Appendix 12.5: Report on Ecosystem Services Valuation

The project was asked to undertake an ecosystem services assessment using the draft EA guide 'Ecosystem services assessments: How to do them in practice'. As a first step, the Wider Programme Delivery Group undertook a qualitative assessment by determining the 'likelihood of impact' of the planned land management measures across the full set of ecosystem services. The Group scored the impact using the recommended UN Millennium Ecosystem Assessment (2005) classification scheme, which groups services into four main categories: provisioning, regulatory, cultural and supporting services. An additional service was added to the list of cultural services in the form of 'education and knowledge'.

The Group met on 21 January 2011 to score the impacts of the project measures, which were grouped into four categories: bund construction, woodland creation, drain/stream channel restoration, and farm-based measures. Each category was scored individually and then a combined score was agreed for each service for the project as a whole. The results of the scoring are included in the Annex (see Table 6).

There was a desire to take the assessment a step further by carrying out an economic valuation of the most significant positive and negative impacts. In view of limited time and resources, it was decided to confine the valuation to the services provided by the woodland creation (85 ha) and large woody debris (LWD) dam (150 dams) interventions, omitting the main bunds and other measures.

Indicative estimates of the value of ecosystem services that may arise from the creation of floodplain woodland, riparian woodland and other farm woodland as part of the 'Slowing the Flow at Pickering' project within the Pickering Beck and River Seven catchments are discussed below. The objective of this exercise is not to estimate definitive values but, rather, to provide some conservative estimates to serve as the foundation for more robust valuation of ecosystem services arising from woodland planting schemes for flood risk reduction. It should also be noted that the application of 'benefit transfer' in catchments is difficult, and that due to the unique features of individual areas the valuation of many ecosystem services (and any associated payments for ecosystem services schemes developed) need to be tailored to the specific catchment.

The impact scoring determined by the Programme Delivery Group for the woodland creation measures identified the following two regulating ecosystem services and two cultural ecosystem services as being potentially significant,[1] and thus selected as candidates for valuation.

1) Water/Flood regulation
2) Erosion Regulation
3) Education and knowledge
4) Social relations[2]

[1] Each of these impacts were considered positive (and ranked '++').
[2] This category essentially corresponds to the 'community development' ecosystem service referred to in the Millennium Ecosystem Assessment.

In addition the value of creating woodland habitats was also identified as significant,[3] while climate regulation was considered the ecosystem service associated with potentially the next most significant impact.[4] A number of other services (fibre and fuel provision, air quality regulation, natural hazard regulation, water purification, recreation and tourism, and aesthetical value, as well as the supporting services of soil formation and primary production) were scored as potentially positive but not significant and were excluded from this evaluation. A reduction in food provision from agricultural production was the only potential negative impact and while this was not scored as 'significant' it was felt that it should be included.[5]

Each of the services selected for economic evaluation is discussed separately below. As the woodland is likely to be established in perpetuity, the impact on associated ecosystem service flows are expected to extend into the far distant future. However, a 100-year time horizon is focused upon for the purposes of this study in order to facilitate comparison with other analyses of woodland projects over a similar time-frame.

Provision of Habitat

Existing evidence on the marginal value of the types of woodland habitat to be created by the project appears very limited at present. Hanley, et al (2002), for example, present willingness to pay (WTP) estimates per ha for different woodland types in the UK[6], but not specifically for riparian, floodplain or farm woodland. The WTP estimate for 'Lowland New Broadleaved' of £0.84/ha/yr may be the closest category, but it is not entirely clear what the relevant population would be if this value were to be used to compute an aggregate value per hectare.

