UK National Ecosystem Assessment

Working Paper

Economic Assessment of Freshwater, Wetland and Floodplain (FWF) Ecosystem Services

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Economic Assessment of Freshwater, Wetland and Floodplain (FWF) Ecosystem Services

1. Introduction

This working paper reports on the valuation of ecosystem services from wetlands, freshwaters (rivers and lakes) and floodplains. Freshwaters, wetlands and floodplains provide a range of ecosystem services, as reviewed in the NEA Chapter on the natural science aspects of Freshwaters (

Table 1

Table 1to which reference is made [1].

Table 1 Freshwater Rivers and Lakes (FWR&L), Wetlands (WL) and Floodplains (FP) provide a range of ecosystem goods and services

Final goods of freshwater habitat *	**FW R&L**	**W L**	**FP**	
Provisioning				Examples and relationships
Food: crop and livestock products	**X**	**X**	**X**	Wetland grasses provide grazing, silage and hay, nutrition level depends upon management. Agricultural floodplains support intensive farming. Commercially significant fisheries based on rivers, lakes and ponds in suitable conditions.
Biomass: fibre and energy materials, including peat		**X**	**X**	Wetlands produce reeds and osiers under saturated conditions. Peatlands provide energy and soil improvement products
Water for use	**X**	**X**		Open water habitats provide a water source for public supply, irrigated crops, power station cooling, industrial processing, fish farming,.
Navigation services	**X**			Navigable waterways require sufficient water depth
Health products	**X**	**X**	**X**	Mineral spas, medicinal plants, medical leeches,
Regulating				
Carbon regulation		**X**	**X•**	Carbon sequestration by vegetation and storage in organic soils, depending on land and water management.
Water flow and flood regulation	**X**	**X**	**X**	River flow, groundwater recharge influenced by landscape location, water storage characteristics and connection with other water bodies. Flood reduction relies on available water storage; permanently saturated habitats with no storage may generate or augment floods
Water quality regulation	**X**	**X**	**X**	Freshwater systems can dilute, store and detoxify waste products and pollutants. Water quality affects suitability for use
Human health regulation	**X**	**X**	**X**	Natural freshwater systems can increase well-being and quality of life if visually attractive and supportive of physical recreation. Freshwaters can be sources of water borne diseases as well as biocontrol agents
Cultural				
Science and education	**X**	**X**	**X**	Lake, floodplain and wetlands sequences contain archives and human

[1] Maltby, Ormerod, Acreman, Blackwell, Durance, Everard, Morris and Spray, 2011. Freshwaters – Open Waters, Wetlands and Floodplains. Draft. UK NEA.

				(pre)history and artefacts that may be lost if disturbed.. Freshwater ecosystems are important outdoor laboratories.
Tourism and recreation	X	X	X	Recreational fisheries, tourism depends on landscape appeal and iconic species. Good water quality and visual appearance required for natural swimming and boating.
Sense of place and history	X	X	X	Water is important in defining specific landscape character and features strongly in art and local culture. Freshwaters and especially wetlands are a recurrent feature at the heart of many historically important places, battlefields, territorial boundaries and many local folklore connections
Supporting services				
Biodiversity	X	•X	X•	All freshwater habitats with open water; species depend on conditions such as, temperature, oxygen level, depth and velocity of water and area with suitable conditions. Some habitats may provide temporary habitat for fish (e.g. for spawning), such as floodplains
Soil formation	X	•X	X•	Wetlands and floodplains are important habitats for soil generation though natural biophysical and chemical processes
Nutrient recyling	X	•X	X•	Recycling of soil and water natural and artificial nutrient occurs in wetlands, supporting enhanced water quality.

*X denotes provision of good or service

The focus of economic assessment here is placed on the range of ecosystem goods provided by wetlands, on the goods provided by freshwaters in terms of the market and non-market benefits of water quantities and qualities, and the flood regulation services of floodplains. The provision of food and biomass goods by agricultural floodplains and the provision of cultural services associated with freshwaters, especially of recreation and amenity, are covered elsewhere.

2. Wetlands

2.1. Overview

Wetlands, viewed as a stock of natural resources, have potential to provide diverse flows of provisioning, regulating and cultural services that are of value to people[2]. They also deliver many supporting services associated with soil formation, nutrient cycling and habitats. Some benefits are associated with the direct use of wetlands, such as the provision of food and materials, and some with indirect use, such as surface and groundwater retention, and flood control. Wetlands also provide benefits associated with 'non-use', typically due to the existence now, and for future generations, of attributes such as biodiversity and cultural heritage[3].

Some of these benefits are associated with so called 'private' goods that are the subject of market transactions between buyers and sellers. Here market prices can provide a basis for valuation, apparent for example in the prices paid and received for food and fuel products. Many other

[2] Barbier, E.B., Acreman, M. and Knowler, D. (1999). Economic Valuation of Wetlands: A guide for Policy Makers and Planners. Ramsar Convention Bureau. Gland, Switzerland

[3] de Groot,R., Fisher, B., and Christie, M. (2009). Integrating the ecological and economic dimensions in biodiversity and ecosystem valuation. Chapter 1 in The Economics of Ecosystems and Biodiversity; The Ecological and Economic Foundations. TEEB project. available on www.TEEB.org, accessed 20.3.2010

benefits, however, are so-called non-market 'public' goods that are enjoyed by society at large[4]. They are not the subject of (and are 'external' to) market transactions. They do not command market prices that can be used to indicate value. The contribution of wetlands to hydrological and climatic regulation and the value to people of outdoor recreation, landscapes and wildlife, are examples of these external benefits. Conversely, the loss of these benefits due, for example, to the 'reclamation' of wetlands for agriculture, constitutes an external cost borne by society, now and into the future, without compensation.

Thus, wetland externalities are associated with two types of failure: (i) the failure of markets to comprehensively value the complete range of services that flow from wetlands, and (ii) the failure of institutions to define entitlements to these external, non market services and explicitly build them into decisions on the use and management of wetlands. Most environmental policies that seek to protect and enhance wetlands are concerned with rectifying these failures in the public interest, or in economic terms, in order to increase social welfare.

In this context, much of the literature on the economics of wetlands has been concerned with issues of valuation, property rights and decision making. For example, Barbier et al (1999)[5] argue that 'a major reason for excessive depletion and conversion of wetland resources is often the failure to account adequately for their non-market values in decision making'. They provide guidance, supported by exemplar cases studies, on the approach to valuation, advising three stages, namely:

(i) defining the purpose of the valuation (eg impact assessment, analysis of proposed change in use, total environmental valuation)

(ii) defining the scope of the assessment regarding the type of benefits to be valued

(iii) designing data collection and suitable analytical techniques.

Estimating wetland benefits

Over the last 30 years, a range of studies, reviewed by Turner et al (2008)[6], has provided estimates of the economic value of wetlands, demonstrating both the range of wetland benefits and the use and reliability of valuation methods. Examples of benefit estimates are contained in Appendix 1.

[4] Perman, R., Ma Y., McGilvray, J. and Common, M, (2003). Natural Resource and Environmental Economics, 3rd edit. Pearson , London

[5] Barbier, et al, 1999, op cit

[6] Turner, K., Georgiou, S., and Fisher, B. 2008,. Valuing Ecosystem Services: The Case of Multifunctional Wetlands. Earthscan, London

The results of valuation studies of wetlands have themselves been used in a number of meta analyses that have sought to draw out generally applicable estimates of wetland services[7]. Brouwer et al, (1999)[8], for example, explored use and non-use values derived by the contingent valuation (CV, willingness-to-pay (WTP)) technique in 30 studies of wetlands in North America and Europe, providing 103 observations of value. Average overall value for the preservation of wetland functions was estimated at a willingness to pay of US$93 per household per year (1995 prices), with a median of US$51. The meta-regression explained about 37% of observed variation in values. Mean WTP per household per year estimates were derived for four main wetland functions, namely, in ranked order of value: flood control, water generation, water quality and biodiversity. The authors conclude that while meta-analysis is useful, more comprehensive information is required on the characteristics of the sample population to ensure the relevance of CV benefit transfer for secondary applications.

Woodward and Wui[9] undertook a meta-analysis of valuation studies for North American and European wetlands only, covering a range of valuation techniques. The resulting data set contains 65 value observations taken from 39 studies. Wetland size was shown to be significant, with diminishing returns to scale. Amenity and aesthetics exerted the greatest positive influence on benefits, with bird watching and bird hunting being significant although counteracting variables. The regression function explained 58% of observed variation.

Along similar lines, Brander et al. (2006)[10] conducted a review of over 190 wetland studies, of which 80 were deemed suitable for meta-analysis, providing 215 observations of value. Their review covered a range of valuation methods, mainly involving studies to derive partial or total economic values. Valuation data were gathered by continent (eg North America, Australasia), by wetland type (eg woodland, freshwater marsh)), by wetland service (eg biodiversity, amenity, flood control), and

[7] Woodward R.T. and Wui, Y.S 2001. The economic value of wetland services: a meta analysis, Ecological Economics, 37, 257-270.

[8] Brouwer, R, Langford, I.H., Bateman, I.J. and Turner, R.K. (1999). A meta analysis of wetland contingent valuation studies, Regional Environmental Change,1: 47-57

[9] Germandi, A, van den Bergh, J.C., Brander, L.M., de Groot, H.L.F., Nunes , P.A. .2008. The Economic value of wetland conservation and creation: a meta analysis. FEEM Working Paper, 79, Sept 2008,

[10] Brander, L.M., Florax, R.J.G.M, and Vermat, J.E. (2006). The empirics of wetland valuation: a comprehensive summary and a meta analysis of the literature. Environmental and Resource Economics, 33: 223-250

by different valuation methods. A mean value of US$2,800 per hectare per year was derived in 1995 US$, with a median of US$150 reflecting considerable skewedness.

Meta-regression by Brander et al was able to explain 45% of the observed variation in economic values for wetlands. While benefits did not vary significantly according to wetland size, they were positively correlated with population density. Linked to this, higher values were evident for wetlands providing indirect uses such as flood control and water quality, and somewhat surprisingly (as the authors note) lowest for direct uses such as hunting and fuel wood. Values (adjusted) were positively correlated with country level GDP/capita. Interestingly, values tended to be lower for designated Ramsar sites, possibly because of restrictions on use and perceived constraints on potential benefit. Brander et al. caution the use of meta analysis results for benefit transfer, especially to policy sites which have different characteristics than those used to derive the compared to benefit estimates.

Ghermandi et al. 2008 expanded the data set used in Brander et al. (2006) to cover 383 independent observations derived from 166 studies. They extended the geographical coverage studies to incorporate recent studies from Africa, Asia and Europe. In addition, man-made wetlands are included. The authors argue that their study recognises the substitution effects between wetland sites and the importance of benefits associated with alleviating human induced environmental pressures. This tends, they argue, to increase the values derived.

Building on the Ghermandi et al. analysis, Brander et al (2008)[11] derived a regression function based on 264 observations that included 78 European sites. They confined data sets to ecosystems that are compatible with the definition of wetland used in the European Environment Agency's land cover data. The resultant semi-logarithmic model was able to explain 43% of the observed variation in benefit estimates. This model was deemed appropriate for application to the UK case as explained below.

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[11] Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P.A.L.D., Schaafsma and M., Wagtendonk, A. 2008. *Scaling up ecosystem services values: methodology, applicability and a case study.* Final Report, European Environment Agency, May 2008.

In a broader setting, as part of the TEEB project, Pascual et al, (2009)[12] have recently reviewed the economics of valuing ecosystems and biodiversity, including wetlands. A review of 314 studies shows that a range of methods have been used to derive values of ecosystem services. Market prices and changes in productivity have been mainly used to value production/provisioning services. Cost-based methods or expressed preference (especially contingent valuation) have been used to value regulation services, and cultural services have been valued mainly with revealed preference (especially travel cost and hedonic pricing) and expressed preference (contingent valuation) techniques. With respect to the economic valuation of wetlands ecosystem services in particular, cost and production based methods were used to derive economic values in 43% of applications, revealed preference in 8% of applications and stated preference in a further 40% of applications. A further 9% of wetland economic valuations used benefit transfer methods[13].

While confirming the suitability of valuation methods, Pascual et al. recognise that economic valuation techniques have their limitations. Gaps in knowledge about ecosystem dynamics, technical issues and/or human preference make predictions uncertain. They argue that researchers and policy makers must make explicit allowance for uncertainty in the way that estimates are presented and used. Where decisions could lead to threshold or irreversible effects, there is need to recognise that current valuation techniques of the kind used for cost benefit analysis 'are simply insufficient'. Echoing the concerns of the Millennium Ecosystem Assessment, they call for a precautionary approach based on safe minimum standards. Furthermore, valuation results, as shown by the aforementioned meta-analyses, are heavily dependent on the social, economic and cultural context, as well as site specific biophysical conditions. In this respect, meta-analysis functions may be more applicable for high level policy and programme appraisal at the regional and national scale rather than appraisal of any one site.

[12] Pascual, U., Muradian, R., Brander, L., Gomez-Baggethum, E., Martin-Lopex, B. and Verma, M. (2009). The Economics of Valuing Ecosystems Services and Biodiversity. Chapter 5 in The Economics of Ecosystems and Biodiversity; The Ecological and Economic Foundations. TEEB project. documents available on http://www.teebweb.org accessed 20.3.2010

[13] Pascual et al, 2009, op cit

2.2.Approach

A review of recent meta-analyses of wetland valuation [14,15] concludes that Brander et al. (2008) [16] provide the most appropriate benefit transfer function for the UK case. For this reason, and others relating to data availability, the Brander et al function was used for the purposes here.

The European CORINE [17] Land Cover Maps, also used to classify wetlands in the Brander et al. function, were used to obtain data on inland wetlands in the UK [18]. CORINE classifies wetlands into five types. Two relate to inland wetlands, namely "Inland marshes" and "Peatbogs". Three relate to coastal wetlands, namely: salt marshes, intertidal mudflats and salines, the first two of which are relevant for the UK.

According to the CORINE data set (Table 2 and Appendix 2) there are 1519 inland wetlands in the UK, covering about 601,500 ha. Of this about 20,000 ha (3% of the total area) are classed as inland marsh, the rest as peatbogs. These were further classified as either lowland or upland according to whether they were below or above 240m OAD respectively. Most inland marshes are below 240m whereas most peatbogs are above 240m (Appendix 2). In addition CORINE identify 693 coastal wetlands, covering about 274,600 ha, of which about 42,000 ha (about 16% of coastal wetland areas) are salt marshes and the rest are intertidal mudflats.

