic benefits of targets	Medium- High	Semi-natural grassland: Wildlife benefits £20m to £40m/yr
Addresses strategic climate risk		Low	Not a high risk habitat, although the fact that it is largely a monoculture makes it less resilient to change induced by climate and other drivers.

Natural capital investment: *Freshwater wetlands*		**Initial rating (from Table 5.3)**	**More detailed discussion/rating**
Scale of economic benefits	**Overall benefits**	Medium/High	Potential to get high level of multiple benefits even when focus is on habitat restoration for conservation, benefits can include Recreation, Water quality, Biodiversity, Flood mitigation- regulating the impact of extreme weather events, Carbon sequestration and storage, Improving connectivity and resilience, Reversing fragmentation.
	Proportion of monetised benefits	Medium	Significant proportion of benefits relate to well-being through recreation, non-use value of biodiversity, and values of regulating services, which are harder to value accurately in monetary terms.
Scalability		Medium/High	There is great potential for scalability, the Wetland Vision (RSPB et al 2009) identifies potential wetland areas based on historic sites and abiotic variables although also stresses the need to make decisions locally. There are other initiatives that are also looking at re-wetting, reinstating historic floodplain areas which could be replicated more widely. These include landscape scale projects rather than only small scale habitat restoration.
Chance of success		High	High chances of success, well established methods for habitat improvements, but some uncertainty over ability to obtain management control over large hydrological units.
Equity		Medium	Range of beneficiaries, those benefiting from downstream water quality, flood regulation, recreational opportunities, nearer to established population centres greater numbers will benefit, may be higher costs for farmers taking land out of production but hopefully opportunities for distribution of payments from other benefits.
Balanced NC investments		Medium	Contributes well, there will be overlap with catchment projects where there are multiple land use types.
SoNC II Risk register	**Risk rating**	Very high	Drainage for agriculture and fragmentation
	Economic benefits of targets	High	Freshwater: Aesthetics up to £410m/yr; Recreation up to £400m/yr; Wildlife up to £440m; Hazard protection up to £50m/yr; Equable climate up to £40m/yr
Addresses strategic climate risk		High	High- small fragmented sites more vulnerable to changes in rainfall. Increased area of wetlands greater ability to regulate the impact of extreme weather events. Better storage of carbon affecting climate regulation.

Natural capital investment: *Semi-Improved Grassland*		**Initial rating (from Table 5.3)**	**More detailed discussion/rating**
Scale of economic benefits	**Overall benefits**	High	Potential to reverse large wildlife losses possible for low opportunity cost, some re-seeding, changes to grazing regimes, fertiliser reduction. Positive (over semi-improved neutral grasslands) for carbon storage, water quality, water quantity, pollination, aesthetic value – measures primarily around biodiversity.
	Proportion of monetised benefits	Medium	Value of wildlife recovery and other ES uncertain
Scalability		Medium	In Countryside Survey 11% of England is classified as Neutral Grassland, improvements in condition could have quite significant impacts on ecosystem services: relatively small changes to biodiversity could have benefits for soil quality and carbon content, resilience and forage quality (source: UK NEA chapter). These benefits have previously been targeted by agri-environment schemes, but this may not continue.
Chance of success		Medium/High –	Techniques understood, may be restricted by cultural barriers in farming and costs to farmers for re-seeding.
Equity		High	Potential low opportunity cost way of increasing returns to society of CAP payments from taxpayers to farmers. May be changed under new agri-environment schemes (NELMS) and focus on funding availability (i.e. may be high quality areas only).
Balanced NC investments		High	Medium–large area, links to catchments (measures that reduce inputs beneficial to water quality and quantity), increased food sources for pollinators, improved soil quality and carbon storage.
SoNC II Risk register	**Risk rating**	Very high risk	High confidence for wildlife (under the assumption that Improved Grassland is included under enclosed farmland).
	Economic benefits of targets	Medium	Semi-natural grassland: Wildlife benefits £20m to £40m/yr.
Addresses strategic climate risk		Medium	Uncertain and variable across different locations/ services, can contribute to resilience from reversing habitat fragmentation.

ANNEX 3: Evidence on appraisal of other capital investments

This annex gives a summary of the evidence on non-natural capital investments gathered in four areas by Regeneris Consulting:

- **Transport.**
- **Broadband.**
- **Regeneration.**
- **Flood defence.**

1. Transport

1.1 Nature of the investment activity

The investment activity is **capital investment** in transport:

- Roads: whether entirely new roads, junction improvements or road widening schemes.
- Rail: light and heavy rail schemes
- Other modes of transport: we also cover "active travel" Interventions (cycling and walking).

1.2 Scope of costs and benefits assessed

The approach to assessing value for money in road investment follows a standard methodology that has been developed and refined over time by the Department of Transport for the appraisal and assessment of all transport schemes. This is essentially a cost benefit analysis method that attempts to capture and monetise a range of costs and benefits. The scope what is and is not included in Benefit Cost Ratios (BCRs) has, however, changed over time[40]. In particular in:

- New Approach to Transport Appraisal (NATA) was introduced by the then Department for Transport, Environment and the Regions as part of the 1998 Integrated Transport White Paper. It was intended to ensure a more balanced assessment of transport schemes taking into account wider environmental considerations as well as the traditional costs and economic benefits.
- In 2009 NATA was revised to take account of the **wider economic benefits** identified in part by the Eddington Review (see below) and in part to ensure that better account was taken account of **environmental costs**[41].

The current methodology for assessing road (and indeed any transport scheme) takes into account and attempts to monetise the following costs and benefits:

- Time and operating costs, savings for consumers and business users and for transport providers,
- Valuations of changes in accidents, carbon emissions, levels of noise, journey time reliability, and physical fitness.
- The economic costs include those met by government (after any developer contributions).

Standard values are used in a value transfer approach for most parameters such as accident savings (loss of life), values of travellers' time and measures of factors as agglomeration benefits etc.

[40] In addition the way in which indirect taxation has been treated has changed

[41] NATA Refresh: Appraisal for a Sustainable Transport System, April 2009

Table 1.1: Elements of Costs and Benefits Currently Monetised in NATA

Impact Category	Type of Impact	Ways to monetise
Economic Impacts for users	Business users & private sector providers	Values of time per person, and its forecasts
		Car & vehicle occupancies
		Proportion of travel &trips
		Market price values of time per vehicle based on distance travelled, and its forecasts
Wider economic effects*	Effects beyond the direct users of any scheme	Agglomerations effects Labour market impacts Outputs effects in imperfectly competitive markets
Environmental Impacts	Noise Impacts	Annoyance responses and valuations of noise changes
	Air Quality Impacts	Damage cost and marginal abatement cost values by pollutant
	Greenhouse Gases	Carbon dioxide emissions per litre of fuel burnt / kWh used (using DECC standard costs of carbon)
Social & Distributional Impacts	Social Impacts	Average prevention values for casualties and road accidents
		Values of cycle & pedestrian journey quality
		Option & non-use values
Notes: * not included prior to 2009		

Currently, other environmental impacts are not quantified in monetary terms. Therefore the BCRs calculated for road schemes do not assess the monetary costs of any impacts on:

- Landscape
- Townscape and historic environment,
- Biodiversity and
- Water environment.