Based on a meta-analysis of data from the UK, the EU and Scandinavia, Eftec (2010a, p.103) hypothesise that the non-use value of woodland biodiversity together with the cultural services value of woodlands ranges from £30-£300/ha/yr, depending on the priority status of the woodland. Although as both riparian woodland and floodplain woodland are priority habitat types and thus values for these might be expected to lie at the high end of this spectrum, the range should be viewed as indicative given the limited hard evidence on which it is based. Limited knowledge of how different generic woodland types affect biodiversity outcomes hampers distinguishing separate values for each (Eftec 2010a). While these are likely to depend upon specific spatial characteristics (e.g. the extent to which they enhance existing habitat networks), broadleaf farm woodlands in general might be expected to be associated with intermediate values neither at the high nor the low end of the spectrum.

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[3] Also considered positive and ranked '++', habitat creation may be considered primarily a biodiversity benefit. Biodiversity is often considered to underpin all ecosystem services rather than constituting an ecosystem service itself, but for the purposes of the current exercise, estimates of the value of habitat creation are covered.

[4] This was ranked '+(+)'.

[5] This was ranked '-'.

[6] The woodland categories adopted by Hanley, et al (2002) are: Upland Conifer (£0.35/ha/yr); Lowland Conifer (£0.33/ha/yr); Lowland Ancient Semi-Natural Broadleaved (£1.13/ha/yr); Lowland New Broadleaved (£0.84/ha/yr); Upland Native Broadleaved (£0.90/ha/yr); and Upland New Native Broadleaved (£0.61/ha/yr)

Encompassing water quality improvement, biodiversity, aesthetic amenity and (non-consumptive) recreation, for inland marshes Eftec (2010b, p.13) suggest an indicative 'default' value of £1,300/ha/yr in a range of £200/ha/yr to £4,300/ha/yr at 2008 prices, but do not present separate estimates for the creation of wet woodland. As the latter constitutes a priority habitat type, it might be expected that they (whether in riparian zones or on the floodplain) would be associated with relatively high values, but there appears minimal evidence in the valuation literature to substantiate this at present. In cases where small (1-10 ha) areas of inland marsh are created and there is no more than 100 ha of existing substitute wetland in the locality, the report suggests using a range for the habitat value of the inland marsh created of £1,250-£1,940/ha/yr (Eftec, 2010b, Table A1.2, p.44). As there is less than 10 ha of existing floodplain woodland in the locality and the size of the parcels of floodplain woodland planted are expected to be in the range of 1-5 ha, the latter range might be considered appropriate to apply in the case of the Slowing the Flow project.

For the purpose of this valuation, a conservative approach is taken to valuing the proportion of riparian woodland created in the floodplain (that lying within the EA Flood Zone 2) that assumes planting occurs in areas of existing inland marsh and does not lead to an increased habitat value. For the remaining riparian woodland planted outside this zone on adjacent side slopes (44 ha out the total of 50 ha), at 2010 prices a value of £300/ha/yr is assumed for the high estimate from the top end of the Eftec (2010a) range, with low and central estimates of £250/ha/yr and £275/ha/yr respectively (these are then reflated to 2011 prices based upon the 2.6% increase in the Treasury GDP deflator currently expected).[7]

For the floodplain woodland, it is assumed that planting occurs on existing areas of improved grassland or arable with understory drainage, with the indicative default value of £1,300/ha/yr at 2008 prices for the creation of inland marsh habitats from Eftec (2010b) assumed to apply (£1,396/ha/yr at 2011 prices) for the central estimate. Low and high estimates are based upon the range for small inland marsh creation with limited substitute wetland (£1,343/ha/yr and £2,084/ha/yr respectively at 2011 prices).

For the farm woodland, an indicative intermediate value at 2010 prices of £165/ha/yr is assumed from the mid point of the Eftec (2010a) range for the central estimate, and £100/ha/yr and £230/ha/yr for low, and high, estimates respectively (each is similarly reflated to 2011 prices based upon the expected change in the Treasury GDP deflator).