Table 2 Types, numbers and size of freshwater inland wetlands in England, Wales, Scotland and Northern Ireland according to CORINE data

	ENGLAND		**WALES**		**SCOTLAND**		**NORTHERN IRELAND**	
Type of wetland	Inland marshes	Peat bogs	Inland marshes	Peat bogs	Inland marshes	Peat bogs	Inland marshes	Peat bogs
Number	74	288	7	14	12	936	8	180
Total area ha	15,270	98,035	639	2,819	1,697	361,651	338	121,100
Mean ha	206	340	87	201	141	386	177	673
Median ha	90	102	59	38	79	79	38	102

[14] Eftec. 2010. *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal. Case Study 3 – Valuing Environmental Benefits of a Flood Risk Management Scheme*

[15] Personal communication: Dr Stephanie Hime, eftec

[16] Brander, L.M., Ghermandi, A., Kuik, O., Markandya, A., Nunes, P.A.L.D., Schaafsma and M., Wagtendonk, A. 2008. *Scaling up ecosystem services values: methodology, applicability and a case study.* Final Report, EEA May 2008.

[17] Corine European Land Cover Maps. http://www.eea.europa.eu/data-and-maps/figures/corine-land-cover-2000-by-country

[18] Data for other administrations is currently under way.

The CORINE data set uses a different classification of wetlands compared with that used by the Biodiversity Action Plans contained within the Wetland Vision, although the data origins are the same, ie CEH Land Cover Map, 2000. Following the conclusion of Smith et al. [19], the CORINE 2000 class for 'inland marshes' is taken to be representative of 'fen, marsh and swamp' under the BAP LCM 2000 classification, and CORINE's 'peat bogs' class are taken to represent LCM's category of 'bog'. It is noted, however, that although the total area of wetlands in the UK according to CORINE and BAP is very similar, the more detailed classification of wetland types used by BAP does not exactly fit the broad categories used by CORINE. The use of CORINE data and classification was justified on the basis of available data and their suitability use in the benefit transfer function. It is recognised, however, that estimation error may arise because wetlands are inappropriately classified. While the approach here is consistent for the assumptions made, the implication of divergence between BAP and CORINE classifications is worthy of further assessment in future.

The procedure outlined in Brander et al, 2008[20] was followed (see Appendix 3). Data on wetland type and area were obtained from CORINE data using the ArcGIS tool to enable the application of the benefit function. Population data was obtained from the *Casweb* extraction tool using the Census 2001 at District level and included in the GIS database in order to estimate the population within a 50 km of radius of the centre of each wetland. Income per capita was obtained from the EUROSTAT database in €2003 at NUTS (Nomenclature of Territorial Units for Statistics) level 2, converted to 2003 US$ using OECD published exchange rates. The benefit estimates in US$ 2003 were then converted to £ 2003 and inflation adjusted at HMT rates to give £ 2010.

In addition to the aforementioned information, the benefit function requires that ecosystem services provided by each wetland are identified and accordingly switched 'on' or 'off' in the function. Services with a positive coefficient have a benefit increasing effect in the function and are mainly associated with resource and environmental enhancement (Table 3). Conversely, services with a negative, benefit reducing coefficient in the function, are mainly associated with direct consumption and extractive activities. These latter services do not have negative values in

[19] Smith, G.M.; Brown, N.J. and Thomson, A.G. 2005. CORINE Land Cover 2000: semi-automated updating of CORINE Land Cover in the UK. Phase II: Map Production in the UK. Final Report. Centre for ecology and hydrology (Natural Environment Research Council). Project. C02041A

[20] Explained in supporting material

themselves but tend to depress the overall value of wetlands in the benefit function compared with those with a positive influence.

Table 3 Assumed typical ecosystem services provided by wetland types in the UK used in the benefit transfer function

		Services assumed typical of wetland type Y=yes, N=no, ?=unsure**			
Services	Coefficient in Regression function*	Inland marsh	Peat bog	Salt marsh	Inter-tidal mudflat
Resource and environmental enhancement services					
Flood control and storm buffering *	+1.102*	Y	Y/?	Y	Y
Surface and groundwater supply	+0.009	Y	Y	N	N
Water quality improvement*	+0.893*	Y	Y	N	N/?
Non-consumptive recreation	+0.340	Y	Y	Y	Y
Amenity and aesthetics	+0.752	Y	Y	Y	Y
Biodiversity*	+0.917*	Y	Y	Y	y
Direct consumption and resource extractive services					
Recreational fishing	-0.288	Y	Y	N	Y
Commercial fishing and hunting	-0.040	N	N	Y	Y
Recreational hunting *	-1.289*	N	N	Y	y
Harvesting of natural materials	-0.544	Y	Y	Y	Y
Material for fuel*	-1.409*	N	N/?	N	N

*From Brander et al, 2008 opcit. * denotes significant in the regression function at 10%, ** ? unsure, or legacy of impacts

The extent to which individual wetland sites provide particular services is not known. For this reason, a range of values were obtained for each wetland site in the UK for different assumptions about service flows. These were: (i) default estimate with the benefit function un-weighted by services, (ii) function weighted by statistically significant services only, (iii) function weighted by services known to be typical of particular types of wetlands that are also statistically significant, (iv) function weighted all typical services, and (iv) function weighted by all services. The natural science team advised on typical wetland services.

For example, most UK inland wetlands, being designated for nature conservation, are not used for hunting, commercial fishing or fuel extraction, although many sites have had peat extracted in the past. There is some harvesting of natural material such as grasses, reeds, berries and occasional use by grazing livestock. Most wetlands are perceived to provide water quality improvement, non-consumptive recreation, amenity and aesthetic benefits, and biodiversity benefits. Many lowland sites also provide flood control and recreational fishing. However, the extent to which upland peat bogs contribute to flood control is unclear: run-off attenuation may be limited if land is already saturated. Clearly the degree to which a given site provides particular benefits varies according to local conditions.

With respect to coastal sites in the UK, salt marshes are commonly used for recreational as well as commercial hunting/shooting of wildfowl. They also provide flood control services, non-consumptive recreation, amenity and aesthetic benefits, and biodiversity benefits. Intertidal mudflats are commonly used for recreational fishing and in some cases commercial fishing. Tidal waters are also abstracted for power generation.

2.3.Estimated benefits by type of wetland ecosystem service

The benefits provided by a given wetland will depend, amongst other things, on the type and range of ecosystem services rendered. Drawing on the analysis of wetland sites for the UK as a whole (as explained and presented in following sections), Table 4 summarises the contribution of each individual benefit stream over and above the ***default*** benefit estimate that assumes that no specified services apply. With respect to benefit 'resource and environmental enhancement services', flood control, water quality improvement and biodiversity are deemed to make the largest contribution to extra benefits per ha of wetlands ***where they apply***. For example, flood control is deemed to contribute £608/ha/year and £3,730/ha/year for the existing stock of inland and coastal wetlands respectively.

With respect to direct consumption and resource extractive services', recreational hunting and materials for fuels have the greatest negative effect on overall benefit value, at around £220-230/ha/year in each case for inland wetlands, and around £1,350 to 1,400/ha/year for coastal wetlands.

Table 4 also shows the potential contribution of individual services to total benefits (£ million per year as explained in following sections) for UK inland and coastal wetlands, assuming they apply in all cases. For example, if all inland wetlands are assumed to generate flood control and storm buffering benefits, the estimated aggregate value is £366 million per year for the UK. Considered separately, if all inland wetlands provided water quality improvements, a further £263 million of benefits are generated.

Table 4 also shows the marginal benefit of particular services when the wetland stock is increased by 10% (as explained in following sections). Extending the area of wetlands by 10% would be associated with lower marginal benefits per ha because of assumed diminishing returns to scale.

The marginal value of benefits per ha are reduced somewhat compared with the aforementioned average benefits, mainly because of declining returns to scale. For example, the marginal benefits of flood control on inland and coastal wetlands are £407/ha/year and £2,498/ha/year respectively. The converse applies when there is a decline in the wetland stock.

At the moment, as mentioned before, it is not clear how many sites provide particular services, nor to what degree and quality. Furthermore , there are likely to be strong interrelations (both synergy and trade-off) between different services flows at the local level so that the assumption of independent service flows (and associated values) may be unrealistic. The estimates here are therefore indicative of direction and magnitude at the broad scale.

Table 4 Estimated average, total and marginal values for specified ecosystem services provided by inland and coastal wetlands in the UK*

	UK Inland Wetlands			UK Coastal Wetlands		
Resource and environmental enhancement services	Extra contribution above default estimate** (£/ha/year)	Total contribution above default estimate *** (£million/ year)	Marginal value of extra provision (£/ha/year)	Extra contribution above the default estimate ** (£/ha/year)	Total contribution above default *** (£million /year)	Marginal value of extra provision (£/ha/year)

Flood control and storm buffering	608	366	407	3730	1534	2498
Surface and groundwater supply	2	2	1	16	514	12
Water quality improvement	436	263	292	2676	1245	1793
Non-consumptive recreation	122	74	82	751	716	504
Amenity and aesthetics	339	204	227	2080	1081	1394
Biodiversity	454	273	304	2786	1275	1866
Direct consumption and resource extractive services						
Recreational fishing	-76	-46	-51	-465	382	-310
Commercial fishing and hunting	-12	-7	-8	-73	489.6	-48
Recreational hunting	-220	-132	-147	-1345	140.4	-900
Harvesting of natural materials	-129	-77	-87	-790	292.8	-528
Material for fuel	-229	-138	-153	-1403	124.5	-938

*Area weighted estimates for all UK inland wetland sites using the Brander et al benefit function and CORINE data sets. £2010 values.
** default average value (see text) for all UK inland wetlands is £303/ha/year. for all UK coastal wetlands is £1,856/ha/year.
*** default total value of existing inland wetland stock is £182 million /year, for existing coastal wetland stock is £509 million /year
**** marginal value of an extra ha of provision of a service, associated with a 10% change in wetland areas, shows change in the average value per ha after a change in the stock of wetlands (+10%) that is attributable to a particular service.

2.4. Benefit Estimates for UK Inland Wetlands

Estimates of annual benefits weighted by area were derived for each inland and coastal wetland site in the UK and its constituent administrations, and then expressed as an overall average weighted by wetland areas (Table 5). The benefit estimates vary considerably according to assumptions about service flows. They also vary between sites (and between administrations) according to adjacent population.

The overall UK default benefit estimate is £303/ha/year for all inland wetlands, and £270/ha/year and £333/ha/year for lowlands and upland wetlands respectively (Table 5). This is probably a safe, albeit unduly pessimistic estimate of benefits in the absence of site specific information on service flows. Estimates for England, Wales, Scotland and Northern Ireland are shown in Appendix 4. Default estimates benefits are greatest for the English case at £837/ha/year, with £2,083/ha/year for lowland sites and £528/ha/year for uplands. The relatively high estimates for England reflect the relatively greater size and prosperity of the population within a 50km radius of the sites, especially for lowland sites. Small wetlands in the vicinity of relatively large population centres have particularly high estimated benefits per ha compared to larger sites that dominate the area weighted estimate. Thus the impact of changes in the provision of wetlands varies considerably between the locations of wetlands.

Table 5 Estimated Average of inland and coastal wetlands in UK using a benefit transfer function*

		Inland Wetlands			Coastal Wetlands		
		Lowland	Upland	All	Salt-M	Intertidal	All
Sites	number	596	735	1519	249	444	693
Area	ha	261631	218480	601550	42,335	232,278	274,613
Default estimate #	£/ha/year	270	333	303	3,615	1,535	1,856
Statistical significant services*	£/ha/year	335	412	375	4,478	1,901	2,298
Typical services that are also statistically significant	£/ha/year	2858	3516	3199	4,311	1,830	2,213
Typical services	£/ha/year	6385	7856	7148	12,343	3,929	5,227
All services assumed	£/ha/year	417	513	467	5,574	2,367	2,861

*Based on Brander et al, 2008. #assumes no specific services are delivered

Assuming that sites provide services that are statistically significant in the benefit transfer function has the effect of lifting benefit estimates by about 20-25% from their default values. Assuming services that are typically provided by sites, but only accounting for those that are shown to be statistically significant in the benefit transfer function, generates an overall average for UK wetlands of £3,199/ha/year, with £2,858/ha/year and £3,516/ha/year for lowland and upland sites respectively (Table 5). Again this benefit estimate is much higher for the English case, at £8,848/ha/year, mainly reflecting relatively high adjacent population densities. Including all typical services for inland wetlands, both statistically significant and non significant, increases the UK estimate for inland wetlands to over £7,000/ha/year. This latter estimates appear unrealistically high and question the validity of benefit transfer function for UK conditions, especially concerning the weight in the function to given to population densities which in England are amongst the highest internationally.

Table 5 also shows, for purposes of comparison, estimates of benefits assuming all wetland services apply (£467/ha/year for the UK). The estimates are about 50% higher than the default. They are not very different from that based on significant variables only because of the counteracting influence of different service flows on overall benefits. It is noted that the estimates here are weighted by wetland areas.

2.5.Benefit Estimates for UK Coastal Wetlands

The default average benefit estimate for coastal wetlands in the UK is £1,856ha/year, with £3,615/ha/year and £1,535/ha /year for salt marshes and intertidal mudflats respectively (Table 5). Benefits are greatest for the English and Northern Ireland cases at around £2,200/ha/year (see Appendix 4). In most cases, salt marshes appear to deliver considerably greater benefits per ha compared with intertidal mudflats. The average values for coastal wetlands are higher than for inland wetlands, particularly relative to the more remote inland peatbogs. In the English case, many are near to important coastal population centres.

If coastal wetlands are assumed to deliver services shown to be statistically significant in the benefit transfer function, estimates benefits are about 25% higher than the default estimated (Table 5). Assuming typical services that are also statistically significant produces an estimate of £2,213/ha/year average benefits for the UK as a whole. If all typical services are assumed, UK average benefits for coastal wetlands rise to about £5,200/ha/year. They are particularly high for salt marshes, associated with flood buffering and recreational hunting benefits. Scottish average benefits per ha appear to be lower than the UK average, mainly reflecting lower population densities. Table 5 also shows that assuming all wetland services apply adds a further 50-60% to the default benefit estimates for coastal wetlands.

2.6.The marginal value of increasing wetland area.

The value of changes in the stock of wetlands was explored by assessing the change in aggregate value associated with an assumed 10% increment in aggregate area[21]. On this basis, and assuming all services apply, the mean marginal value for all UK inland wetlands over a 10% increment in total area is £251/ha/year, and highest in England at £694/ha/year (Table 6). This value is lower than the mean average value for the existing stock, indicating diminishing returns to scale for the whole

[21] The Brander et al benefit transfer function includes an option for calculating the marginal benefits of wetlands, that is the benefit associated with increasing a wetland by one hectare. There is, however, considerable uncertainty in the estimates of marginal benefits as these were based on a relatively small set of observations in the original meta-data.

stock. It is noted, however, that wetlands in the vicinity of population centres have much higher benefits per ha than average. It is noted that estimated marginal values are considerably higher if based on estimates of the value of typical services (as per Table 3).