The assessment approach for these impacts is based on a **qualitative** 'environmental capital' style approach which then feed into the Appraisal Summary Table (AST) for the decision maker.

Active Travel Interventions

In addition to the costs and benefits outlined for general transport projects, active travel schemes such as **walking and cycling interventions** require other costs and benefits to be valued. These include:

- Health impacts – these are calculated by estimating the number of new walkers or cyclists as a result of a new scheme; the time per day they spend active; and change in monthly mortality rates applicable to the group affected by the scheme.
- Absenteeism – as a further health benefit, the benefits from reduced absence from work is estimated using the number of new walkers or cyclists who are commuting; time per day they will spend active; and the average absenteeism rates and labour costs.
- Change in amenity – this includes fear of potential accidents and safety concerns, as well as infrastructure and environmental conditions on a route. Judgement needs to be used in valuing these based on perceived quality of an intervention, using published research figures.
- Risk of accident – accident benefits or disbenefits are calculated from changes in the usage of different types of infrastructure by different modes of transport and their respective accident rates.

- Environmental impacts (decongestion and change carbon emissions) – these are valued using the marginal external cost method (MEC) and the provided values for fuel consumption, carbon emissions and carbon values.

1.3 Summary of evidence on range of BCRs

In its 2005 assessment of value for money on transport schemes, the DfT stated that a project will generally be regarded as: "poor" if the BCR is less than one; "'low" if the BCR lies between 1 and 1.5; "medium" if the BCR lies between 1.5 and 2; and "'high" if the BCR is greater than 2. Since 2005 the DfT have introduced a further category of "very high VfM" if the BCR is greater than 4.0.

There is a reasonable evidence base on the BCRs for road investment schemes, although the great majority of the information is based on the business case made and the BCRs as approved. **There is limited ex-post evidence on actual BCRs achieved**.

The most useful work we have reviewed is:

- The Eddington Review[42], published in 2006, which examined the relationship between transport and economic productivity, growth and stability. This review helpfully drew together the existing evidence base on value on money from different transport investments including roads.
- The RAC Foundation in 2009 produced a useful overview of BCRs for road schemes (and other transport schemes), using and accessing more the detailed evidence prepared by DfT underpinning the Eddington Review and quoting further earlier evidence[43] as well as earlier information published by DfT in 2004.

The Eddington Review considered BCRs for transport schemes using different scopes for what was captured:

- **"Conventional" benefit:cost ratio** (**NATA BCR**): the benefit:cost ratio set out in (the then) DfT's appraisal guidance. Captured and monetised within this BCR are: changes to the overall costs of travel, the value of changes to travel times, safety benefits, and the financial costs of doing the project including impacts on taxation revenues.
- **Wider benefit:cost ratio** (BCR): which adds the "missing" GDP effects into the conventional NATA BCR which at the time did not account for effects such as agglomeration effects from transport schemes (which have subsequently been included).
- **Value for money** (VfM) or **Full BCR**: this value for money assessment is broader by incorporating the most significant environmental effects into the monetised assessment by using what was then the most recent valuation evidence on environmental effects (estimated in this way are carbon (using the then Defra guidance), air quality, noise and landscape).

[42] The Eddington Transport Study: The case for action: Sir Rod Eddington's advice to Government, December 2006, Volume 3 The Evidence

[43] Rates of Return on Public Spending on Transport, John Dodgson for the RAC Foundation, June 2009

Evidence on Road Schemes

The values calculated on the sample were as set out below. The key points were:

Type of Road Schemes	Numbers	Average BCR
Highways Agency	93	4.66
Local Road Schemes	48	4.23
Source: analysis of schemes reviewed in Eddington report in Table 2 RAC Foundation 2009		

- The basic BCRs as then assessed (excluding environmental costs and wider economic benefits) were averaging 4.2 to 4.7 for the c. 140 road schemes reviewed. This was the ex-ante BCR as assessed in the NATA appraisals.
- The Eddington review also assessed the impact of widening the scope of the costs and benefits, this suggested that the average BCRs changed as follows for those schemes where this exercise could be carried out:
  - "Conventional BCR" (largely ignoring environmental costs and benefits) = **3.4**
  - "Wider BCR", (including wider economic benefits, but not environmental costs) = **5.7**
  - "Full BCR" (or as Eddington put it VFM) as the Wider BCR but including several wider environmental costs = **4.8.**
- This exercise was not intended to demonstrate the actual average BCR rather the impact of including different factors in the value for money assessment. It shown the significant impact of including wider economic benefits on some road schemes, but also the depressing effect on BCRs of monetising some environmental effects.

The RAC Foundation study quoted earlier information published by the DfT in 2004 in which the BCRs for a number of road schemes were shown. This indicated rather lower BCRs that the schemes reviewed as part of the Eddington work, with average BCRs for strategic roads of 3.6 and for local major roads 3.1. However, it is important to note that these BCRs were drawn from a different sample than the Eddington sample and would have excluded the assessment of wider economic benefits (and environmental costs).

Table 1.2: BCRs of Transport Schemes Approved in 2002-2004 by DfT

Nature of Transport schemes	Number of projects	Average BCR	Minimum BCR	Maximum BCR
Strategic roads	50	3.64	1.2	9.9
Local major roads (>£5m)	50	3.13	negative	10
Local transport schemes	25	2.36	0.4	7.7
Major maintenance schemes	4	2.18	1.5	2.9
Street lighting	4	5.55	3.5	8.4

Source: RAC Foundation 2009, Table 2, this is a record of the BCRs for all transport schemes approved by DfT in the three years to 2004
Note: the BCRs are narrow BCRs and exclude wider economic benefits and environmental costs

The Highways Agency carries out studies of the impact of their schemes one and five years after the project has been opened. These studies compare the ex-ante BCRs with an estimate of the actual (ex-post BCR taking account of revised estimates of construction costs and traffic measurements. This work is assessed in the RAC Foundation report[44] and the conclusion is that the economic and traffic benefits and costs are not systematically nor or overestimated although there is wide variance between predicted and actual for individual schemes (both under and over).