In each of the above cases the habitat values are assumed to increase linearly from zero on planting until they are fully realised, either once trees reach 55 years old (low estimate), or 20 years old (central estimate), or 10 years old (high estimate). Thus for the total 79 ha of riparian (non-floodplain) woodland, floodplain woodland, and farm woodland planted, the maximum aggregate value is reached either in 2068, 2033, or 2023 (i.e. year 57, 22 or 12) respectively, thereafter being assumed to remain constant.[8] The approach implies a maximum of around £131,000/yr for the low estimate, £139,000/yr for the central estimate, and £191,000/yr for the high estimate.

[7] See: http://www.hm-treasury.gov.uk/data_gdp_fig.htm (accessed 29/3/11).
[8] Note that the phased planting from 2011-13 affects when stabilisation occurs.

Flood Regulation

Pickering has experienced significant flooding five times in the last 10-15 years (1999, 2000, 2002, 2007 & 2008). The 2007 floods were particularly severe, causing an estimated £7m in damage to homes and businesses.[9] An attempt is made below to evaluate the potential contribution that the riparian woodland planting and large woody debris dams could make to reducing future flood risk at Pickering.

Modelling suggests that to prevent flooding in the town for events similar to that of 2007 would require creating 650,000 m^3 of flood storage upstream in the Pickering Beck catchment (Odoni and Lane, 2010). As the planned riparian woodland planting and creation of 100 large woody debris dams is predicted to provide the equivalent of 53,000 m^3 of flood storage in such cases, this would contribute ~8% of the total required. Providing other measures were also put in place such that the total storage requirement was met, the contribution of the woodland measures could be considered to translate into an avoided damage saving of ~£0.6m (i.e. ~8% of the expected damage avoided). Such events are thought to occur roughly 1 in 100 years, implying an equivalent expected annual benefit of around £6,000.

For smaller events such as the 2000 floods, although it is known that 50-60 properties were flooded, estimates of the cost of the total damage caused at Pickering are not available. However, according to Defra (2010, p.13), typical damages in England range from around £23,000 to £30,000 per household flooded. Were these assumed to apply to Pickering, it would imply a total damage cost of around £1.2m to £1.8m. Modelling suggests that to prevent flooding in the town for events similar to that in 2000 would require creating ~250,000 m^3 of flood storage in the Pickering Beck catchment. The woodland planting and creation of 100 large woody debris dams is expected to contribute the equivalent of 15,000 m^3 of flood storage in the upper catchment for such an event. This could be viewed as contributing 6% of the total required, which might be considered to translate into an avoided damage saving of £72k to £108k (and an expected annual benefit, assuming such floods to be 1 in 25 year events, of ~£3,000 to £4,000).

It is recognised that the above calculations only give a very rough guide to the potential contribution of the woodland measures and illustrate some of the difficulties in estimating their value for flood risk mitigation. Notably, a lack of data prevented an assessment of the effect of the measures on a wider range of flood events at Pickering, while the absence of modelling data for the adjacent River Seven catchment precluded any assessment of the effect of the planned 30 ha planting of floodplain woodland and construction of 50 large woody debris dams.

For the purposes of this appraisal, tentative indicative estimates of the annual value of the woodland measures for flood risk reduction in Pickering of £3,000 (minimum), £6,000 (central) and £10,000 (high) are assumed. Since the large woody debris dams were predicted to exert a stronger effect than the woodland planting and these are now largely in place, the full benefits are assumed to accrue from year 3 onwards (i.e. after all the woodland has been planted), and to increase linearly from 70% of this level in 2011 (i.e. year 0) up to the maximum in 2014.

[9] See: http://www.forestresearch.gov.uk/fr/INFD-7ZUCL6.