Table 6 Summary of average, total and marginal ecosystem benefit estimates for inland and coastal wetlands in the UK and constituent administrations

Inland wetlands	Number	Area (ha)	Average value £/ha/year	Total value £million/year	Marginal value £/ha/year*
England	362	113,307	837-1,291	95-146	£694
Scotland	948	363,347	128-197	46-72	£106
Wales	21	3,458	644-992	2.2-3.4	£534
Northern Ireland	188	121,438	318-491	39-60	£264
UK	1,519	601,550	303-467	182-281	£251
Coastal wetlands					
England	400	164,616	2,231-3,440	367-56	£1,850
Scotland	144	53,240	919-1,416	49-76	£762
Wales	119	48,443	1,528-2,356	74-114	£1,267
Northern Ireland	30	8,314	2,338-3,604	19-30	£1,939
UK	693	274,613	1,856-2,861	510-786	£1,539

Based on application of Brander et al. model to CORINE data sets. *Assuming 'all services' apply as per Table 3.

2.7.Aggregate benefits of UK wetland sites

In summary, assuming that average benefits range between the 'default' and 'all services' estimates, the 1519 inland wetlands and 693 coastal wetlands in the UK generate total estimated benefits of between £692 and £1,067 million per year (Table 6). If the estimate of benefits is based on 'typical services that are also statistically significant', aggregate benefits for the UK amount to £2,531million per year, and £5,734million per year if 'all typical services' are assumed. These latter estimates are equivalent to about £40 and £95/capita per year respectively for the UK population, or about £100 and £220/household per year. The estimates vary considerably according to assumptions and it is not clear which gives the most reliable estimate.

2.8.Case study examples

The benefit transfer function was applied to four wetland sites[22] in selected target areas contained in the Wetland Vision for England[23] that sets aspirational targets for wetland restoration. These areas comprise mainly (but not exclusively) peatland areas in which the retention of soil carbon is an important objective (although not included in the benefit transfer function here) (Table 7). Incremental benefits associated with wetland restoration on peat soils (excluding carbon benefits) ranged between about £330 and £5,000/ha/year.

Estimated values are much higher for inland marshes compared to peat bogs that tend to be more isolated and less diverse in their services, at least in the broader European context. It is clear that values are highest where large populations of 'users' can benefit from the site, especially associated with recreation and amenity. Furthermore, flood control, water quality and biodiversity are major sources of potential benefit. On these designated sites, it is assumed that there is limited extraction of materials (including extraction of peats for fuel) and limited gaming of wildlife that would tend to compromise conservation objectives and depress overall values.

Table 7 Estimates of the values of services generated by restored wetlands in selected peatland areas, using a benefit transfer function

	Target Area (ha)	**Average value £/ha/year**	**Aggregate average value £million/year**
The Great Fen: Cambridgeshire	3,594	502-2,184	1.8-7.8
Humberhead (South Yorkshire and Humberside)	673	1,203-5,233	0.8-3.5
Middle Parret Floodplain: Somerset	6,877	329-1,430	2.2-9.9
Lyth Valley (Cumbria)	610	437-1,901	0.2 -1.1

Note: lower values are for peat bogs in wetland areas, higher values for inland marshes. Source Morris et al, 2010

These estimates must be treated with caution, not least because of reservations about whether specific individual English cases can be reliably represented using data mainly from other European

[22] Morris, J., Graves, A ,Angus, A., Hess, T.M., Lawson, C, Holman, I., . and Camino, M. 2010. Impact of Peatland Restoration on Agricultural Production and Food Security. Report to Natural England. Cranfield University , Bedford

[23] http://www.wetlandvision.org.uk/ - A 50 year vision for wetlands.

countries. The estimated benefits are however positive and substantial and support the argument that restored wetlands in peatlands can add significant value. These benefits of wetland restoration compare favourably with the estimated net benefits (excluding subsidies) from farming which are about £150-200/ha/year for moderately intensive grassland, £400/ha/year for intensive arable including potatoes, and over £1,200/ha/year for specialist horticulture and salad crops.

2.9.Carbon storage benefits

The Meta-regression function used above does not include carbon storage benefits. Carbon storage benefits are estimated at about £220/ha/year for peatbogs based on estimated annual sequestration rates of about 4.1 t tCO_2e /ha [24] and DECC's current prices of £52/tCO_2e for non-traded CO_2 [25]. Conversely, inland marshes typically generate estimated net carbon emissions of about 4.22 tCO2e, equivalent to a cost of £220/ha/year. By comparison, peat-based wetlands that have been drained and farmed for arable production can generate CO_2 emissions approaching 24 tCO_2e /ha equivalent to about £1,200/ha/year [26] due to the wastage of organic soils.

Estimates of carbon storage of wetlands are not available at the time of writing for the UK as a whole. Natural England estimate that some 6,700 ha of peatland stores the equivalent of 584 Mt C, equivalent to about 2.14 billion tCO_2 e, about one third in bogs and the balance in lowland fens[27]. Based on land use and estimated emissions by type of land use, the estimated emissions from peatlands are currently about 2.48 M t CO_2 e /year, about half of which are associated lowland fens and half with mainly upland bogs. This is equivalent to about £130 million per year at DECC's 2010 price per tCO_2e. Natural England identifies a range of peatland management options that could achieve carbon neutrality[28].

2.10. Sensitivity analysis

The various benefit assumptions show how estimations vary with changes in the set of ecosystem services delivered. Estimates also vary according to spatially defined social and economic factors and the relative abundance of wetland sites. A +/-10% change in either population within a 50 km radius or GDP/capita results in a +/-5 to 6 % change in benefits per ha. The area of substitute sites has limited influence in the benefit transfer function, although considered over large changes in wetland provision, this could become important.

[24] Natural England, 2010. *England's Peatlands: carbon storage and greenhouses gases*. Natural England. Peterborough

[25] DECC, 2009. Carbon valuation in the UK: a revised approach. http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx,,

[26] Graves et al, op cit

[27] Natural England. 2010. Op cit

[28] Natural England. 2010. Op cit

2.11. Comparison between Benefit Transfer Estimations and Unit Values

Appendix 1 contains a summary of unit values for selected services provided by wetlands. A very crude estimation of total aggregate values suggests average benefits of about £3,000 to £5,000/ha/year where the full range of services are provided assuming average population densities of about 250 persons/km^2 for the lowland cases. While this comparison is very approximate, since the unit values have been taken from very different studies and the definition of ecosystem services may differ from those used in the benefit transfer function here, the estimates are within the range of the values derived above.

Another approach is to use single estimates for ecosystem services for a given wetland site drawn from a variety of sources. This was done, for example, for proposed wetland creation on the River Tamar in south western England [29]. Services included provisioning of food, fish, freshwater and fibre, regulation of GHG (especially carbon storage in peat), and flood and erosion control, cultural services associated with tourism and heritage, and supporting services associated with water cycling and habitats. Total value, before costs of wetland creation, over this 80km reach was £3.9 million/ year, over half of which was due to climate regulation. This is equivalent to about £6,300/ha over 615 ha of wetland.

2.12. Robustness of Benefit Transfer estimations

It is not clear whether the Brander function gives a good fit for the UK wetlands. Many of the caveats alluded to above in the literature on benefit transfer methods apply here. While the benefit function used here is oriented towards European wetland ecosystems, some of the characteristics of wetlands in the UK, especially for inland lowland areas, may not apply. For example, recreational and commercial hunting, and the harvest of natural material and fuels are probably much more common for many international wetlands compared with most English inland wetlands that are now protected conservation areas. Yet these variables, where they are present, have strong (relatively) negative and statistically significant influence in the benefit function. Equally, where they are not present, as in the case of many UK lowland inland sites, the importance of other (relatively) positive variables in the function has been determined as if they are present, and there may be a tendency to

[29] Everard, M (2009) Ecosystem Services Case Studies, Science Report: SCHO0409BPVM-E-P, Environment Agency, Bristol

overestimate benefits as a consequence. It is noted that such 'direct consumption and resource extractive services' are more pertinent for coastal sites in the UK, and it seems that the meta analysis function gives intuitively more realistic assessments for these sites.

It is also noted that population densities, a strong positive driver of benefits, are relatively high in England by European standards. These factors, combined with relatively high GDP/capita, probably produce an optimistic bias for the English case compared with the range of international cases from which the transfer function was derived. It is noted that a large number of small sites adjacent to towns generate relatively large benefits per ha. The average estimates here are however weighted by area, such that larger more remote sites exert a proportionately greater influence.

The Brander et al function, as its authors are aware, does not include a number of potentially important services, such as carbon storage benefits, pollination services and possible option values associated with future genetic/pharmaceutical benefits. These could be included as 'extras' once the function has been applied, but doing so could result in inconsistencies in the estimates. Furthermore, the benefit transfer function used here does not allow for differences in the quality (eg degree of water quality improvement) or intensity (eg degree of flood alleviation provided) of services. For these and other reasons, the results derived here need cautious interpretation, especially when attempts are made to assess the benefits of particular wetland cases rather than obtain a broad overview of benefits at the regional or national scale.

It may be possible at a later date to rework and possible extend the Brander et al and other data sets to better suit circumstances in the UK. The application of meta-analysis models of this type could be refined by including more bio-physical information in the GIS framework[30], such as soil type, land cover and use and location within a catchment. For instance, soils data could help to assess carbon storage benefits and habitat potential. Land cover/use data could help estimate the likely contribution to pollination services, and, together with location in the catchment, the potential for flood alleviation. For the moment, however, the approach adopted here can be used, albeit cautiously, to support the assessments of the likely benefits associated with broad scale changes in wetland management.

[30] Troy, A. and Wilson, M.A. 2006. Mapping ecosystem services: practical challenges and opportunities in linking GIS and value transfer. Ecological Economics. 60, 435-449

2.13. Scenarios

Changes in the value of wetland ecosystem services can be assessed, using the benefit transfer function, in response to changes in the type and area of wetlands, changes in the mix of services provided by wetlands, or changes in the demographic factors (including GDP and population densities) in the geographical areas over which wetlands exert influence. The incidence of wetlands and other factors relevant to benefit assessment can be expressed spatially, per km2, for this purpose.

3. Valuation of Freshwater

3.1. Overview

Freshwater refers here to natural moving waters in rivers and streams, and natural still waters in ponds and lakes. Groundwater is considered separately elsewhere. Freshwater has potential to provide a range of ecosystems services, associated with use and non-use, some of which are provided by water in situ and some by extracting water for use 'out of stream or lake'[31]. The value of water resources provided by rivers and lakes depends on the quantities and qualities of water and how these affect the generation of ecosystem services relative to needs. Appendix 5 contains a listing of sources of estimates of the value of water related services from rivers and lakes.

3.2. Water Quantity:

The natural environment is the ultimate supplier of freshwater for human use, whether sourced from surface or underground, generating a wide range of ecosystem services (reference natural science report). The value of natural waters varies according to how water (of a given quality) is 'used'; whether abstracting it for use elsewhere, using it in situ, or alternatively leaving it 'unused' in the natural water environment. In theory, the value of water supplied by freshwater ecosystems can be expressed in terms of the value added or lost by employing one more or less unit of water in a given application, or alternatively by retaining more or less water in the environment with consequences for river flows and groundwater levels.

3.2.1. Abstractions and water values in use

In the UK, permission to abstract freshwater (and tidal) water is controlled by the award of licences. Abstraction charges for licensed quantities are set to cover the cost of administering the licensing system rather than to reflect the value of water. There is no charge for water itself, although in England and Wales additional levies were introduced in 2008 to reflect the cost of 'environmental compensation,' ranging from zero in Northumbria to an additional 20% charge in the Anglian region

[31] See Table 1 in the NEA Freshwater, Wetland and Floodplains natural Science

[32]. In England, abstractions are strategically managed under the Catchment Abstraction Management System that seeks to balance demand and supply[33].

About 22 billion m^3 of water are abstracted in the UK each year, 52% from rivers and lakes, 11% from groundwater and about 37% from tidal waters (mainly used for cooling)[34,35]. Of the 13 billion m3/year extracted from non tidal sources in England and Wales, about half is used for public water supply (Table 8). A further third is used for electricity power generation. Industry takes about 10% and aquaculture and amenity about 9%. Spray irrigation accounts for less than 1% of total abstraction but this is concentrated in the relatively dry Anglian region in summer. Total reported abstraction quantities have remained more or less constant over the last 15 years (Environment Agency, 2010), although this partly reflects recent deregulation of small abstractions.

Table 8 Estimated water abstractions from all sources except tidal by purpose and Environment Agency regions for England and Wales, 2006-2008

	Public water supply	Spray irrigation	Agric (excl. spray)	Electricity supply	Other industry	Fish farming	Private water supply	Other	Total
North West	52.7%	0.1%	0.2%	24.6%	20.5%	1.8%	0.0%	0.2%	8.2%
North East	67.3%	0.4%	0.1%	13.8%	4.4%	13.9%	0.1%	0.1%	9.3%
Midlands	46.1%	0.8%	0.1%	27.2%	25.2%	0.4%	0.1%	0.1%	15.8%
Anglian	86.0%	4.7%	0.2%	0.6%	5.6%	2.5%	0.2%	0.1%	6.8%
Thames	90.0%	0.2%	0.2%	2.4%	2.6%	4.3%	0.2%	0.3%	12.5%
Southern	49.1%	0.5%	0.2%	0.1%	4.2%	44.5%	0.1%	1.3%	7.7%
South West	37.8%	0.1%	0.5%	20.0%	6.5%	34.3%	0.1%	0.7%	9.1%
Wales	16.6%	0.0%	0.0%	77.1%	4.4%	1.8%	0.0%	0.0%	30.6%
Total	48.2%	0.6%	0.2%	32.0%	9.2%	9.6%	0.1%	0.3%	100.0%
Ml/day	16542	198	52	10992	3153	3295	30	91	34353
Million m3/year	6038	72	19	4012	1151	1203	11	33	12539

Source: Environment Agency, 2010. Based on average annual abstractions 2006-2008 ##

Actual reported abstraction averages about 45% of licensed quantities, lower in dry years. In the drier south eastern part of England actual abstractions exceed safe environmental levels and no new

[32] Environment Agency 2010. Water abstraction charges. See http://www.environment-agency.gov.uk/business/regulation/38809.aspx
[33] Catchment Abstraction Management Strategy, at www.environment-agency.gov.uk/cams eg The Ouse and Bedford Ouse Catchment Abstraction Strategy March, 2005
[34] Environment Agency. 2009. Water for people and the environment: Water Resources Strategy for England and Wales< Environment Agency, Bristol http://publications.environment-agency.gov.uk/pdf/GEHO0309BPKX-E-E.pdf
[35] SEPA, 2004. An Economic Analysis of Water Use in the Scotland River Basin, Summary Report, Scottish Environment Protection Agency, Edinburgh

licences are available[36,37]. In these circumstances, water can act as a constraint on development, the value of water is relatively high and measures to increase the efficiency of use or supplement its supply are often economically justified.

It is difficult to derive values for water that are generically applicable because the context of water demand and supply varies spatially and temporarily. In this respect, willingness to pay for water tends to be much higher (and price elasticities much lower) in the short compared with the longer term when users of water may have time to adopt strategic responses to water shortages, for instance by switching behaviour or accessing alternative supplies.