[44] See Table 6 in RAC Foundation (2009)

Evidence on Rail Schemes

The evidence on rail BCRs is also contained within the Eddington Review and the RAC Foundation study. The sample for rail schemes is much smaller compared to road schemes. These projects require substantially higher costs and BCRs for rail are generally lower than BCRs for roads:

Type of Rail Schemes	No.	Average BCR
Heavy Rail	11	2.83
Light Rail	5	2.14
Source: analysis in Table 2 RAC Foundation 2009		

- The basic BCRs averaged between 2.1 and 2.8 for the 16 reviewed rail schemes.
- In employing the impact of wider costs and benefits, the Eddington Review only provides the VFM value for 3 light rail schemes out of the whole sample. It suggests the following average BCR values:
  - Conventional BCR = **2.61**
  - Wider BCR = **2.8** (based on 2 heavy rail schemes)
  - Full BCR (or VFM) for two of assessed rail schemes was the same as the conventional BCR at **2.3** and **3.6**, and for one the VFM value was greater than the BCR (although the study does not specify by how much, the BCR was classed as 'medium' while the VFM value was 'good').

The sample provided by the DfT of rail schemes, quoted in the RAC Foundation study, is also rather small consisting of only 7 rail schemes. The average BCR values are lower than the ones from the Eddington report, but there is insufficient information on the methodology to identify what drives these differences.

Table 1.3: BCRs of Transport Schemes Approved in 2002-2004 by DfT

Nature of Transport schemes	No. of projects	Average BCR	Minimum BCR	Maximum BCR
Rail	4	>1.6	1.1	>2
Light rail	3	1.33	1.1	1.6
Source: RAC Foundation 2009, Table 2, this is a record of the BCRs for all transport schemes approved by DfT in the three years to 2004				

The RAC Foundation study also provides a more substantial sample of 59 rail schemes published by Network Rail, although these mostly relate to enhancements to the present network. The main points were:

- Average BCR = 2.9
- Range of BCRs was between 1.1 and 9, (where the highest value excludes investment costs and so is not comparable to others).

Evidence on active travel schemes

The main evidence on walking and cycling interventions is presented in two reports, one by Sustrans' Research and Monitoring Unit[45], and one produced jointly by the Department for Health and the

[45] Sustrans' Research and Monitoring Unit (2011) *Value for Money of Walking and Cycling Interventions: Making the Case for Investment in Active Travel*

Government Office for the South West[46]. The key findings include from the latter are presented in 0. For all these UK projects the average BCR is **19:1**.

Table 1.4: BCRs for walking and cycling projects

Type of Scheme	BCR	Number of projects	Study
Canal towpath	24.1	1	DfT, 2005
Cycling	10.1	5	SQW consulting, 2008
Cycling	2.6	1	Cycling England
Resurfacing, signing & lighting	29.3	1	Sustrans
New crossing	32.5	1	Sustrans
New path	14.9	1	Sustrans

- The research undertaken for DfT provides an ex post BCR of **24.5:1**, which included savings from absenteeism and savings due to increased physical fitness based on numbers of prevented deaths.
- An average BCR of **25.6:1**, obtained using the NATA approach to three Link to School schemes.
- An average BCR of **2:1** for five cycling schemes, produced by SQW Consulting. This BCR excludes an outlier that was a Hull cycling study. Including it generates an average BCR of **10.1**. A 30 year benefit duration period was used.
- A BCR between **2.6** and **3.5** was generated by the Cycle Demonstration Towns programme. The additional benefits included amenity, reduced congestion and reduced absenteeism. The range in values is due to uncertainty over accident disbenefits.

The report by Sustrans' Research and Monitoring Unit provides valuations for two schemes, where in addition to health benefits, accident disbenefits and absenteeism benefits, other impacts were calculated and a separate BCR was provided. The inclusion of these other impacts brought the valuation closer to a NATA approach[47]. These include:

- Ambience benefits: these were valued using WebTAG guidance on values for different types of route improvements.
- Decongestion benefits: these are also calculated using WebTAG guidance on the basis of car kilometres replaced.

The schemes use an appraisal period of 10 years. The main findings were:

- A BCR of **1.2** for a cycling project based on health and absenteeism benefits only, which went up to **1.3** when decongestion and amenity benefits were included.
- A BCR of **12.8** for a new pedestrian route, which went up to **13.4** when other benefits were included (that is, amenity and decongestion).

[46] Government Office for the South West, Department for Health (March 2010) *Value for Money: An Economic Assessment of Investment in Walking and Cycling*

[47] Originally the schemes use the Scottish Transport Appraisal Guidance (STAG).

2.1 Nature of the investment activity

The investment activity is public **capital investment in broadband infrastructure,** in areas where there is market failure (that is, where the market alone is not providing superfast broadband in particular for commercial reasons, but where the socio-economic benefits of this provision are considered to justify the public sector costs).

Note that this summary note draws on the inputs of Anderson Economics[48] as well as the experience of Regeneris Consulting in the appraisal and evaluation of broadband infrastructure programmes and projects across the UK.

2.2 Scope of costs and benefits assessed

In contrast to other, traditional areas of public sector infrastructure investment such as transport, public sector involvement in broadband is a relatively new phenomenon. Consequently the techniques used to appraise projects and assess impact are evolving, and there is less in the way of formal, commonly accepted frameworks for cost-benefit analysis.

However, there is an emerging evidence base which has developed from the need to appraise, and develop business cases for, individual projects and programmes, some of which involve very substantial amounts of investment (e.g. the national Broadband Development UK programme. BDUK National Infrastructure Plan also contains provision for almost £1 billion worth of investment in digital communication).[49] Early techniques used typically seek to place a value on the productivity-enhancing benefits of access to faster broadband for businesses and individuals. Such approaches have recently been extended to encompass a much wider set of impact measures, taking into account a wider range of economic impacts as well as social and environmental consequences.

The most comprehensive contribution to this approach is to be found in recent work for DCMS,[50] which reviewed the existing literature on the economic, social and environmental impacts of broadband. This literature review was used as the basis for the development of a model to project the likely impacts of future public investment in broadband. This is positioned as the "*most in-depth and rigorous forward-looking quantification of broadband impacts developed to date in the UK.*"[51] The three components of benefit covered are as follows:

- **Economic** (measured in market terms as increase in net employment and Gross Value Added): productivity of broadband-using enterprises, safeguarding of local enterprise employment, teleworker productivity, and labour force participation.[52]
- **Social** (measured in market terms as the net cost savings for households as well as in non-market terms as increases in the value of leisure time): the value of household savings as a result of increased teleworking (taking into account the net effect of the reduction in travel costs and the increase in heating costs), and the increase in the value of leisure time resulting from a reduced need to commute to work.
- **Environmental** (measured in non-market terms as the value of net savings in CO_2 emissions at the prevailing carbon price): the value of net carbon savings resulting from increased teleworking, decreased business travel, and increased use of cloud computing.

[48] Anderson Economics (2014) *Review of Evidence on Non-natural Capital Infrastructure Investments in the UK*, note for Natural Capital Committee

[49] Anderson Economics (2014) ibid

[50] SQW (2013) *UK Broadband Impact Study*

[51] SQW (2013) *ibid*

[52] Construction impacts are also considered but excluded from the CBA in line with HM Treasury guidance.

It is worth noting that these are the benefits which were able to be monetised in a robust fashion and therefore feature in the BCR. There are a range of other potential benefits and disbenefits in the social and environmental arenas, which are not monetised. Including these in the CBA would serve to change the BCR, although the net effect is unclear. Examples of such benefits and costs not included are:

- Social: change in consumption of video content, change in online gaming, change in video communications, time savings from faster downloads, etc.
- Environmental: end user device emissions, changes in travel associated with telehealth, telecare, temporary increases in emissions from the construction of the network, changes in energy consumption of the network.

A summary of the benefits considered in this framework and the approach to monetising them is provided in the table below.

A similar approach is being adopted for the ongoing evaluation of the Rural Community Broadband Fund, undertaken by Regeneris Consulting (due to be complete in 2016).

Table 2.1: Elements of Costs and Benefits Monetised in UK Broadband Impact Study

Impact Category	Type of Impact	Ways to monetise
Economic	Productivity growth of broadband-using enterprises	Estimating increases in broadband speeds, take up rates and average productivity enhancement per firm. Valued in terms of net additional GVA.
	Safeguarding of local enterprise employment	The effect of access to quality broadband on safeguarding employment at a local level. Uses an approach that estimates annual growth of enterprises and employment in an area as a function of Relative Broadband Quality in a particular year. Valued at the GVA associated with these jobs.
	Productivity of teleworkers	Data on the proportion of employed people who are tele-work eligible, estimates of increases in teleworking arising from increases in broadband speeds, estimates on the duration of a two-way commute and the proportion of time saved used for work. Valued in terms of net additional GVA.
	Labour force participation	Numbers of working age people who are economically inactive due to looking after home or family, the proportion of these who would like a job and are telework eligible; the number of unemployed disabled people and the proportion of these who are telework eligible, effect of increase in household speed on home working, GVA per additional worker. Valued in terms of net additional GVA.
Social	Value to households from teleworking	Estimates on the total commuting distance saved as a result of teleworking, and the modes of transport used; data on the average cost per passenger km of different modes of transport. Then applying unit energy costs to the additional usage of space heating fuels in the home. Valued in terms of net cost savings.
	Value of leisure time saved	Estimates of leisure time saved as a result of teleworking, valued using values of leisure time advised by DfT guidance. Valued in terms of increase in leisure time.
Environmental	Carbon emissions savings from:	
	increased teleworking	Assumptions on emissions savings per vehicle KM and from avoided energy usage in offices, estimates of energy use and associated emissions in households. Valued at prevailing cost of carbon.
	Reductions in business travel	Data on business trip rates and business trips avoided as a function of increased broadband speed. Emissions valued at prevailing cost of carbon.
	Cloud computing	Estimates of electricity use associated with servers, proportion of server capacity shifted to cloud, associated energy use and emissions implications. Emissions valued at prevailing cost of carbon.

2.3 Summary of evidence on range of BCRs

As alluded to earlier, the evidence base on BCRs has been growing in recent years. Consequently it is possible to draw out from this some key points on the BCRs associated with this area of investment. However, it is important to note the **lack of ex-post evidence** on BCRs.

The UK broadband impact study uses the impact model described above and applies it to the current set of broadband interventions (the rural programme, RCBF, and the Urban Broadband Fund, also known as super-connected cities). It then calculates the increase in GVA and other monetised benefits by the year 2024 on both a snapshot and cumulative basis. The rationale for the use of 2024 is that the appraisal period is taken to be 15 years, and the baseline year is 2008 (driven by data availability at the time).

The key points to note are that:

- That the market-based economic impacts (measured in GVA) account for the majority of the total benefits: £6.3bn at 2024. The value of the social and environmental benefits is much lower (at £0.2bn in total at 2024).
- Of the economic impacts, the vast majority are accounted for by productivity growth amongst broadband-using enterprises.
- Using the cumulative discounted increase in GVA attributable to the public interventions considered, the BCR associated with these interventions is 20:1. The other market and non-market benefits are not included in this BCR, but given their relatively small scale, the effect on the overall BCR is negligible.

  The report acknowledges that this is an exceptionally high BCR. The justification offered is that ICT is a key productivity, the interventions are targeted at improving a General Purpose Technology across the UK, and that the impacts would be highly unlikely to be delivered by the private sector alone (that is, deadweight is low).

Table 2.2: Elements of Costs and Benefits Monetised in UK Broadband Impact Study

Impact Category	Type of Impact	Monetised benefit at 2024
Economic	Productivity growth of broadband-using enterprises	£5bn
	Safeguarding of local enterprise employment	£0.8bn
	Productivity of teleworkers	£0.3bn
	Labour force participation	£0.2bn
	Total economic	**£6.3bn**
Social	Value to households from teleworking	£45m
	Value of leisure time saved	£75m
	Total social	**£120m**
Environmental	Carbon emissions savings from:	
	increased teleworking	
	Reductions in business travel	
	Cloud computing	
	Total environmental	**£100m**
Total monetised benefit		**£6.5bn**
BCR (economic only)		**20:1**

In addition to this macro UK level projection, other evidence is available for individual projects and programmes. Here we have drawn on Regeneris Consulting's recent experience in broadband impact assessment across the UK. Again, this is all modelled ex-ante, rather than ex-post, evidence. This evidence is summarised below.

Most of this analysis focussed on economic benefits (especially productivity benefits), driven by the needs of the funders. The variation in the BCRs generally reflects differences in the beneficiary populations (businesses and their sector and residents) across the study areas. However, it is important to note that in the case of the Cheshire and Warrington and Greater Manchester, the scope of the cost-benefit analysis was wider. For Cheshire and Warrington the analysis covered other aspects of social impact including educational impacts and benefits of the use of tele-health. It also covered the impacts arising from new business start-ups. The Greater Manchester study also looked at these impacts but went even further and quantified the impacts from expenditure on wireless broadband in public areas and transport, a digital demonstrator suite and in support for business to maximise productivity enhancements through uptake of fibre broadband.

Table 2.3: Benefits, Costs and BCRs within other ex-ante studies (over 15 years)

Impact Category	Type of Impact	The Economic Impact of Digital Greater Manchester (2014)	The Value of Superfast Broadband in Cheshire, Warrington and Halton (2012)	West Yorks BDUK Phase 2 Mapping (2014)	Connecting Cumbria Cost Benefit Analysis (2013)	Black Country Local Broadband Plan (2013)
Economic	Productivity growth of broadband-using enterprises	£96.4m	£400m[53]	£240m	£115m	£24m
	Safeguarding of local enterprise employment					
	New Business Starts	£39.9m				
	Productivity of teleworkers	£15.6m				
	Labour force participation	£7.4m	£13.6m			
	Total economic	**£240m**	**£413.6**	**£240m**	**£115m**	**£24m**
Social	*Cost savings to NHS from telehealth*		£3.1m			
BCR		**7.7:1**	**21:1**	**9.6:1**	**2.6:1**	**12:1**
Source: Regeneris Consulting						

[53] Incorporates both productivity gains and those generated as a result of new business start-ups

3.1 Nature of the investment activity

The investment activity is investment in regeneration activity. This is a broadly defined area, covering both:

- Capital investment in physical regeneration, including investment areas such as housing and commercial property and
- Other, predominantly revenue, interventions, such as skills, employability and business support.