Prices charged for abstraction do not reflect the full value of water either in its natural state or in any particular application. Rather they reflect the cost of managing the licensing system and there is concern that this leads to inefficient use. Water prices vary from £0.003 -£0.06/m3 for abstracted raw water, through to £1.50/m^3 for metered treated potable water piped to households. Abstraction charges are highest in Anglian and Northumbrian and lowest in Yorkshire and North West regions[38]. These cost-based prices grossly underestimate the very considerable consumer surplus that water users enjoy above the prices paid for this essential good. Research by Ofwat, for example, indicates that households are willing to pay the equivalent of £10/day not to have their water supply and sanitation disrupted[39], equivalent to about £33/m^3 for water supply only at average consumption levels. While these estimates are for treated water, they are dependent on the security of supply, ultimately from freshwater sources.

The value of water varies considerably between uses (Table 9). The Scottish Government provides estimates of water values that are broadly indicative of the UK as a whole [40;41.] The estimated marginal value for household treated water ranges from £0.50/m^3 to £1.20/ m^3. For raw water, the marginal value for irrigation water ranges between £0.23/ $m^3$and £1.38/ m^3 for the Scottish case, comparable with values well in excess of £1.50/ m^3 for irrigated potato and salad crops in eastern

[36] Environment Agency. 2009. Water for people and the environment: op cit.
[37] Defra. 2008. Future Water: The Government's strategy for water in England. Department for Food and Rural Affairs, London
[38] Environment Agency 2010. Water abstraction charges. Op cit.
[39] OFWAT, 2008. Guaranteed Standards Scheme. http://www.ofwat.gov.uk/consumerissues/rightsresponsibilities/standards/gud_pro_gss08.pdf, accessed 24/04/09
[40] SEPA, 2004. An Economic Analysis of Water Use in the Scotland River Basin, Summary Report, Scottish Environment Protection Agency, Edinburg

[41] Moran, D., and Dann, S. 2008. The economic value of water use: implications for implementing the Water Framework Directive in Scotland, Journal of Environmental Management , 87, 484-496

England[42, 43]. Marginal values for raw water vary considerably according to industrial processes, highest where high water quality is required for chemicals and whisky manufacturing. The energy sector shows relatively low marginal values for water for cooling but for large throughputs. The value of water for hydropower is particularly sensitive to assumptions about the economic price of energy and the cost of alternative sources. Table 9 also shows the relative use of abstracted water across the sectors, but it is not clear whether the estimates are entirely comparable between the administrations.

Table 9 Estimates of the Value of Water Use based on the Scottish Case

Sector	Water value in use p/m^3 for Scotland* (2004 prices)	Valuation assumptions: MV marginal, AV average TV total values **	Scotland: Estimated abstraction Million m^3/year*	England and Wales: Estimated abstraction: Million m$^{3/}$year***
Households : (treated water)	50 - 120	MV for treated water only based on WTP estimate	876	6,038
Agriculture-irrigation	23-138 8-150#	MV based on value added.	57	72 (+19 non irrig)
Aquaculture	0.126	AV assumes avoided cost of waste disposal	1,582	1,203
Salmon angling	£175/day	TV benefit transfer estimate.	-	-
Industry	4-37.5 eg 16p/m3 paper and pulp, 35p/m3 chemicals	MV benefit transfer from Canadian industry study	675 chemicals, food, textiles and paper	1,151
Energy	0.049 –0.817	MV comparative cost of alternative energy sourcing: coal, gas, windpower	23,755 hydro throughput Non hydro 3,783 including tidal	4,012 non tidal 6,672 tidal

Source: * SEPA, 2004 .An Economic Analysis of Water Use in the Scottish River Basin, SEPA, Edinburgh,** see Moran and Sabin, 2008, ***Environment Agency for England and Wales: 2010: Abstraction Data (estimated actual). It is noted that the abstraction estimates are not comparable. # Morris et al , 2004 for eastern England

[42] Knox, J.W., Morris, J., Weatherhead, E.K., and Turner, A.P. (1999). Mapping the financial benefits of spray irrigation and potential financial impact of restrictions on abstraction: a case study in Anglian Region. *Journal of Environmental Management*, 58, 45-59

[43] Morris, J., Weatherhead, E.K., Knox, J.,Vasilieou, K., de Vries, T., Freeman, D., Leiva, F., and Twite, C.(2004). Irrigation: The Case of England and Wales. in Burbel, J. and Martin, C.G., The Sustainability of European Irrigation under Water Framework Directive and Agenda 2000. EC Director General for Research. Global Change and Eco systems

Thus, changes in freshwater ecosystems that affect their capacity to provide reliable supplies of water for abstraction can result in significant economic consequences. Conversely, abstracting at volumes that reduce water flows, levels and qualities to the point where ecosystems are damaged also generates economic losses associated with loss of biodiversity and final goods such as informal and formal recreation, amenity and property values, as discussed in other parts of the NEA assessment. A survey of household willingness to pay to leave water in the environment in situations where abstraction could lead to environmental damage produced an estimate of £0.29/m^3 [44].

3.2.2. The value of secure water

Changes in freshwater ecosystems due to development pressures, exacerbated by climate change, could affect their capacity to provide sufficient and reliable quantities and qualities of water for people. Reductions in water available for abstraction could result in (i) loss of value from water use and/or (ii) extra costs of providing water from alternative sources, or the adoption of water saving technologies and behaviour. 'Unsecured' sources for irrigation and water for industrial/mineral washing applications are likely to be most vulnerable to variations in supply. This may justify additional expense of securing water by means, for example, of winter storage reservoirs or water saving technologies. High value uses of water, such as those associated with public water supply, clearly justify relatively high investment to improve water security. This may also include measures to secure water for nature conservation, especially in protected areas. Failure to restrict abstraction in the face of declining freshwater resources would compromise the non-market ecosystems services referred to elsewhere in this chapter.

In the long term, the economic value of freshwater provisioning will reflect the costs of achieving an appropriate balance of the demand for and supply of water. On the demand side, the Environment Agency report that measures such as compulsory metering to reduce household water consumption by a target of 15% (from 150 to 130 litres/day) could cost between £1.40 and £1.6/m^3.[45]. By comparison, options to enhance freshwater supply appear more expensive, namely surface and ground water development (£1-£5/m^3), reservoirs (£3-£10/m^3) and desalinisation (£4-£8/m^3). A detailed review of water supply options in1998[46] however, estimated incremental average costs ranging between £0.21/m^3 and £1.36/m^3 in 2010 prices for water delivered from large scale

[44] Eftec, ref from Jacobs report
[45] Environment Agency. 2009. Water for people and the environment: opcit
[46] Mott MacDonald. 1998. Review of Costs to Balance Water Supply and Demand. Report no 48550/WSD/02B, August 1998. Ofwat, Birmingham

reservoir development (excluding treatment) assuming on average that 50% of available reservoir capacity is used each year.

Increased investments may be required in future in order to avoid pressures on freshwater ecosystems associated with changes in climate and/or demographics[47]. A moderate climate change scenario could reduce water available for immediate abstraction by 10% by 2060, equivalent to about 1.4 billion m^3/year for the UK at current levels of abstraction. Assuming water storage and transfer costs of between £1 and £1.5/ m^3 for large scale provision, securing this amount of water would cost about £1.4 to £2.1 billion per year for the whole UK population assuming similar abstraction rates across the nation (equivalent to about £23 to £35/year/capita of population affected). These investment costs could be higher if the climate change impact is greater and the growth in water demand is unconstrained. While these figures do not estimate the value of water services provided by freshwater ecosystems, they indicate the equivalent cost of securing water supplies for use while maintaining the non-market ecosystem services of rivers, lakes and aquifers. In some cases, investments in supply enhancement and regulation may also achieve environmental enhancement.

3.3.Water Quality Valuation

Water quality, defined mainly in terms of chemical, biological and hydro-morphological characteristics, is a major determinant of the capacity of the freshwater ecosystems to provide a range of market and non-market services. It is important here to distinguish between the total value of water quality and the marginal value of a change in quality. As discussed below, the quality of most water bodies in the UK is moderate to good accordingly to the WFD classification. Much of the discussion below refers to a change in quality around the current 'reference' position, recognising the significant ongoing measures to protect water quality by the water industry and others. Clearly a major deterioration in water quality could result in complete loss of ecosystem services and final goods, such as water for drinking, irrigation, bathing and fishing, or require major expenditure to mitigate the consequences of loss of quality. Within the limits of available information, the assessment here focuses on selected marginal changes from the current situation, mostly associated with the European Water Framework Directive (WFD).

3.3.1. Non-market benefits of water quality

[47] For example, the Environment Agency forecast change in water demand for England and Wales for the 2050s ranging from -4% through to +35% according to different scenarios: http://www.environment-agency.gov.uk/research/library/publications/40731.aspx

A number of UK studies have attempted to estimate the non-market value of ***improvements*** in water quality associated with ecological or chemical status, especially linked to the WFD[48 49].

In a major study undertaken for Defra as part of their preparations to implement the WFD, NERA[50] (2007) use a mixture of contingent valuation (CV) and choice experiment (CE) methods to estimate the value that households in England and Wales put on water quality as it affects biodiversity (in terms of fish and other aquatic life), aesthetic quality (viewing, clarity, smell, insects) and recreation (suitability for relaxing, in stream and near stream activities). Estimates of willingness to pay (WTP) for water quality varied according to the methods of elicitation, with mean WTP between £45 and £168 per household per annum for improving water quality in 95% of rivers and lakes to Good Quality Standards. CE methods were used to derive 'implicit prices' and hence marginal WTP for given increments [51] in water quality. These provided estimates of marginal WTP per 1% improvement in river water quality, either nationally or locally.

For the purpose here of valuing non market ecosystem services from freshwater, data were provided by the Environment Agency on over 7000 water bodies in England and Wales regarding:

Type of water body : river or lake
Catchment/river basin
Length (km) and area (km2
Water quality: historical, observed 2009, predicted 2015.

Defra and the Environment Agency have identified the increments in water quality required to meet the objectives of the WFD, namely to achieve Good Water Quality status, on each length of river and area of lake, based on compliance with chemical, biological and hydro morphological conditions. Whether this can be met by 2015 or left over to be achieved subsequently has also been identified. Estimates of WTP for given increments in water quality (from low to moderate, moderate to high) are based on the marginal rates of WTP derived from the above CE estimates, calibrated against the estimates derived using contingent valuation methods to give WTP within a range of £45-£85/hh/year, with a 'preferred' estimate of £55/hh/year.

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[48] **Water Framework Directive Economic Analysis Collaborative Research Programme On River Basin Management Planning Economics** http://www.wfdcrp.co.uk/

[49] Personal communications: Dr Anna Maria Giacomello, Environment Agency; Dr Kevin Andrews, Defra; Paul Metcalfe, Independent consultant

[50] NERA (2007) The Benefits of Water Framework Directive Programmes of Measures in England and Wales, Final Report to Defra, CRP Project 4b/c.

[51] eftec, 2010.Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal Case Study 4 – Valuing Improvements in River Water Quality. eftec, London

The values of different degrees of water quality improvement is given in Table 10 that also reports aggregate benefits across England and Wales of £1,140 million per year. The greatest proportion of extra benefits is associated with improvements from moderate to good water quality. This reflects not only the greater share of water bodies in this improvement category but also, as expected, the relatively high values for improvements in more populous areas. 67% is associated with improvements in water quality from Moderate to Good and 26% from Poor to Good. 93% of these additional benefits relate to English Rivers and Lakes. The Thames, Humber, Anglian and Severn Catchments account for about 66% of total benefits.

Table 10 Non-market benefits associated with improvements in water quality in rivers and lakes in England and Wales

Initial quality status of water bodies - rivers and lakes (2009)	Benefit of planned improvement in water quality to be achieved in the period 2009-2015 (£m/year)	Remaining benefits associated with achieving Good quality status post 2015 (£m/year)	Total benefits of improvement to Good quality status (£m/year)	Distribution of extra benefits of water quality improvement by 2009 class (%)
Moderate	46.4	720	766.4	67%
Poor	26.3	273.8	300.1	26%
Bad	9.1	55.7	64.8	6%
Not known	0.7	8.1	8.8	1%
			1,140.0	100%

Source: based on EA data and NERA benefit estimates

Drawing on the preceding analysis, the Environment Agency has compiled estimates of the benefits of improvements in water quality per km for the main river basins in England and Wales. Average benefits are £15.6/km, £18.6/km and £34.2/km for improvements that lift water quality from low to medium, from medium to high and from low to high respectively. Benefits per km are much greater than these average values in river basins with higher population densities (Table 11).

Table 11 Benefits of river water quality improvement in England and Wales

River basin district	Average benefit (£ per km per year) of increments in river water quality by change in status		
	Low to Medium	Medium to High	Low to High
Solway Tweed	6.8	7.7	14.5
Western Wales	10.1	11.7	21.8
South West	10.2	11.9	22.1
Northumbria	11.7	13.8	25.5
North West	13.4	16.2	29.5
Dee	14.1	16.7	30.9
Severn	15.0	17.7	32.7
Humber	15.2	18.3	33.5
Anglian	17.9	21.1	39.0
South East	18.7	22.4	41.1
Thames	32.2	39.5	71.6
England & Wales	15.6	18.6	34.2

Source: Environment Agency (2009) Benefits Review June 09

Another perspective on freshwater quality is given by the estimated annual equivalent expenditure of £1.1 billion per year (in 2008 prices) to meet WFD quality targets over the next 43 years through to 2052[52]. Reflecting pressures and vulnerabilities, most of this expense is associated with supporting water abstraction and discharges (£889 million/year), habitat and fisheries (£160 million/year), urban drainage and reservoir safety (£91 million/year) and agricultural pollution (£57 million).

It is recognised that the preceding figures do not indicate the value of the total benefits of non market goods associated with freshwater quality. Rather they indicate in broad terms the expected benefits of services associated with achieving given increments in water quality about current quality levels, and a (potential) revealed willingness to incur costs to obtain these incremental

[52] Environment Agency, 2011. Water Framework Directive: Water for life and livelihoods: River Basin Management Plans. Available at http://www.environment-agency.gov.uk/research/planning/33106.aspx

benefits. Neither do they tell us about the willingness to pay to avoid the loss of non market benefits if there were considerably lower standards of water quality in UK freshwaters, other than suggesting these are likely to be very significant.

3.3.2. Market Benefits associated with Water Quality.

The quality of water will obviously affect a range of market benefits for particular sectors and groups such as businesses as they abstract and use water, such as water companies, those involved in commercial fisheries and those providing recreation and tourism services [53,54]. Household drinking water supplies are routinely treated to bring them up to potable standards. Both common sense and empirical studies have confirmed the massive net benefits of such treatment. Ecosystems contribute to these benefits by improving water quality through natural processes. That said, it is arguable that the economic benefits of such services should be measured in terms of a reduction in treatment costs rather than any estimation of the benefits of avoided ill health.

Numerous natural habitats such as upland and peatland areas contribute both positively and negatively to water quality, and hence to the costs and benefits accruing to water users. In particular the management of peatlands can influences water colouration. Colour problems due to run-off of dissolved organic carbon (DOC) have increased over the last 20-30 years. The practice of moorland 'gripping' (digging and enlarging drainage ditches) may have contributed to this problem. Avoided cost calculations can be made of the benefits of reducing colouration problems by blocking drains to reduce peat wastage. These will vary on a catchment-to-catchment basis and are not known at a national level. However, one study showed benefits from avoided costs of treatment were around £5 million over 10 years.