3.2 Scope of costs and benefits assessed

Various guidance has been issued over time to inform the application of HM Treasury approved techniques to the appraisal and evaluation of regeneration activities.[54] A relatively recent report issued by the Department for Communities and Local Government (DCLG)[55] sought to take stock of the existing evidence on the impact of regeneration investment, in order to develop an analytical framework for valuing these benefits and comparing them with relevant costs. The focus was on developing a practical methodology for placing an **economic value** on the benefits produced by regeneration policies in line with the HM Treasury Green Book.

The process used by DCLG is the same across all areas of regeneration investment, using a common impact pathway. The steps involved are to:

- Estimate net additional outputs delivered by the regeneration investment using unit cost evidence from evaluations
- Put a monetary value (market/non-market) on these outputs
- Estimate the way in which the benefits build up and then persist over time
- Sum and discount these values to a Present Value.

In attributing the benefits arising from the public sector intervention it is critically important to adjust for additionality effects. This typically involves assessing:

- Deadweight: the extent to which the benefits would have occurred anyway in the absence of public intervention (e.g. if the private sector would have delivered a physical development on its own)
- Displacement: the extent to which benefits observed from the intervention are offset by reductions elsewhere in the area concerned (e.g. if a business support intervention leads some businesses to grow at the expense of others operating in the same area and same markets).
- Substitution: the extent to which the intervention causes economic actors (normally firms) to substitute one input (e.g. labour) for another, in order to benefit from a public subsidy.
- Leakage: the extent to which benefits from the intervention "leak" outside the area concerned (e.g. if businesses outside an impact area benefit from a business support programme or if residents from outside the area take new jobs that are created)
- Multipliers: the extent to which the direct benefits observed lead to further indirect (supply chain) and/or induced (personal expenditure) benefits.

[54] E.g. ODPM (2004) *Assessing the Impacts of Spatial Interventions Regeneration, Renewal and Regional Development 'The 3Rs guidance'*

[55] Valuing the Benefits of Regeneration, DCLG, December 2010

Since regeneration activity is typically spatially focussed, the impact area (or "economic jurisdiction") concerned is important here. An intervention may have strong additionality at a very localised level, but very low additionality at the level of, say, a region. An example would be an intervention to develop an enterprise zone, which may result in businesses moving in to the zone. If all of these businesses move into the area from other locations in the region then additionality is high for the area itself but at the level of the region the net effect would be zero due to displacement effects.

Estimating these additionality factors is often a matter of judgement, informed by data from market assessments and beneficiary surveys, for example. Of these factors, of fundamental importance is deadweight, i.e. the difference the intervention has made compared to what would have happened in its absence. This is fundamentally unobservable and therefore involves a counterfactual assessment. Recent reviews of the evidence on local economic development have been undertaken by the What Works Centre.[56] These have found that in several policy areas (e.g. business support), the evidence on deadweight is weak and often relies on beneficiaries' self-reported outcomes rather than more robust statistical approaches to assessing the counterfactual.

The DCLG guidance remains the most up-to-date store of evidence on the BCRs associated with regeneration, although the point about the treatment of the counterfactual made above should be borne in mind. Our consultation with the Homes and Communities Agency also suggests that the BCR evidence is not routinely used for benchmarking purposes, and appraisals often concentrate on other measures (e.g. public financial metrics and unit costs per job created). Nonetheless, it is the only systematic review of BCRs available at present.

The specific output/benefits, associated values and persistence effects vary across the various areas of investment. We consider separately the scope of the cost-benefit analysis used for physical regeneration and then other regeneration activities below.

Investments in physical regeneration

Capital investments in physical regeneration covers investments in industrial and commercial property, housing and environmental improvements to open space and public realm, each of which has a separate preferred valuation approach advised by DCLG.

The key benefit associated with **industrial and commercial property** is the net additional employment created for a particular area, and the associated economic value of this employment, measured in terms of Gross Value Added. The rationale is that by creating space in which these jobs can be housed it is possible then to attribute the associated employment/GVA benefits to the public sector investment. The approach is therefore to estimate the gross employment housed on the development, to adjust this for additionality factors and then to estimate the GVA associated with these jobs based on the economic sector to which they belong. This annual GVA is then summed and discounted over the life of the asset: the evidence suggests that these effects might take 3 years to build up and last a further for 10.

[56] http://whatworksgrowth.org/

Table 3.1: Industrial and commercial property preferred valuation approach

Principal outputs and outcomes to be valued	Valuation approach	Data Sources for deriving outputs & outcomes	Data sources for deriving values
Net employment creation	Use of market based data through revealed preference techniques	Primary data from existing evaluations showing net additional full time equivalent jobs created/ safeguarded	Gross Value Added data from Annual Business Inquiry

Source: DCLG 2010

In valuing **housing growth and improvements**, the benefits can be split into two categories, covering a mix of market and non-market benefits:

- **Consumption benefits**: the key market benefit included is the value uplift from new or improved housing. Other benefits are then considered, including the benefit or cost from gain or loss of amenity, the benefit from reduced carbon emissions, and benefit from improved security, health and warmth. Wherever possible, market valuations are used to value these non-market benefits:
    - Carbon emissions are valued as cost and efficiency savings, or using guidance on the traded or untraded price of carbon[57];
    - Warmth, security and health impacts can be valued through reduced costs to the NHS and criminal justice systems, reduction in working days lost through illness[58].
- **Production benefit** to the economy: this is the market benefit arising from employment enabled by new housing (valued at the GVA associated with this employment) and associated transport infrastructure.

The evidence review concludes that, in reality, the benefits from **reduced carbon emissions** as a result of more efficient dwellings can be difficult to estimate due to their project-specific nature. DCLG note that further work is needed to set out a common framework to make the carbon emissions reductions applicable and transparent.

Values are summed and discounted over 30 years.

It is worth noting that the effect of **reducing homelessness** has not been valued due to limited regeneration resource targeted at this activity.

DCLG and the Department for Transport (DfT) developed a methodology to better capture the economic benefits from new or improved housing developments, captured in the DfT's New Approach to Appraisal.[59] By adopting these conventions in TAG 3.16D, the value to society of new housing takes:

- The private betterment value, represented by the uplift in land values arising from a planning permission for housing development *less*
- The external impact of housing development, represented by loss or gain in the amenity value of the land compared to its existing use. As this is a non-market factor, assessing the loss of

[57] For policies in sectors covered by the EU Emissions trading Scheme should use guidance on 'traded price of carbon', and those sectors that are not covered should use 'non-traded price of carbon' values.

[58] Ealing Decent Homes Health Impact Assessment (2008) provides these monetary values in their study

[59] DfT (2010) Appraisals in the Context of Housing Development

amenity value involves a value transfer approach from reported estimates of external benefits of undeveloped land. For previously developed land, external impact should be valued as zero.

A summary of the approach and data sources advised by DCLG is provided in the table below.

Table 3.2 Housing growth and improvement preferred valuation approach

Activity Types	Principal outputs and outcomes to be valued	Valuation approach	Data Sources for deriving outputs & outcomes	Data sources for deriving values
New build	Net new dwellings	Use of market based data through revealed preference techniques Adjusting for loss of amenity value derived using stated preference techniques Cost to society of carbon emissions revealed through traded and untraded price of carbon (tCO2)	Primary data from appraisals (HCA) and existing evaluations (e.g. HMR) on relationship between expenditure and: net additional dwellings; net additional reductions in carbon savings (where known) -net additional FTE jobs enabled through the creation of new housing	Valuation Office Agency (VOA) data on land prices Amenity values by land type from Entec/eftec study for ODPM/Defra Traded and untraded price of carbon (DECC) GVA/employee (Annual Business Inquiry)
Improving existing stock	Net improvements to existing dwellings	"	Primary data from appraisals Homes and Communities Agency (HCA) and existing evaluations (e.g. Housing Market Renewal) on relationship between expenditure and net additional dwellings refurbished and net additional reductions in carbon savings (where known)	Valuation Office Agency (VOA) data on land prices Amenity values by land type from Entec/eftec study for ODPM/Defra Traded and untraded price of carbon (DECC)
Demolition/ new build	Net new dwellings	"	Primary data from appraisals (HCA) and existing evaluations on relationship between expenditure and net additional dwellings following acquisition and demolition	Valuation Office Agency (VOA) data on land prices Amenity values by land type from Entec/eftec study for ODPM/Defra

Source: DCLG 2010

Finally, the preferred valuation of **environmental improvements** to open space and public realm uses stated preference techniques, such as contingent valuation and choice experiments, to monetise unit costs per hectare of land improved. Hence the benefits in this framework are wholly of a non-market nature. The benefits include improvements in water quality, air quality, open space, community space, green routes (footpaths and cycle paths) and blue routes (improved river and canal bank access). See 0 for a summary.

Table 3.3 Environmental improvements preferred valuation approach

Activity Types	Principal outputs and outcomes to be valued	Valuation approach	Data Sources for deriving outputs & outcomes	Data sources for deriving values
Open space Public realm	Net additional hectares of open space or public realm provided	Application of values derived using stated preference techniques – contingent valuation and choice experiments	Range of monitoring and evaluation evidence on unit costs per hectare. All improvements considered wholly additional, since they represent public goods.	Stated preference pilot survey undertaken as part of this research

Source: DCLG 2010

It is clear that, across these areas of physical regeneration investment, certain external costs/benefits are not included within this cost-benefit approach:

- For industrial and commercial property, no environmental costs or benefits are included.
- For housing interventions, only carbon emissions savings from increases in the efficiency are considered, and these have generally not been included in the actual BCRs presented below due to issues with measurement
- For open space and public realm, a range of environmental benefits are included, but it is not comprehensive (e.g. biodiversity values do not appear to have been included).

Investment in other types of regeneration

Other types of regeneration include investments in worklessness, skills and training, enterprise and business development, and community development. Rather than being concerned with the creation of assets these are generally revenue interventions, focussed on providing ongoing support to businesses and individuals to increase economic activity, where there is deemed to be market failure. Again, the preferred approach in valuing benefits involves moving from regeneration expenditure to net additional outputs, and applying unit values to these outputs:

- Worklessness, skills and training: for worklessness interventions the key benefit is the number of individuals moved into work. This is then valued directly using data on the average earnings of these individuals moving into work. Benefits also included here are the Exchequer cost savings to the public sector arising from the likelihood of reduced crime and improved health, valued using shadow prices for these effects. For skills and training interventions the key benefit is the improvement in people's qualification levels, which can then be valued using evidence on earnings premiums. The assumed persistence rate is 3 years.
- Enterprise and business development: the key economic benefit here is the net additional employment created within the businesses supported, whether through general business support, support for start-ups or the promotion of R&D. Hence the benefits captured are wholly market benefits. These net additional jobs are then valued at the level of associated Gross Value Added. There is clearly an element of simplification here – in particular, this framework does not capture the benefits of interventions that are primarily designed to increase productivity, independent of any increase in employment. A duration of 3 years is assumed for the schemes.

- Community development: the key benefits include better quality of life and can feed into economic benefits such as employment and desirability of neighbourhood. The valued components mainly focus on valuing volunteer activity, where volunteer time is used along with the minimum wage as a proxy for value of input, which then translates into Gross Value Added and only 1 year of benefit duration. For investment in community organisations, the social Gross Value Added is derived through using the level of local income generated and treating it as a turnover. The benefit duration here is assumed to last 3 years.

The approach is summarised in 0.

Table 3.4 Preferred valuation approach for other types of regeneration

Activity Types	Principal outputs and outcomes to be valued	Valuation approach	Data Sources for deriving outputs & outcomes	Data sources for deriving values
Worklessness, skills and training				
Tackling worklessness (Helping people to become work-ready and Helping people into work (including re-entrants))	Net individuals into work	Use of market based data through revealed preference techniques	Primary data from existing evaluations showing: - Unit cost which enables the number of beneficiaries to be derived - Net positive outcomes into employment	Data on average earnings (entrants into work) from: - the Annual Survey of Hours and Earnings - the Labour Force Survey/Annual Population Survey
Helping employees and businesses with skills development in the workplace	Net improvements in qualification by NVQ Level	Use of market based data through revealed preference techniques	Primary data from existing evaluations showing: - Unit cost which enables the number of beneficiaries to be derived - Net improvements in qualifications	Data on earnings improvement related to qualifications: - Centre for Economics in Education (LSE)
Enterprise and business development				
General support for business growth and competitiveness	Net employment creation	Use of market based data through revealed preference techniques	Primary data from existing evaluations showing net additional full-time equivalent jobs created/safeguarded	Gross Value Added per employee data from Annual Business Inquiry
Start-up assistance and promotion of spin-outs	"	"	"	"
Promotion of business enterprise research and development	"	"	"	"
Community Development				

Activity Types	Principal outputs and outcomes to be valued	Valuation approach	Data Sources for deriving outputs & outcomes	Data sources for deriving values
Net additional volunteers	Shadow pricing techniques, using wages as proxy for benefits	Institute for Volunteering Research on gross cost per gross volunteer; evaluation evidence on additionality. itizenship Survey on hours of volunteering	inimum hourly wage x 1.21 for non-wage labour costs mployment costs to GVA via GVA/employee for health and social care activities (Annual Business Inquiry)	
Net additional social enterprise assists	Shadow pricing techniques, using local income generated as proxy for turnover	ffice for Third Sector data on average turnover, support for new starts vs. existing enterprises and evaluation evidence on average additional benefits to turnover	Turnover to GVA via GVA/turnover ratios for health, social care, education and 'other service activities'	

Source: DCLG 2010

Again, there are a range of factors that are not included in the valuation:

- For worklessness, skills and training **helping people to stay in work** is not included due to insufficient evidence on costs and values.
- For community development, **formal participation** have not been included because the evidence is scarce and mostly qualitative. **Community facilities** has also been excluded due to their variety and the difficulty this creates in conducting an across the board valuation.