Evidence suggests (Defra, 2010) [55] , however, that direct market benefits associated with the incremental changes in water quality to be achieved under the WFD are unlikely to be significant in total and difficult to estimate at a national level using data available. It is noted however that a major loss of water quality would seriously compromise the market based services provided by freshwater ecosystems and for some purposes would be similar to a curtailment in water supply.

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[53] University of Brighton . 2008. Collaborative Research Programme On River Basin Management Planning Economics. Valuation of recreational benefits of improvements in water quality – potential benefits and data requirements. University of Brighton

[54] Entec.2008 .Potential Market Benefits of the Water Framework Directive. Collaborative Research Programme On River Basin Management Planning Economics . Report to Defra

[55] Defra, 2010. Overall Impact Assessment for the Water Framework Directive (2000/60/EC), http://www.defra.gov.uk/corporate/consult/river-basin/, accessed Aug 2010

3.3.3. Scenarios

The value of water provisioning by surface and ground freshwater sources can be assessed in terms of licensed and actual quantities, with water valued at the cost of supply (which includes environmental compensation), or more correctly, at its value in use. There is scope to combine data on points and quantities of abstraction with type and quantities of use, aggregated per km^2 of land surface. In this way, the implications of changes in water demand and supply at the relevant scale (possibly sub-catchment) can be assessed[56] .

The benefit transfer function for wetlands included a relatively modest contribution for water supply. Care is required to avoid double counting where this is thought to be significant.

3.4. Flooding

Floodplain areas by definition regulate hydrological processes by facilitating the conveyance and storage of potential flood water. The development of floodplains can however affect natural hydrological processes and associated ecosystem services. Indeed, the economic benefits of floodplain development can be compromised if changes in climatic conditions or changes in the management of the catchments as a whole result in increased flooding.

The economic effects of changes in hydrological conditions can be assessed in terms of changes in flood risk, namely a change in (i) probability and/or (ii) the damage costs of floods of a given magnitude. Data, methods and guidance are available to support the economic appraisal of flood risks[57,58] .

Flooding has become more problematic in the UK[59]. The annual cost of flooding in the UK is about £1.4bn. A further £1bn per year is spent on flood risk management.[60] In the UK as a whole, probably over 5 million properties are exposed to moderate to low probability of flooding (less than 0.5% to

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[56] Data on abstraction were subsequently made available to the NEA for England and Wales by point source (EA) and for Scotland (SEPA) and could be used in future work.

[57] Penning-Rowsell E, Johnson C, Tunstall S, Tapsell S, Morris J, Chatterton J, and Green C, (2005) The Benefits of Flood and Coastal Risk Management, A Manual of Assessment Techniques. Flood Hazard Research Centre, Middlesex University, Enfield, London.

[58] Defra. 2009. Appraisal of Flood and Coastal Erosion Risk Management. Department for Environment, Food and Rural Affairs, London. http://www.defra.gov.uk/environment/flooding/documents/policy/guidance/erosion-manage.pdf. For Scotland see: http://www.scotland.gov.uk/Topics/Environment/Water/Flooding, and Flood Risk Management (Scotland) Act 2009: http://www.legislation.gov.uk/asp/2009/6/pdfs/asp_20090006_en.pdf

[59] Pitt, M. 2008. Learning Lessons from the 2007 Floods. Cabinet Office, London.

[60] Environment Agency, 2009a Flooding in England, Environment Agency, Bristol
Environment Agency, 2009b Flooding in Wales, Environment Agency, Cardiff

1.3% chance of flooding each year). Climate change, however, could increase their exposure to higher levels of flood risk[61].

3.4.1. Urban Flooding

The greatest share of total annual flood costs is borne by urban households and businesses, evident in the profile of the 2007 floods in England (Figure 1) which resulted in estimated economic costs of £3.2billion[62].

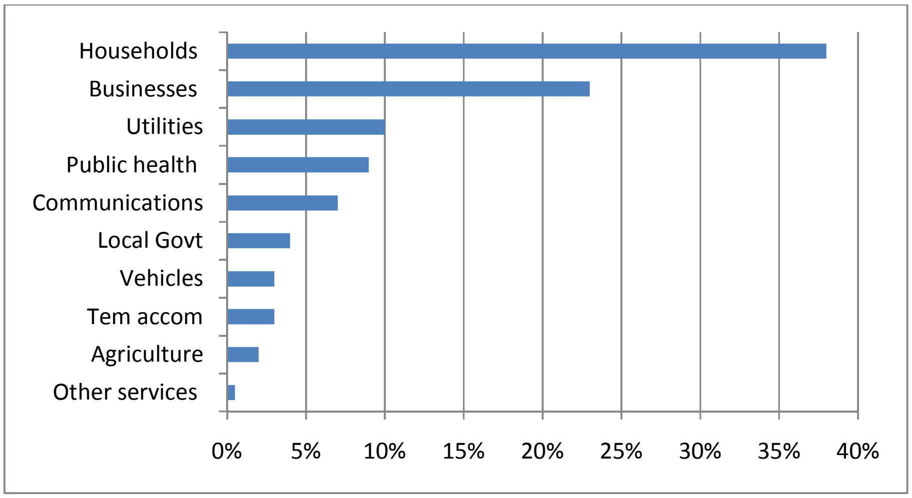

Figure 1 Cost profile of the 2007 Summer Floods in England (% of total economic costs*)

Source : Chatterton et al, 2010, * total economic cost £3.2 bn

The cost of urban flooding mainly depends on the size of the area flooded, the number and type of properties affected and the depth of flooding. There is comprehensive guidance on flood estimation costs for urban areas, covering residential, business and infrastructure[63]. Average annual damage costs to residential properties, usually the major category of flood damage costs, vary according to standards of protection and flood warning lead times.. For example, a property protected against the 1 in 100 year flood event (ie with a 1% annual probability of flooding) has an equivalent annual flood damage cost of £84 (in 2010 prices) without flood warning (about £70 with warning). Unit rates for estimating the cost of flood damage to commercial and industrial property and infrastructure are also available.

[61] Environment Agency, 2009c Investing for the Future. Flood and Coastal Risk Management in England, Environment Agency, Bristol

[62] Chatterton J., Viavattene, C., Morris, J., Penning-Rowsell, E., and Tapsell, S. (2010) The Costs of the Summer 2007 Floods in England. Science Project SC070039. Environment Agency. http://publications.environment-agency.gov.uk/pdf/SCHO1109BRJA-e-e.pdf

[63] Penning–Rowsell, op cit, 2005, opcit

Direct intangible impacts on flood victims include stress and health risks. A survey of households[64] showed a weighted average willingness to pay of £200/household per year to avoid the intangible costs associated with 1% per year chance of flooding, equivalent to a present value sum of about £5,000 over 50 years. Evidence from the 2007 floods suggests this is probably an underestimate. There are currently about 600,000 households in the UK at serious risk of flooding[65]. This equates to a willingness to pay to avoid intangible costs of £120 million/year. Climate change could double numbers of households exposed to serious risk for the UK by 2060[66], costing an additional £120 million per year. Furthermore, it is likely that households facing a lower level of risk (probably a further 5 million properties in the UK) would also be willing to pay, albeit at a lower amount, to avoid the intangible costs of flooding.

The cost estimates used in guidance were shown to be consistent with the cost recorded in the severe 2007 floods in England[67]. Damage to 60,000 residences averaged £24,000/property, with a further £2,900/property due to vehicles and temporary accommodation. Damage to 8,000 business premises averaged £55,000/business, plus an additional £20,000/business in lost or disrupted activity. Damage and disruption to critical infrastructure and services was £674 million. The ratio between costs of the combined damage to households and businesses and the total damage costs of the event was about 1: 1.5.

Climate change could double numbers of households exposed to serious risk for the UK by 2060[68]. Looking forward to 2080, the Foresight Future Flooding Project (2004) [69] identified a possible increase in river and coastal flood annual damage costs to property of £14-£19 billion (in 2004 prices) under future consumption oriented scenarios in the absence of additional measures to control flood risk (Table 12). This is equivalent to about £17-23 billion in 2010 prices: or about £11-£17 billion per year in 2060 (the NEA time horizon) assuming a linear increase in damage cost over time. Incremental flood damage costs were estimated at £0.5 to £3.8 billion for 2080 (£0.4 to £3.4

[64] RPA and FHRC et al., 2004. The Appraisal of Human Related Intangible Impacts of Flooding. R&D Technical Report FD2004/TR. Defra, London

[65] Foresight Flood and Coastal Defence. 2004. http://www.bis.gov.uk/foresight/our-work/projects/published-projects/flood-and-coastal-defence,

[66] Environment Agency. 2009c opcit estimates that the number of households exposed to flooding in England alone will rise from 500,000 to 800, 000 by 2035 excluding new build.

[67] Chatterton et al, 2010. opcit

[68] Environment Agency, 2009 Investing for the Future. Flood and Coastal Risk Management in England, Environment Agency, Bristol

[69] Foresight Flood and Coastal Defence. 2004. http://www.bis.gov.uk/foresight/our-work/projects/published-projects/flood-and-coastal-defence

billion in 2010 prices for NEA year 2060) under sustainability oriented scenarios, reflecting a combination of reduced flood probability and event damage costs. Additional costs were identified for urban flooding not connected with river and coastal sources.

Table 12 Estimated Annual economic flood damage to residential and commercial properties for the UK under current (2000) and future (2080) scenarios according to Foresight Flood Defence.

2004 prices	Current flooding: Year 2000,	Consumption oriented scenarios*	Sustainability oriented scenarios**
Flood source	£ million	£ million	£ million
River and coastal	1,088	15,175-20,600	1,508-4,820
Intra- Urban	270	5,100-7,900	740-1,870
Total	1,358	20,275-28,500	2,248-6,690

Source: Foresight Flood Defence, 2004. *National Enterprise and World Market Scenarios ** Local Stewardship and Global Sustainability Scenarios.

3.4.2. Agricultural flooding

The cost of a flood event on agricultural land varies mainly according to land use and time of year. The average cost of a flood occurring at any time within a given year (Table 13) on intensively farmed Grade 1 agricultural land (£1,220/ha) is much higher than on extensively grazed grade 4 land (£160/ha). The cost of summer flooding is particularly high. For example, damage costs on 42,000 ha of farmland in the Summer 2007 floods in England in 2007 averaged £1,200/ha on all arable land use and £600/ha on grassland[70]. Almost 90% of agricultural flood costs related to damage to crops and grassland.

Table 13 The cost of a single flood occurring in a year by agricultural land grade and land use in the UK

Agricultural Land Class		Land use					
		Horticulture	**Intensive arable**	**Extensive arable**	**Intensive grass**	**Extensive grass**	**Flood costs £/ha**
1	% of area	5%	85%	10%			
	Flood cost	4800	1100	460			**1220**

[70] Posthumus, H., Morris, J., Hess, T., Neville, D., Philips, E. and Baylis, A., 2009. Impacts of the summer 2007 floods on agriculture in England, Journal of Flood Risk Management, 2009: 1-8.

	(£/ha)						
2	% of area	5%	60%	35%			
	Flood cost (£/ha)	3300	930	380			**860**
3a	% of area		30%	70%			
	Flood cost (£/ha)		750	300			**440**
3b	% of area			50%	50%		
	Flood cost (£/ha)			270	160		**220**
4	% of area				100%		
	Flood cost (£/ha)				160		**160**
5	% of area					100%	
	Flood cost (£/ha)					80	**80**

* Totals are rounded. Crop damage based on loss of yields, plus extra costs net of savings. Grassland costs based on value of replacement feed, plus other costs. Extensive arable land use provides a 'default' for all arable land and for intensive dairy land. Most flooding tends to occur in winter. These estimates that assume an equal distribution over the year are likely to the cost of seasonally variable flooding.

Source Penning Rowsell et al, (updated 2010)

Frequent flooding is usually associated with poor drainage and waterlogging. A persistent reduction in agricultural flood protection and drainage standards may result in either a reduction in the value added by existing land use or a shift in land use, for example, from intensive arable to extensive grassland). Where flooding results in abandonment of agricultural land, Defra advises that the present value of future loss of output can be expressed in terms of prevailing agricultural land prices (currently between £11,000 and £15,000/ha[71]), reduced by about £600/ha to allow for the effects of income support[72]. In reality, however, agricultural land prices are not a reliable indicator of agriculture value added because of other, particularly local, factors influencing land prices.

Agricultural floodplain land has potential to store water to avoid downstream flooding of urban areas, possibly as a designated washland[73]. The cost of providing the flood storage facility can be

[71] RICS Rural Market Survey: http://www.rics.org/ruralmarketsurvey

[72] Department for Environment, Food and Rural Affairs (Defra), 2009. Valuation of Agricultural Land and Output for Appraisal Purposes. FCDPAG3. May 2008. Department for Environment, Food and Rural Affairs, London

[73] Morris J., Hess T. M., Gowing, D. G., Leeds-Harrison P. B., Bannister N., Vivash, R. M. N. and Wade, M. (2004) Integrated Washland Management for Flood Defence and Biodiversity. English Nature Research Report , 598, English Nature , Peterborough

assessed in terms of the opportunity cost of agricultural production, whether increased flood damaged costs or the reduction in value-added associated with land use change.

There are about 1,336,000 ha of agricultural at risk of flooding in England and Wales, of which 62 % are liable to flooding by rivers only, 23 % by sea only and 15% by both. About 421,500 ha currently benefit from flood defences in England and Wales (of which 70,000 ha (17%of total) are grade 1 and 2), and 424,000 benefit from coastal defences (of which 158,000 ha (37%) are grade 1 and 2). About 1,280,000 ha in England and Wales also benefit from pumped drainage to avoid either flooding or waterlogging, over 90% of which is used for agriculture, and a third of it in the Anglian region.

An assessment of land use, estimated flood damage costs, and flood return period in years for defended and undefended areas in England and Wales [74] (Table 14) shows that flood defence reduces expected annual damage costs from river flooding by £5.2 million, and from coastal flooding by £117.7 million. These estimates, however, under-value the considerable associated benefits of land drainage and the management of water levels for farming. Estimates are not available for other parts of the UK at the time of writing.