Clearly, there is also no consideration given in this framework to a range of non-market benefits in the social and environmental arena.

3.3 Summary of evidence on range of BCRs

The same DCLG report[60] applies the set out valuation approaches to derive BCRs for each of the categories of regeneration activity.

Unit costs per net additional output – a key element in the calculation - are derived from a review of the existing, ex-post evaluation evidence. Consequently, depending on the extensiveness of the evidence for each area, degrees of confidence around the observed average unit costs (and hence the BCRs) vary. As an example, for the worklessness arena the mean unit cost is £13,000, with a range of £7,300 to £19,300 at the 95% confidence level. A range of factors were found to drive this variation, including the work-readiness of individuals, and fundamentally the nature and intensity of support offered/required.

Across all investment areas, the evidence base is not sufficiently extensive to allow any further breakdown of BCRs by these key factors, such as the intensity of business support (which can be expected to be more costly but also to achieve greater impact).

[60] Valuing the Benefits of Regeneration, DCLG, December 2010

It is important to note that the report authors found little in the way of robust evaluation evidence on the persistence effects from the interventions. This can only be gleaned from longer term ex-post monitoring and evaluation evidence. This is a major weakness in the evidence, but is dealt with through sensitivity testing – specifically, testing the impact of a reduction in the assumed base case persistence rate on the overall BCR. In all cases the BCR remains positive.

For each area of activity, DCLG present both a central valuation and a cautious valuation. The cautious valuation is based on a lower persistence factor for the benefits, and in some cases a more cautious average value per net additional output.

Investments in physical regeneration

The evidence on BCRs for industrial and commercial property and housing is presented in 0. Key points to note are as follows:

- For industrial and commercial property the central BCR is almost 10:1, In this case the cautious valuation involves reducing the duration of benefit from 10 to 5 years, and reducing the GVA/employee from £35,000 to £33,000. Whilst this brings the overall BCR down from almost 10 to 5.8, this still suggests very strong value for money.
- The BCRs for new build housing are much lower, at 2.6 in the central valuation. The applied valuation of new build housing uses a database provided by the Homes and Communities Agency to analyse 25 observations. In this case, the benefits from reduced carbon emissions was not monetised due to the difficulty of generalising these. Including this would therefore increase the BCR to some degree. The difference in cautious and central valuations here is driven by lower GVA per job for production benefit (£33,000) and lower benefit duration (15 years rather than 30).
- The evidence on improvements in existing housing stock shows lower BCRs again, at 2:1 in the central valuation. It uses three sources to derive unit costs: The National Audit Office's 2009 report on Decent Homes Programme, DCLG's 2009 National Evaluation of Housing Market Renewal Pathfinders, and a 2004 House of Commons Select Committee Report on Decent Homes activity. There are some variations in costs of these projects driven by the nature of improvement works required: i.e. it costs more to bring some homes up to decent homes standard than others based on their initial state. The difference between the central and cautious BCR is, once again, driven by the sensitivity exercise (benefit duration of 15 years rather than 30).
- The analysis of acquisition, demolition and new build evaluations uses very limited evidence and has been derived solely from the DCLG's 2009 National Evaluation of Housing Market Renewal Pathfinders. The computation of BCRs here includes the benefits arising from enhanced visual amenity, which is only an illustrative calculation and, as the authors state, should be treated with caution. The calculated BCRs range between 5.5 and 3.7.

In valuing open space improvements and public realm, evidence from a variety of local authority documents was used to source information on costs per hectare of public open space improved. Costs for public realm were also estimated on the basis of discussions with landscape architects.

Benefit values had been derived from a pilot stated preference survey, which asked questions on willingness to pay for open space improvements such as local parks. The subsequent values for BCRs for open space improvements are between 2.7 and 1.8, where the reduction is caused by reducing the benefit duration period from 30 to 15 years. For public realm, BCRs are 1.4 and 0.9 based on the same reason.

Table 3.5: Overall BCRs by DCLG: Industrial/Commercial Property and Housing

Activity Type	Valuation Basis	Central Valuation	Cautious Valuation
Industrial and commercial property			
Industrial and commercial property	Production benefit - GVA	9.96	5.8
Housing growth and improvements			
New build housing	Consumption (property betterment) and production benefits (GVA)	2.6	1.7
Housing improvement	Consumption benefits - property betterment and social benefits	2.0	1.3
Acquisition, demolition and new build	Consumption benefits - property betterment and visual amenity enhancement	5.5	3.7

Source: DCLG 2010

However, the report notes that these BCRs do not include **production benefits**, such as stimulated footfall, dwell time and expenditure in shops or cafes. This is due to the highly project specific nature of these benefits, and lack of consistent evidence to draw upon. These would serve to improve the overall BCRs if included.

The BCRs are summarised in 0.

Table 3.6: Overall BCRs by DCLG: Environmental Improvements

Activity Type	Valuation Basis	Central Valuation	Cautious Valuation
Environmental: open space	Consumption benefits - Willingness To Pay	2.7	1.8
Environmental: public realm	Consumption benefits - Willingness To Pay	1.4	0.9

Other types of regeneration

The DCLG report provides the following BCRs for the different types of non-physical regeneration. These are summarised in 0.

- The BCR for **tackling worklessness** is at the low end of the possible range, therefore a cautious valuation was not conducted. Importantly, in the absence of the crime and health benefits the BCR is actually found to be below 1, indicating poor value for money. This reflects the often high costs involved in moving people into work, and the typically low levels of GVA associated with successfully doing so. Of course, this does not reflect any longer term benefits to the individual and society, if individuals are subsequently able to up-skill and progress in their jobs.
- For **skills & training** the cautious BCR of 1.6 uses a duration period of 2 years instead of 3.
- The highest BCRs are observed for supporting start-ups and for general business support, with central valuations of 9.3 and 8.7 respectively. The cautious BCR for **business support** activity uses a lower GVA of £33,000 per job instead of £35,000 and a duration of 2 years instead of 3. This reduces the value from 8.7 to 6. The same sensitivity exercise is used for **research and development activity**, bringing the BCR down from 2.5 top 1.8. For **start-ups and spin-out** activity it was not possible to distinguish between created jobs and safeguarded jobs in the BCR calculations. The lower value uses a 2 year duration period instead of 3, holding GVA

constant. Again, in interpreting these figures it is worth reiterating the view of the What Works Centre on the robustness of much of the underlying evidence here.