Table 14 Expected annual damages of flooding on agricultural land in protected and unprotected areas in England and Wales

	Expected Annual Damage <u>with</u> defences (£ million)		Expected Annual Damage <u>without</u> defences (£ million)	
	River	Coastal	River	Coastal
England	4.25	6.47	9.26	117.3
Wales	0.87	1.27	1.08	8.25

Source: Roca et al, 2010[75]

The Foresight Future Flooding Project[76], revisited by the Pitt Review[77] and the Foresight Land Use Futures Project[78], reviewed possible responses to flood risk. Some of the most effective and

[74] Roca, M., Bast, H., Panzeri, M, Hess, T., and Sayers, P. (2010). Developing the evidence nase to describe the flood and coastal erosion risk to agricultural land in England and Wales. Defra R&D Technical Report, FD2634/TR, May 2010. HR Wallingford Ltd, Wallingford.
[75] Roca et al, 2010 op cit
[76] Foresight. 2004 Flood and Coastal Defence Project. Govt Office for Science, London http://www.bis.gov.uk/foresight/our-work/projects/published-projects/flood-and-coastal-defence
[77] Evans, E.P., Simm, J.D., Thorne, C.R., Arnell, N.W., Ashley, R.M., Hess, T.M., Lane, S.N., Morris, J., Nicholls, R.J., Penning-Rowsell, E.C., Reynard, N.S., Saul, A.J., Tapsell, S.M., Watkinson, A.R., Wheater, H.S. (2008) An update of the Foresight Future Flooding 2004 qualitative risk analysis. Cabinet Office, London
[78] Foresight. 2010. Land Use Futures: making the most of land in the 21st century. Govt Office for Science, London. http://www.bis.gov.uk/foresight/our-work/projects/current-projects/land-use-futures

potentially cost beneficial approaches involve aspects of land management, namely catchment scale storage, land use management and coastal defence and realignment. All of these have implications for the management of terrestrial and aquatic ecosystems and the hydrological regulation services that they provide. The economic dimensions of these services are readily apparent.

3.4.3. Scenarios

The assessment of the value of freshwater, floodplain and wetland flood regulation services can in theory be determined by the contributions to the alleviation of flood risk, due to a change in flood probability and/ or damaged costs. Flood probability can be assessed using broad-scale hydrological estimates[79] . Estimates of the cost of flooding can be based on broad land use, whether urban or rural, and associated damage costs per ha flooded, as referred to above. Data are available on areas that are currently protected from flooding[80]. While information is available to determine local flood probability[81], integrated data on flood probabilities, land use and resultant risk for unprotected areas are not in the public domain at the moment[82].

The benefit transfer function for wetlands included contributions to flood control. Care is required to avoid double counting.

4. Other Uses of Freshwaters

4.1.Discharges to the Freshwater Environment

Rivers and lakes act as conduits and receptors for waste, discharged from point and diffuse sources. Point sources are controlled by discharge consents, with based on the volume and potential toxicity of the discharged material. The value of the waste assimilation service provided by freshwaters can be assessed in terms of the cost of alternative disposal, by implication a more expensive option. Although restricted information is available on types, volumes and charges for permits to emit to water, it has not as yet been integrated with other aspects of water resources management. [83].

[79] CEH. 1999. The *Flood Estimation Handbook*. Centre for Ecology & Hydrology, Wallingford. ISBN: 9781906698003

[80] Defra subsequently made this available to NEA and they could be used in future work.

[81] SEPA: http://www.sepa.org.uk/flooding/flood_risk_maps.aspx, EA: http://www.environment-agency.gov.uk/homeandleisure/floods/default.aspx

[82] Defra is exploring whether this can be made available to NEA

[83] Made available December 1st 2010. SEPA are able to provide for Scotland. This could be used in future work.

4.2. Navigable inland waterways

Freshwaters also include non-tidal navigable 'Inland Waterways', including water bodies that have been heavily modified such as canals and navigations. A recent review of the benefits of inland waterways, both tidal and non-tidal, in England and Wales concluded that they provide a range of ecosystem services[84]. Provisioning services include enhanced residential property values, transport and water supplies. Regulation services include potential savings in carbon emissions, and the regulation and purification of water. Cultural services include a range of recreational, amenity, heritage and educational services. The methods and unit rates for estimating benefits are similar to those for freshwaters generally. Benefits are particularly dependent on proximity to user populations.

4.3. Angling

Angling is a major pastime activity in the UK and an important cultural service provided by freshwaters. There are about 1 million licensed anglers in England and Wales, although an estimated 2.6 million people go fishing each year. Licensed anglers fished a total 30 million days during 2005, about 26 million for coarse fishing and 6 million for game (salmon and trout) fishing. 60% of fishing is on still waters[85]. Recreational fishing involves estimated expenditures of about £1 billion per year in England and Wales, associated with the equivalent of 37,000 full time jobs. The economic gross value added from an extra 1000 days course fishing is estimated at £15,000-19,000/year, varying according to region[86].

5. Concluding Remarks

This analysis has, using a variety of methods, derived estimates of the value of selected ecosystem goods and services generated by wetlands, freshwaters and floodplains in the UK and, where data have been available, for its constituent countries.

A benefit transfer model regarded as applicable to the UK case was used to estimate the value of services provided by inland and coastal wetlands in the UK. In the absence of information about the type or services provided, the default estimates of annual benefits are £303/ha/year for inland wetlands and £1,856/ha for coastal wetlands. Where wetlands provide the regulatory services of

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[84] *O'Gorman, S.; Bann, C., Caldwell, V (2010). The Benefits of Inland Waterways (2nd Edition). A report to Defra and IWAC. Reference number,WY0101, Jacobs Engineering , London*

[85] Environment Agency, 2009. Economic Evaluation of Fishing. Science Report SC050026/SR2, Environment Agency, Bristol

[86] Environment Agency, 2009. Economic Evaluation of Fishing. Science Report SC050026/SR2, Environment Agency, Bristol

flood control and storm buffering and water quality improvements and the cultural value of amenity and biodiversity, benefits are considerably higher. Services known to be typical of the type of wetlands found in the UK generated average benefits in excess of £2,000/ha. The marginal values of increased wetland areas also vary according to the type of services rendered and proximity to centres of beneficiary populations. In England, for example, a conservative estimate puts these at about £700/ha for inland wetlands and £1,900/ha for coastal wetlands, although local conditions could generate much higher benefits.

Aggregate annual benefits for UK wetlands amount to £2,531million - £5,734million depending on assumptions. These estimates are equivalent to about £40 and £95/capita per year respectively for the UK population, or about £100 and £220/household per year. The estimates vary considerably according to assumptions and it is not clear which gives the most reliable estimate

In spite of a cautionary approach, it is not clear whether the benefit transfer function used here gives a good fit for UK wetlands. Many of the caveats alluded to above in the literature on benefit transfer methods apply. While the benefit function is oriented towards European wetland ecosystems, some of the characteristics of wetlands in the UK, especially for inland lowland areas, may not apply. It would be appropriate to confirm the validity of high level analysis with detailed local case studies.

With respect to freshwater rivers and lakes, the focus here was placed on the provision of water for human use. About 22 billion m^3 of water are abstracted in the UK each year, 52% from rivers and lakes, 11% from groundwater and about 37% from tidal waters. It is difficult to derive values for water that are generically applicable because the context of water demand and supply varies considerably, both spatially and temporarily. Prices charged for water abstraction in no way reflect the full value of water either in its natural state or in any particular application. While some estimates are available of willingness to pay for water and of its value in use, these tend to be very context specific.

Gaps in and fragmentation of data sets makes it is difficult to assemble a coherent argument about water values. For example, data on abstraction, water use (both in and out of stream), discharges to water and water quality are not as yet brought together in an integrated format. Neither do they appear to be coordinated with relevant land use information that can help predict or explain water values in the context of diverse ecosystem services. Recent developments in catchment based planning for abstraction, flooding and water quality under the WFD are moving towards this. This is a potentially important area for further work.

It seems likely in the long term that the economic value of freshwater provisioning will reflect the costs of achieving an appropriate balance of the demand for and supply of water. Increased investments in the protection and enhancement of water resources will undoubtedly be required to avoid pressures on freshwater ecosystems associated with changes in climate and/or demographics. A moderate climate change scenario could reduce water available for immediate abstraction by 10% by 2060. Securing this amount of water through aquifer storage and reservoir development, for example, could cost about £1.4 to £2.1 billion per year for the whole UK , equivalent to about £23 to £35/year/capita of population affected. These investment costs could be higher if the climate change impact is greater and the growth in water demand is unconstrained. There is need to place these likely increases in demand for water into a broad ecosystems framework in which investments in water resource development can be judged against the wide range of potential benefits.

The quality of water obviously affects a range of market benefits for particular sectors and groups such as businesses as they abstract and use water, such as water companies, those involved in commercial fisheries and those providing recreation and tourism services. For their part, households in England and Wales have expressed an aggregate willingness to pay £1.14 bn per year to achieve the non market benefits of water quality associated with WFD objectives. These accord with an estimated annual equivalent expenditure of £1.1 billion per year (in 2008 prices) to meet WFD quality targets.

The regulation of flooding is an important ecosystem service. Flooding has become more problematic in the UK[87] where the annual cost of flood damage is about £1.4bn, with a further £1bn per year spent on flood risk management. Climate change could double the number of households exposed to serious risk for the UK by 2060, possibly increasing damage costs to £11-£17 billion per year in 2060 in the absence of additional measures. Flood defences, protecting over 420,000 ha of agricultural land, currently reduce expected annual damage costs from river flooding by £5.2 million, and from coastal flooding by £117.7 million. Again, climate change could affect the efficacy of these services.

The preceding assessment attempted a review of selected ecosystem benefits associated with wetlands, freshwaters and floodplains, using a range of methods. The use of benefit transfer functions for the assessment of wetland benefit has potential merit, as demonstrated here. But there is a particular need to generate additional wetland cases studies not only to confirm the

[87] Pitt, M. 2008. Learning Lessons from the 2007 Floods. Cabinet Office, London.

validity of this high level approach but also provide locally relevant cases to improve the fit of the benefit transfer function for regional and national applications.

This exploratory enquiry confirms the potential value of developing an ecosystems framework for assessing the value of freshwater in its various uses and non uses. There is considerable scope to compile existing and assemble new data to support an integrated approach to water valuation and governance. The development of a benefit transfer function for water resources is one possibility. The many recent initiatives prompted by and associated with the WFD, underpinned by a much more strategic approach to water management at national scales, suggest the time is right to do this. At present, information and data on water resources (as well as responsibility for the various aspects of resource management) are fragmented and often detached from other potentially relevant information that determines water use and value, including information on land use. Joining up data on water resources, set in an ecosystems framework to represent the diversity of values, is a priority for future water resource management. In particular, there is need to derive estimates of the marginal value of changes in freshwater ecosystem services under a range of plausible future scenarios. This could be done initially at a pilot regional scale to demonstrate the approach and its potential value.

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6. Appendices

1: Examples of Values of Wetlands from literature

2: Areas of wetland in the UK according to CORINE data sources

3: Estimating the Benefits of wetlands using the Brander et al Regression model: Supporting information

4: Estimated benefits of UK wetlands by UK administrative areas

5: Examples of Values for Rivers and Lakes from literature

Appendix1: Examples of Values of Wetlands from literature

The table below summarises estimates derived from studies of wetland sources, mainly from European and North American applications.

	Indicator of value	Unit values	Reference
Flood control and storm buffering	Flood control	464 US$2000/ha/year	WWF, 2004
	Flood risk infrastructure and properties for the Beckingham Marshes	5.9-26.94£/ha	Posthumus et al., 2010
	Household benefits of reduced flood impacts	£224 per household per year in high risk area	RPA (2005)
	Flood control calculated by damage prevented (US)	$440	Roberts and Leitch, 1997
	Willingness to pay for wetlands providing flood protection, water supply and water pollution control	74-80 US$/respondent	Stevens et al., 1995
	Economic value of disturbance and water regulation for wetlands based on published studies and original calculations	4554 (1994 US$/ha/yr)	Costanza et al., 1997
	Water storage worth in The Insh marshes (7.5*1.5 kms of floodplain)	£83,000 per year (£73,7/ha/year)	Alveres et al., 2007 in NEA scientific team report, October 2010
Surface and groundwater supply	Water supply	45 US$2000/ha/year	WWF, 2004
	Water regulation and supply value of freshwater wetland for Maury Island	17,866 US$2001	Troy and Wilson, 2006
	England and Wales costs of eutrophication	£75.79-114.03 million per year	Pretty et al., 2003

	Water supply by estimating a residual return to public utilities (US)	$94	Roberts and Leitch, 1997
	Economic value of water supply for wetlands based on published studies and original calculations	3800 (1994 US$/ha/yr)	Costanza et al., 1997
Water quality improvement	Water filtering	288 US$2000/ha/year	WWF, 2004
	Nitrogen mitigation for the Mississipi alluvial valley	$918-$1896 (US$2008/ha/year)	Jenkins et al, 2010
	Nitrogen retention (Restoration of floodplains along the River Elbe)	455-8277 €/ha/year	Meyerhoff and Dehnhardt, 2007
	WTP for contamination control	51.92-233.86$/household	Pate and Loomis, 1997
	Economic value of waste treatment for wetlands based on published studies and original calculations	4177 (1994 US$/ha/yr)	Costanza et al., 1997
	Cost savings from using **coastal** wetlands for substitute wastewater treatment	$785-34,700/acre	Breaux et al, 1995
	Marginal cost of abating 1kg of nitrogen through restoring wetlands	20-63 SEK/kg N	Gren, 1993
	Willingness to pay for the improvement of wastewater treatment for the prevention of algal blooms	£75 per year per household	Turner et al., 2004
Gas regulation	Economic value of gas regulation for wetlands	133 (1994 US$/ha/yr)	Costanza et al., 1997

	based on published studies and original calculations		
Food provision	Marginal costs of wetland converted from cropland	1,184 US$/acre	Heimlich, 1994
	Economic value of food production for wetlands based on published studies and original calculations	256 (1994 US$/ha/yr)	Costanza et al., 1997
Commercial fishing and hunting	Mean predicted values for commercial fishing in wetlands	778 (1990US$/acre)	Woodward and Wui, 2001
Recreational hunting	Recreational hunting Mean predicted values for bird hunting in wetlands Mean marginal value of an additional acre-foot of water in waterfowl hunting Impact of contaminated irrigation run-off on waterfowl hunting benefits	123 US$2000/ha/year 70 (1990US$/acre) 20.40-0.64 $/acre 55.41 $/hunter/day	WWF, 2004 Woodward and Wui, 2001 Cooper and Loomis, 1993 Cooper, 1995
Recreational fishing	Recreational fishing Recreational fishing Fishing revenue in The Insh marshes (7.5*1.5 kms of floodplain)	374 US$2000/ha/year £35.81/person/year £35000 per year (£31,1/ha/year)	WWF, 2004 Kaval, 2006 Alveres et al., 2007 in NEA scientific team report, October 2010
Harvesting of natural material	Materials Economic value of raw material for wetlands based on published studies and original calculations Direct full-time	45 US$2000/ha/year 106 (1994 US$/ha/yr) £4 million per year	WWF, 2004 Costanza et al., 1997 GHK, 2004 in NEA

	equivalent jobs and further contract work supported by reedbed management in the UK		scientific team report, October 2010
Material for fuel	Fuel wood	14US$2000/ha/year	WWF, 2004
Non-consumptive recreation	Mean predicted values for bird watching in wetlands	1212 (1990US$/acre)	Woodward and Wui, 2001
	Recreational value of the Cley Reserve Service-use: recreation, habitat. (WTP)	WTP fee (incl. Zero-bids in UK£):1.58 £/household/year WTP fee (excl.): 2.22 £/household/year	Klein and Bateman, 1998
	WTP for the preservation of the current state of the wetlands Service-use: recreation, habitat	42.83 £/ha	Willis, 1990
	General recreation	£57.12/person/day	Kaval, 2006
	Recreational boaters	$37.85-69.80	Mannesto and Loomis,1991
	Recreation by DVM (US)	$8	Roberts and Leitch, 1997
	Economic value of recreation for wetlands based on published studies and original calculations	574 (1994 US$/ha/yr)	Costanza et al., 1997
	Economic value of recreational visits in The Insh marshes (7.5*1.5 kms of floodplain)	£132,000 per year (£117,3/ha/year)	Alveres et al., 2007 in NEA scientific team report, October 2010
Amenity and aesthetics	Aesthetic and amenity value of freshwater wetland for Maury Island	17,866 US$2001	Troy and Wilson, 2006
	Average WTP to preserve present landscape. Service-	Use values: 78-105 £/person/year	Bateman et al., 1992

	use:habitat		
	Mean predicted values for amenity in wetlands	3 (1990US$/acre)	Woodward and Wui, 2001
	Aesthetics by DVM (US)	$6	Roberts and Leitch, 1997
	Economic value of cultural for wetlands based on published studies and original calculations	881 (1994 US$/ha/yr)	Costanza et al., 1997
	Value for enhanced landscape appearance	£15.98-36.84/hh/year	Moran et al., 2004
Biodiversity	Biodiversity	214 US$2000/ha/year	WWF, 2004
Habitat provisioning	Public benefits of agricultural wildlife management on Dutch peat	113-131.4 Dutch guilders/year	Brouwer and Slangen, 1998
	Mean donation per mailing to the RSPB fund raiser	£1.73/mailing	Foster et al., 1998
	Average WTP per person/year	4.12-42.83 $/person/year	Whitehead, 1991
	Marginal value of waterfowl habitat as cropland per acre per year	37.97 US$/acre/year	Van Kooten, 1993
	Economic value of habitat refugia for wetlands based on published studies and original calculations	304 (1994 US$/ha/yr)	Costanza et al., 1997
	Fish/wildlife habitat by DVM (US)	$7	Roberts and Leitch, 1997
	Willingness to pay value per household in New South Wales (median value)	A$100 per household	Streever et al.,1998
	Mean willingness to pay for the additional environmental benefits	$69/year	MacDonald et al., 1998

	(wildlife habitat)		
	Mean willingness to pay for the protection of endangered species and habitats	€5.3 per household	Meyerhoff and Dehnhardt, 2007
	Willingness to pay for Everglades restoration (wildlife species habitat)	$29.33-59.26 per household	Milon and Scrogin, 2006
	Willingness to pay for conserving peat bogs	£16.79(mean individual one-off) (95% CI £12.82 - £20.86) (£1991)	Hanley and Craig, 1991
	Non-users' values for preserving Norfolk Broads wetlands	Mean WTP per annum (non-users): £26.16 (£ 2001)	Bateman and Langford, 1997
	Willingness to pay to avoid 10% reduction in abundance of wetland	£128.72/hh/year (Lower bound £110.96, upper bound £146.48)	Oglethorpe, 2005
	Value for enhanced wildlife habitats	£40-59/hh/year	Moran et al., 2004
	Estimated value of wetland restoration in Gotland, Sweden	Value of a marginal increase in wetlands restoration £34.26 per kg of nitrogen abatement. Value of a marginal increase in sewage treatment £8.05 per kg of nitrogen abatement. Value of a marginal increase in agriculture £0.27 per kg of nitrogen abatement. (£ 2001)	Gren, 1995
Carbon storage	GHG mitigation for a Mississipi alluvial valley	$193-$366 (US$2008/ha/year)	Jenkins et al, 2010
	Total economic value of benefits from woodlands and associated soils,	£1007 million per annum	O'Gorman and Bann, 2008

	wetlands and peatlands in England	
TOTAL VALUE OF ECOSYSTEM SERVICES FOR FRESHWATER WETLANDS		
Brander (+ Carbon)	Value for freshwater wetlands in England	Average: 2,792-5,267 £/ha/year Marginal: 8,845-17,279 £/ha/year
Troy and Wilson, 2006	Freshwater wetland	8,474 – 72,787 $2001/ha/year
Sum of unit values marked in red	Unit values taken from UK studies (when possible)	5,372.88 £/ha/year

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Appendix 2 : Areas of wetland in the UK according to CORINE data sources

Table A2.1. Types, numbers and size of freshwater inland wetlands in England, Wales, Scotland and Northern Ireland according to CORINE data

	ENGLAND		WALES		SCOTLAND		NORTHERN IRELAND	
Type of wetland	Inland marshes	Peat bogs	Inland marshes	Peat bogs	Inland marshes	Peat bogs	Inland marshes	Peat bogs
Number	74	288	7	14	12	936	8	180
Total area ha	15,270	98,035	639	2,819	1,697	361,651	338	121,100
Mean ha	206	340	87	201	141	386	177	673
Median ha	90	102	59	38	79	79	38	102

Table A2.2. Correlation between Elevation and Wetland types in England, Scotland and Wales.

	England				Scotland				Wales			
	Peatbogs		**Inland marshes**		**Peatbogs**		**Inland marshes**		**Peatbogs**		**Inland marshes**	
Elevation, m AOD	No	%	No	%	No	%	No	%	No	%	No	%
<100	27	9%	62	84%	222	24%	6	50%	4	29%	6	86%
100-240	5	2%	2	3%	257	27%	4	33%	1	7%	0	0%
240-300	17	6%	2	3%	89	10%	0	0%	0	0%	1	14%
300-400	46	16%	5	7%	129	14%	0	0%	1	7%	0	0%
>400	193	67%	3	4%	239	26%	2	17%	8	57%	0	0%
Total	288	100%	74	100%	936	100%	12	100%	14	100%	7	100%

Table A2.3. Types, numbers and size of coastal wetlands in UK by regions according to the CORINE data sets

	England		Wales		Scotland		N Ireland		UK
Wetland type	Salt marshes	Inter-tidal marsh	Salt marshes	Inter-tidal marsh	Salt marshes	Inter-tidal marsh	Salt marshes	Inter-tidal marsh	Total coastal
Number	200	200	22	97	27	117	0	30	693

Total area ha	33,555	131,061	5,772	42,671	3,008	50,232	0	8,314	274,613
Mean ha	168	655	262	440	111	429	0	277	396
Median ha	89	108	100	90	76	107	0	104	93

Note: according to CORINE: equal number of marsh types in England, no salt marshes in NI

Appendix 3. Estimating the Benefits of wetlands using the Brander et al Regression model: Supporting information

Regression coefficients

Table 1. The Meta-regression Function for Wetland Benefit Assessment after Brander et al, 2008

Variable	Coefficient value	The value of explanatory variable	Default assumption for lowland wetlands
Constant*	-3.078	-3.078	
Wetland type			
Inland marshes	0.114	0/1	Specified
Peatbogs*	-1.356	0/1	
Saltmarshes	0.143	0/1	
Intertidal mudflats	0.110	0/1	
Economic valuation method			
Contingent valuation	0.065	0/1	Not specified
Choice experiment	0.452	0/1	
Hedonic pricing	-3.286	0/1	
Travel cost	-0.974	0/1	
Net factor income	-0.215	0/1	
Replacement cost	-0.766	0/1	
Production function	-0.443	0/1	
Opportunity cost	-1.889	0/1	
Market prices	-0.521	0/1	
Marginal or average value	1.195	0/1	Specified
Ln Wetland size*	-0.297	Ln (area(ha))	Specified
Flood control*	1.102	0/1	1
Surface and ground water supply	0.009	0/1	0
Water quality improvement*	0.893	0/1	1
Recreational fishing	-0.288	0/1	1
Commercial fishing and hunting	-0.040	0/1	0

Recreational hunting*	-1.289	0/1	0
Harvest of natural material	-0.554	0/1	0
Material for fuel*	-1.409	0/1	0
Non-consumptive recreation	0.340	0/1	1
Amenity and aesthetic services	0.752	0/1	1
Biodiversity*	0.917	0/1	1
Ln (GDP per capita (2003 US $))*	0.468	ln (GDP)	Specified
Ln (Population within 50 km (inhabitants)*	0.579	ln (population50km)	Specified
Ln (Wetland area within 50 km (ha))	-0.023	Ln (substitutes sites(ha))	Specified

*Significant at 10%

Spatial data for wetland valuation

The procedure followed to create a GIS database in ArcGIS 9.3 is the same followed by Brander et al. (2008). Here, we point out the main steps and sources used.

Wetland area

The wetland area was obtained from CORINE data by calculating it using "Calculate geometry" ArcGIS tool.

Income per capita

The GDP per capita use in the meta-analysis function by Brander et al. (2008) comes from the EUROSTAT database, which provide with GDP per capita in 2003 € at NUTS (Nomenclature of Territorial Units for Statistics) level 2. We have downloaded these data for the entire England. Then, using OECD purchasing power parity rate, 0.87 (Eftec, 2010), it was converted from € to 2003 US $.

Population

Population data was obtained from the *Casweb* extraction tool using the Census 2001. The total population was downloaded at District level and then included in the GIS database. Next, the same procedure as explained in Brander et al. (2008) was applied to calculate the population within 50 km of radius around the wetland center for each individual wetland.

Wetland abundance

The wetland abundance is defined as the total area of an ecosystem type within 50 km radius of the center of each ecosystem site.

First of all, three different approaches were investigated in order to determine the best source of data to calculate the area of substitute sites. The three possible data sources are: 1. Land Cover Map 2000 produced by CEH, 2. CORINE 2000 land cover dataset and 3.Designated wetland sites.

Table 2 Alternative estimates of the area of substitute wetland sites

Approach 1. LCM2000

Land cover classes	LCM Number
Water (inland)	13.1
Saltmarsh	21.2
Bogs (deep peat)	12.1
Fen marsh and swamp	11.1

Approach 2. CORINE 2000

Land cover classes	Code
Inland marshes	4.1.1.
Peat bogs	4.1.2.
Salt marshes	4.2.1.
Salines	4.2.2.
Intertidal marsh	4.2.3.

Approach 3. Designation sites

Type of Designations
RSPB sites
Ramsar
BAP: Coast floodplain
BAP: Fens
BAP: Lowland raised bogs
BAP: Reedbed

Substitute sites were calculated following the three datasets for a pilot wetland. The wetland abundances achieved were very similar for the three approaches. Therefore, the unmodified CORINE data was used as the main data source on wetland types, areas and locations, facilitating the use of the Brander et al function. All five wetland types present in CORINE dataset have been used to calculate the wetland abundance, ie including salt marshes and salines. The summed area of all types of wetlands in the CORINE data set (including saltmarshes and salines) located within a 50 km radius from the target wetland center was calculated and included in the GIS database.

The final database consists of a file that includes the centroid of each wetland, the area for the specific wetland, the summed area of the surrounding wetlands of types 411, 412, 421, 422 and 423 in a circular zone of 50 km around each wetland centroid, the GDP per capita at NUTS 2 level and the total population living in a circular zone of 50 km around each wetland. This table was exported to Excel (see Table 2) and a spreadsheet was prepared to apply the function.

Table 3. Example of spatially specific data for wetlands.

area HA	Substitutes (ha)	COUNTY	GDP	Population density	TotalPop50
4	3433	South Yorkshire	24022.99	426	3345804
6	3433	South Yorkshire	24022.99	428	3361512
14	23301	Greater Manchester	29080.46	840	6597360
25	3023	Norfolk	28735.63	180	1413720
26	2400	Northumberland	26781.61	69	541926
29	1388	Dorset	25632.18	230	1806420
29	5951	South Yorkshire	24022.99	404	3173016
32	520	Shropshire	24482.76	306	2403324
35	23175	Greater Manchester	29080.46	841	6605214
36	5381	Cornwall	20114.94	153	1201662

Appendix 4: Estimated benefits of UK wetlands by UK administrative areas

Table A5.1: Summary of estimated area weighted benefits of ecosystem services (£/ha/year) by lowland and upland inland wetlands and UK administration *

		England			Wales			Scotland			N. Ireland	UK		
		Lowl	Upl	All	Lowl	Upl	All	Lowl	Upl	All	All**	Lowl	Upl	All
Sites	number	96	266	362	11	10	21	489	459	948	188	596	735	1519
Area	ha	22519	90787	113307	2795	663	3458	236317	127030	363347	121438	261631	218480	601550
Default estimate	£/ha/year	2083	528	837	643	646	644	93	191	128	318	270	333	303#
Statistical significant services*	£/ha/year	2580	654	1037	797	800	797	115	237	158	394	335	412	375
Statistical significant and typical services	£/ha/year	22016	5582	8848	6798	6825	6803	985	2022	1348	3364	2858	3516	3199
Typical services	£/ha/year	49193	12472	19770	15189	15249	15201	2202	4519	3012	7517	6385	7856	7148
All services assumed	£/ha/year	3212	814	1291	992	996	992	144	295	197	491	417	513	467

*sig at 10%, estimates weighted by wetland areas, ** lowland/upland breakdown not available for NI

the default estimates for benefits unweighted by area of wetlands are for the UK, mean £753/ha/yr, mode £614/ha/yr, median £341/ha/yr and for England, mean £1,676/ha/yr, mode £616/ha/yr and median £822/ha/year

Table A5.2: Summary of estimated area weighted benefits of ecosystem services (£/ha/year) by salt marsh and inter-tidal coastal wetlands and administration in the UK

		England			Wales			Scotland			N Ireland		UK		
		Salt-M	Int-tidal	All	Salt-M	Int-tidal	All	Salt-M	Int-tidal	All	Int-tidal	All	Salt-M	Int-tidal	All
Sites	number	200	200	400	22	97	119	27	117	144	30	30	249	444	693
Area	ha	33,555	131,061	164,616	5,772	42,671	48,443	3,008	50,232	53,240	8,314	8,314	42,335	232,278	274,613
Default estimate	£/ha/year	4,076	1,758	2,231	1,696	1,505	1,528	2,154	845	919	2,338	2,338	3,615	1,535	1,856
Statistical significant services*	£/ha/year	5,049	2,178	2,763	2,100	1,864	1,892	2,668	1,046	1,138	2,895	2,895	4,478	1,901	2,298
Statistical significant and typical services	£/ha/year	4,861	2,097	2,660	2,022	1,795	1,822	2,568	1,007	1,095	2,787	2,787	4,311	1,830	2,213
Typical services	£/ha/year	13,918	4,501	6,421	5,789	3,853	4,084	7,353	2,162	2,455	5,984	5,984	12,343	3,929	5,227
All services assumed	£/ha/year	6,285	2,711	3,440	2,614	2,321	2,356	3,321	1,302	1,416	3,604	3,604	5,574	2,367	2,861