- The BCR for **community volunteering** is based on minimum wage with only one year of benefit. Therefore there is only one BCR value of 1.1.
- For **investments in community organisations** the central valuation BCR of 1.8 goes down to 1.3 when the benefit duration is reduced to 2 years from 3.
- The BCR calculation for **neighbourhood renewal** is based solely on shadow pricing techniques from the evidence based on New Deal for Communities (NDC), which suggests a BCR of 3.

Table 3.7: Non-Physical Regeneration Overall BCRs

Activity Type	Valuation Basis	Central Valuation	Cautious Valuation
Tackling worklessness	Consumption benefits (earnings) plus indirect crime and health benefits	1.04	1.04
Skills and training	Production benefit - Earnings uplift arising from skills enhancement	2.2	1.6
General business support	Production benefit - GVA	8.7	6.0
Start-up and spin-outs	"	9.3	6.8
Business enterprise research & development	"	2.5	1.8
Communities: Volunteering	Shadow price of volunteer inputs - minimum wage	1.1	1.1
Communities: investing in community organisations	Shadow price of social enterprise 'GVA'	1.8	1.3
Neighbourhood renewal	Consumption benefits - value transfer from NDC evaluation which adopted shadow pricing approach	3.0	3.0

4 Defence

4.1 Nature of investment activity

The investment activity is investment in flood and coastal erosion defences.

4.2 Scope of costs and benefits assessed

The approach to best practice implementation guidance has altered over time, driven by Government policy. The most recent appraisal guidance focuses on flood and coastal erosion risk management and has been set out by the Environment Agency in 2010.[61] The main requirement of the appraisal is to adopt a risk-based approach, where the likelihood and the consequence of flooding and erosion are assessed.

This guidance is very detailed, and states that a range of factors are typically valued in the current appraisal process, including:

- **Costs**: design, capital, operational, maintenance, monitoring and compensatory habitat costs associated with implementing the project. The guidance states that these should be calculated over the lifecycle of the project.

- **Damages**: these include loss of environmental quality, such as reduced amenity, loss of habitat, visual impact or unsustainable resource consumption.

- **Benefits**: these include the damages avoided as a result of reducing the likelihood of flooding or erosion by reducing the consequences, as well as the positive environmental and biodiversity impacts from allowing flooding or erosion to continue.

The typical timeframe for a flood or coastal erosion project appraisal is **100 years**. This is because as the Treasury Green Book suggests, the period should reflect the useful lifetime of the project. Subsequently, any additional uncertainty created by the longer period should also be accounted for.

0 outlines the main costs and benefits that are assessed. The key focus tends to lie on the change in risk through changing probability and consequence, particularly reduced risk of damage to buildings. For example, a floodwater management project would reduce the probability of flooding by redirecting floodwaters away from the village. This would also reduce the likely damages to buildings as a consequence. To value this:

- The depth of flooding has to be considered first and whether it would change, so that lower depth-damage values can be applied.
- Then the change in timing of flooding or erosion should be considered, as the value of the change in consequence is derived from discounting (according to set out guidance).
- The benefits should then be assessed based on the duration of impact: for example, the less time the flood is on land, the smaller the direct damages.
- The next step is to assess whether those at risk would change: i.e. more vulnerable people or habitats would be protected, reducing risk.
- It should then be considered whether floodwater velocities would decrease, and finally
- Whether erosion rates would be decreased.

[61] Environment Agency (March 2010) Flood and Coastal Erosion Risk Management appraisal guidance

Table 4.1 Flood and Coastal Costs and Benefits

Impact Category	Means of Assessment
Economic Impacts	Construction and maintenance costs
	Changes in risk of damage to buildings
	Abandonment of buildings
	Changes in risk of loss of agricultural output
	Abandonment of agricultural land
	Changes in risk of disruption to trade
	Effects on transport/utilities/emergency services
Environmental Impacts	Intangible effects of flooding
	Changes in environmental and heritage values
	Intensification of land use
	Changes in tax revenue and subsidy payments
Social Impacts	Changes in recreational value
	Effects on personal and property rights
	Changes in health and wellbeing

While the guidance aims to put monetary values on all costs and benefits, it is acknowledged that some of these might be difficult to value and therefore not all are necessarily included in individual cost-benefit analyses:

- A decline in **water quality**, for example, could be difficult to monetise, but should still be considered during decision-making as it is a very significant factor.
- **Landscape values** should also be recognised and recorded as part of the assessment, although may not always be monetised.
- **Heritage structures and features** can have monetary values attached to them, but these values may not fully reflect the heritage and cultural values of them. Thus, the additional benefits from maintaining the feature in its existing location should be considered.
- **Caravan parks** are often valued using fixed infrastructure costs and the costs of moving caravans, but such valuation does not account for loss of tourism or revenue supporting operations in the area. Such factors should be considered when drawing comparisons between options.

The assessment approach with descriptions of all the factors that are being considered, quantified data and monetised estimates of impacts should be recorder within the Appraisal Summary Table (AST).

4.3 Summary of evidence on range of BCRs

The Environment Agency and DEFRA periodically publishes details on achieved BCRs from their programmes. This evidence is necessarily of an ex-ante nature, since one of the key metrics revolves around the reduction in the expected (i.e. probability-adjusted) damage cost from flooding over a long appraisal period. That is, the interventions serve to reduce the probability of flood events occurring, and hence of the associated flood damage and attendant costs.

Defra has a requirement for the Environment Agency to achieve an average BCR of at least **5:1**, although it has been shown that historically the Environment Agency has achieved schemes with a BCR of at least **8:1**[62].

[62] Environmental Agency (2009) *Flooding in England: A National Risk Assessment*

The summary report published by the Agency[63] on the progress made towards achieving flood and coastal erosion risk management outcomes in England in the first quarter of 2014 outlines the following:

- A whole life BCR of **12.1:1** for schemes completed in 2013/2014;
- A BCR of **9.2:1** for the programme as a whole if capital expenditure on items including flood incident management and coastal monitoring is included.
- A forecast BCR of **8:1** for the whole programme under a medium risk of delivery.

Unfortunately it is unclear from all of these evidence sources on average BCRs the underlying evidence that has been used to arrive at these figures. Consequently it is unclear which precise benefits and costs have been factored into the BCRs, and it is not possible to comment on the robustness or comprehensiveness of this analysis. The appraisal guidance implies that the comprehensiveness of benefits and costs included will vary from project to project. We can, however, assume that the dominant benefit is the potential damage costs avoided as a result of the intervention.

[63] Environment Agency (2014) *Flood and Coastal Erosion Risk Management Outcome Measures*

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