- Sig at 10%, Salt-Marshes, Intertidal marshes,

Appendix 5. Examples of Values for Rivers and Lakes from literature

Ecosystem services	Reference	Indicator of value/cost	Valuation approach	Value
Provisioning				
Fish (Commercial fisheries)	Lawrence and Spungeon (2007)	Benefits of maintaining salmon stocks	Contingent valuation	WTP to prevent "severe decline in salmon populations across all of England and Wales" was £15.80 per household per year
	Spurgeon et. al (2001)	Value of public to pay for environmental benefits of having healthy fisheries in England and Wales.	Contingent valuation	£2.40 per household per year
	TEEB Appendix C (2010)	Monetary value of services provided by Rivers and Lakes biome	Unit values/Benefit transfer (Based on 3 monetary values)	Values in Int.$/ha/year: Maximum: 196 Minimum: 27
	ABC (2001)	Restocking costs (2001 prices)	Market prices	Trout fry: £210 Grisle (young) salmon: £2,200 Pre-salmon: £2,300 Salmon: £2,400 Carp: 25p each
Food production	Costanza et al. (1997)	Economic value of food production for rivers and lakes based on published studies and original calculations		41 (1994 US$/ha/yr)
Aqualculture	**Moran and Dann (2008)**	**Average value of water for aquaculture (considers water use for disposal of solid waste only)**	**Avoided cost: costs calculated based on running costs of the largest effluent filters bought without a loan**	**0.126 p/m^3**
Water use	Jacobs (2008)	Value of water abstracted (agriculture)	Unit value is based on South-east England	£37 million/year
Household	Moran and Dann (2008)	Marginal value of household use of water	1. Gibbons' willingness to pay formula (includes value of both clean and dirty water) 2. Benefits tranfer from stated preference study	1. 0.102-0.244 p/m^3 2. 0.067 p/m^3
Irrigation	Moran and Dann (2008)	Average value of water for agricultural irrigation (includes both naturally available water and	Net-back analysis	23-138 p/m^3

		water applied through irrigation)		
Industry	Moran and Dann (2008) –taken from Renzetti and Dupont (2003)-	Marginal value of water for industry (assumes industrial water use in Scotland and NI is the same as for Canada)	Benefits transfer from marginal productivity approach study	0.3-15.7 p/m^3
	Ofwat (2008)	Average household bill (period 1989-2008)	Market prices	Average household bill: 274.7 £/household/year
	ERM (1997)	Benefits of Low Flow alleviation carried out by the Environment Agency (South West of England)	Willingness to pay	£53.03 household per year WTP for improvements for informal recreation £0.02 to clean up a mile of polluted river and up to £0.06 per mile to improve conditions on low flow rivers
	Eftec (1998)	Benefits of increasing water level (Yorkshire area) –Extraction of water for drinking water supply by Yorkshire Water Plc-	Contingent valuation-payment card	Regional survey: mean WTP for no abstraction is £4.70 User survey: mean WTP for no abstraction is £5.60
Water supply	TEEB Appendix C (2010)	Monetary value of services provided by Rivers and Lakes biome	Unit values/Benefit transfer (Based on 2 monetary values)	Values in Int.$/ha/year: Maximum: 5,580 Minimum: 1,141
	Costanza et al. (1997)	Economic value of water supply for rivers and lakes based on published studies and original calculations		2117 (1994 US$/ha/yr)
Water quantity	Eftec (2003)	Environmental benefits of increasing the availability of water in the environment	Benefits transfer	Average social benefit of increased water in the environment of £0.27 per m3 per day (£ 2003).
	Garrod and Willis (1996)	Benefits of improved flow levels in the River Darent and for all 40 low flow rivers in England and Wales	Contingent valuation	Benefits in all 40 low flow rivers in England: £21.14 per local resident household per year. Non-user: £14.32 per household per year. (£ 2001)
Hydropower	Wang et al. (2010)	Environmental cost per unit of electricity (Developed in China)	market value method, opportunity cost approach, project restoration method, travel cost method, and contingent valuation method	0.206 Yuan/kW h, (0.02 £/KWh)

	Moran and Dann (2008)	Marginal value of water for hydropower	Avoided cost: compares hydropower costs with costs from other fuels and technologies	0.00-0.049 p/m^3- compared to gas, nuclear and coal- 0.245-0.817 p/m^3 –compared to windpower-
Regulating				
Carbon regulation	DECC (2009)	Marginal abatement costs required to reach UK target (target consistent approach)	Social cost of carbon	Short term traded price of £25 per tonne in 2020, with a range £14-31. Short term non-traded price of £60 per tonne, with a range of £30 to £90.
Flood regulation	RPA (2005)	Household benefits of reduced flood impacts	Contingent valuation, choice experiment and cost-benefit analysis	Approximately £200 per household
	O'Gorman and Bann (2008)	Total economic value flood control and storm buffering benefits provided by a subset of England's habitats	Market value, consumer surplus and total WTP.	£1.2 million in England
	Jacobs report (2008)	Flood damage costs in the UK	Damage costs	£1.17 billion per year
	Jacobs report (2008)	Flood prevention measures in the UK	Defensive expenditure	£500 million per year
	Werrity 2002, Werrity and Chatterton 2004	Damage to property	Direct economic loss	Approximately £30 million for Tay/Earn flood in 1993 £100 million for Strathclyde flood in 1994
	Dunderdale and Morris (1997)	Annual benefits per hectare from river maintenance (reduction in costs due to less frequent flood are included in the benefit estimate) (Set of river in Wales)	Actual Market pricing methods (change in productivity)	Benefits per hectare (model estimates) range from £4 to £54 depending on the river Benefits per hectare (Farmer assessment) range from £9 to £112
	Shabman, and Stephenson (1996)	Benefits of the Roanoke Flood Control Program by flood zone and by valuation method (United States)	Hedonic price Avoided property damages Contingent valuation	Annual benefits: Hedonic price: \$196-\$2,331 Avoided property damages: \$15-\$908 Contingent valuation estimates: \$203-\$980
	Eftec (2000)	Benefits of avoid a derease in water levels and a change in bird species composition	Contingent valuation (payment card)	Mean WTP from £23 to £43
	Miyata and Abe (1994)	Increase in land rent/reduction in annual	Hedonic pricing	4,202.6 million of 1990Yen/31,269 million of

		expected damage		1990Yen
	NEA scientific team report, October 2010	Costs of groundwater flooding	Cost avoided	£4-14 million per year
Water quality regulation	Nera and Accent (2007)	Benefits from water quality improvements due to the Water Framework Directive	Contingent valuation	£44.5 to £167.9 per household per year (BT)
	Van Houtven et al (2007)	Benefits from water quality improvement (United States)	Benefit transfer (meta-regression model)	WTP/one-unit change in water quality Linear function: nonusers: $3-5 Users: $56-58 Log-linear function: Nonusers: $11-13 Users: $32-37
	Loomis et al. (2000)	Benefits from restoring a river (United States): dilution of wastewater, natural purification of water, erosion control	Contingent valuation	Households WTP $21/month $252/year
	Huber and Viscusi., 2006	Benefits of improvements to inland surface water	Choice experiment	Each 1% improvement in national water quality had a mean value of $39 and a median value of $20
	Pretty et. al (2003)	Damage costs of freshwater eutrophication in England and Wales	Damage costs and policy costs	£75-114.03 million per year
	Georgiou et al. (2000)			£3-5 per household per annum for a unit increase in RFF water quality scale
	Jacobs report (2008)	Surface water quality in rivers and transitional waters	Damage cost	£5.988 per km per year
	Matthews et al. (1999)	Benefits of reducing phosphorus levels by 40%	Contingent valuation	$14.07/year (using income tax payment vehicle) $19.64/year (using water bill)
	Costanza et al. (1997)	Economic value of water regulation for rivers and lakes based on published studies and original calculations		5445 (1994 US$/ha/yr)
	Lago and Glenk (2008)	Improvement in river and loch water quality by 2015 (1% increase in total area of good status)	Choice experiment	Rivers: £2.18 (95% CI £1.55 - £3.15) Loch: £1.60 (95% CI(£1.17 - £2.34)

		Scotland		
	Moran et al., (2004)	Value for general water quality enhancement	Choice experiment	Different values for different parts of Scotland that ranges: £43.56-66.90 Scotland: £55.27 (95% CI £42.90 - £70.70)
Waste assimilation	Bateman et al., 2006	WTP to reduce the impact of eutrophication	Contingent Valuation	User mean £75.41 and median £69.07
	TEEB Appendix C (2010)	Monetary value of services provided by Rivers and Lakes biome	Unit values/Benefit transfer (Based on 2 monetary values)	Values in Int.$/ha/year: Maximum: 4,978 Minimum: 305
	Costanza et al. (1997)	Economic value of waste treatment for rivers and lakes based on published studies and original calculations		665 (1994 US$/ha/yr)
	Hanley (1991)	Mean willingness-to-pay to reduce nitrate levels in drinking water to EU and WHO standards	Contingent valuation	£15.89 per household per annum (£ 2001)
Provisioning of habitat	Loomis et al. (2000)	Benefits from restoring a river (United States): habitat for fish and wildlife	Contingent valuation	Households WTP $21/month $252/year
	Holmes et al. (2004)	Benefits of four hypothetical riparian restoration programs in United States	Contingent valuation	Median WTP range from US$6.91 to US$27.26
	Broadhead et al. (1998)	Mean WTA for programme (preserving riparian habitats).France	Contingent valuation	Mean WTA for programme 1,373 FF/ha
	Knowler et al., 2003	Value of protecting habitat ecosystem services for salmon in Canada	Bioeconomic model and empirical anlysis	C$0.93 to C$2.63/ha
Cultural				
Tourism and recreation	Tang (2010)	Economic value of ecosystem services of water tourism (Heilongjiang Province)	Market value approach, substitution engineering method and replacement cost method.	97.05 billion Yuan (2006)
	TEEB Appendix C (2010)	Monetary value of services provided by Rivers and Lakes biome	Unit values/Benefit transfer (Based on 5 monetary values)	Values in Int.$/ha/year: Maximum: 2,733 Minimum: 305
	Costanza et al. (1997)	Economic value of recreation for rivers and lakes based on published		230 (1994 US$/ha/yr)

		studies and original calculations		
Fishing	Loomis et al. (2000)	Benefits from restoring a river (United States): recreation	Contingent valuation	Households WTP $21/month $252/year
	Paulrud and Laitilla (2004)	The value of catching an extra fish per day in the Kaitlum River (Sweden)	Conjoint analysis	Point estimate WTP for catching an extra fish of different sizes per day from SEK17 to SEK333
	Buchli et al. (2003)	Increase in the annual consumer surplus for a typical angler caused by an enhancement of river flow		Increase in consumer surplus for a typical angler: 440 SFr
	Butler et al. (2009)	The value of recreational rod fisheries for Atlantic salmon, brown and sea trout, pike and non-native rainbow trout in River Spey (Scotland)	Contingent valuation	Fisheries value: £12.6 million/year/household £970/fish (salmon and sea trout) £1/m2/year for riverine nursery habitat
	Lawrence and Spungeon (2007)	Value of inland fisheries in England and Wales	Contingent valuation	£15.80 per household per year to prevent "severe decline in salmon populations across all of England and Wales"
	Willis and Garrod (1998)	External costs of water abstractions: benefit to anglers and general public from increasing river flows to an environmentally acceptable flow regime	Contingent valuation	Angler WTP £3.80/additional day fishing User households WTP £0.0475/km
	Willis K.G. and Garrod G. (1999)	Recreational benefits (including angling benefits), of increasing flow of rivers in South-West England	Contingent valuation and choice experiments	Anglers WTP £3.80 per day
	Green and Willis (1996)	Benefit per angling trip for improvements in a coarse fishery (2001 prices)	Contingent valuation	Anglers WTP: 4.3-6.87 £/person/trip Marginal value of improvements in fishery quality: 0.23-4.30 £
	Entec (2008)	Angler expenditure per day		£81.20/angler/day
	Moran and Dann (2008)	**Marginal value of water for salmon angling**	**Benefit transfer of travel cost method study**	**£175/day**
	NEA scientific team report,	Recreational asset value of Britain's freshwater	Market prices	Coarse fisheries: £850 million Angling industry turnover:

	October 2010	fish populations		£191,000 Fishing rights for migratory salmonids: €165 million
	NEA scientific team report, October 2010	Salmon anglers travelling from outside Scotland	Travel cost method	£189/day/angler
	Curtis, 2002	WTP of the average salmon angler visiting Donegal	Travel cost method	£206/day
Lakes/Reservoirs	Chizinski et al.(2005)	Per-day consumer surplus for anglers at a reservoir	Travel cost method	$61-122/per day/ per angler
	Eiswerth et al		Pooled revealed preference/contingent behaviour model	Average annual consumer surplus ($485-$664) Changes in annual recreator values due to water level change ($11.60 - $18.54 annually per person per change in water level)
Rafting	Johnstone and Markandya (2006)	Use value of rivers for angling in uplands and lowlands.	Travel cost method	CS value for a 10% improvement in specific river attributes is £0.04 to £3.93 per trip
Boating	Carson and Mitchell (1993)	Determine WTP for improvements to water quality in a variety of water body types	Contingent Valuation	Boatable to Swimmable: $242
	Willis and Garrod (1991)	Benefits of maintaining access to canals. "Boating trip"	0.45 to 1.12 £/trip	
Non-use recreation	Loomis (2005)	Willingness to pay for water leasing to maintain stable lake levels at an irrigation reservoir	Contingent valuation method	Median Willingness to pay: $368/year/lakefront residents $59/year/off-lake residents
	Cordell and Bergstrom (1993)	Recreational benefits of three water level alternatives in a reservoir	Contingent valuation	41.70-75.05 $/individual/year
	Green and Tunstall (1991)			0.09-0.65 £/visit
	Coker et al. (1990)			1.35 £/visit
	Tapsell et al. (1992)			2.91-3.61 £/user
	Jacobs Gibb (2002)			0.12-0.87 £/household/year
	ERM and Willis			8.20 £/visitor household/year

	(1992)			
	ERM (1997)			11.42-13.42 £/visitor household/year
	Eftec and CSERGE (1998)	Changes in water level and effects on ecology and recreation	Contingent Valuation	5.61-16.91 £/visitor household/year
	Garner et al. (1995)			8.75 £/adult/visit
	Gürlük and Rehber, 2008	Average travel cost per capita per visit (Lake Manyas, Turkey)	Travel cost method	6.22-537 NTL
	NEA scientific team report, October 2010	Wildlife tourism in Scotland's rural economy: Osprey viewing and bird watching	Visitors spenditure	£2.2 million (Osprey viewing sites) £5 million (bird watching)
Landscape	Garner et al (1995)	2 scenarios: 1. Maintaining current river recreation 2. Improving river, trhough river restoration scheme		Today's vist: £6.86/adult With restoration scheme: £8.75/adult/visit £25.67/adult/year
	Coker et al. (1990)	Scheme A: Channel filled with water; rubbish cleared; gravel pathway provided Scheme B: paved pathway and seats provided.		Scheme A: £1.35 per visitor per visit Scheme B: £1.57 per visitor per visit.

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