Climate Regulation

Carbon sequestration estimates covering standing biomass, soils and woody debris were obtained from Forest Research's C-SORT model along with estimates of carbon emissions from associated forestry operations. The carbon sequestration estimates are for a Sycamore-Ash-Birch mix (yield class 6) planted on a gley soil and assuming 1.7 m initial spacing. These species are considered to best represent the woodland most likely to be planted under the scheme.[10] The estimates assume declining thinning over time after the first 40 years (rather than continued intermediate thinning),[11] no ploughing of the initial ground, fencing based on rectangular 2 ha blocks, no forest roads constructed or maintained, and no extraction or transportation of material from the site (or processing of material off site).[12]

In estimating associated values, staged planting of riparian, floodplain and farm woodland over 2011-2013 (with 10 ha in 2011, 45 ha in 2012 and 30 ha in 2013) is accounted for, as is an assumed 20% open space.[13] Estimates are reduced by one fifth to account for the 20% open ground, and for sensitivity analysis, the carbon estimates were ranged by +/-20%. While it is envisaged that the woodland planted will be maintained in perpetuity, non-permanence risks (e.g. associated with windthrow and fires) were then also accounted for by applying a buffer of 30% (low estimate), 20% (central estimate), or 15% (high estimate) to reduce the carbon estimates.[14] This is broadly in line with the 15%-30% buffer currently recommended by the Woodland Carbon Code.[15] The (low, central and high) social values of carbon currently recommended by the Department of Energy and Climate Change (DECC) for sectors not covered by the EU Emissions Trading Scheme (ETS) are then applied.[16]

Both carbon sequestration rates and carbon values vary over time. The estimates show net carbon emissions in the first two years (year 0 and year 1) as a consequence of factors including soil disturbance and use of machinery for planting, followed by increasing abatement rising to a maximum approaching 1,400 tCO_2/yr (central estimate) after thirty years, thereafter declining. The mean over the 100 year period[17] is around 530 tCO_2/yr (central estimate). This is equivalent to an average annual carbon sequestration rate of about 6.3 tCO_2/ha/yr. As a consequence of the assumed

[10] It is assumed that floodplain woodland would include birch and willows, for which the SAB model is currently the recommended approach. (See http://www.forestry.gov.uk/forestry/INFD-864g2r#advice for further discussion).
[11] E.g. the estimates assume the volume of thinnings per hectare of woodland (excluding the open space) declines from 21 m^3 in years 26, 31, 36 and 41, to 18.3 m^3 in year 46, 12 m^3 in year 51, 11 m^3 in year 56, 9.3 m^3 in year 61, 8.4 m^3 in year 66, 7.5 m^3 in year 71, 6.6 m^3 in year 76, 5.7 m^3 in year 81, 4.9 m^3 in year 86, 4.3 m^3 in year 91, and 3.7 m^3 in year 96.
[12] i.e. any trees felled is to waste.
[13] The original per hectare carbon sequestration estimates for woodland planting were reduced by one fifth.
[14] These are assumed to apply to the positive sequestration estimates (but not to the soil carbon losses in the first 3 years from initial planting or the forestry operations emissions).
[15] See: http://www.forestry.gov.uk/forestry/infd-864j3r#per.
[16] The values recommended for 2100 are also assumed to apply in subsequent years.
[17] i.e. years 0-99 inclusive.

increasing social values of carbon over time, the total annual value of net carbon abatement (taking into account standing biomass, woody debris, soils and forest operations) valued at central DECC carbon values increases to a maximum of over £0.3m/yr (central estimate) after about 40 years. The mean over the 100 year period is £107,000/yr (central estimate).

Erosion Regulation

Planting riparian woodland is expected to reduce the amount of sediment reaching watercourses, reducing any consequent need for downstream dredging, and potentially providing other beneficial impacts (e.g. in helping maintain soil fertility and preventing deterioration of habitats for fish and other aquatic species).[18] For the potential riparian woodland planting sites in the Pickering Beck catchment, estimates suggest an annual volume of sediment delivered per hectare in the range of 0.02 to 0.63 m^3/ha/yr, which could be potentially retained by the planned planting.[19] The reduced sedimentation benefits of planting the floodplain woodland in the River Seven catchment are likely to be less significant than this, being expected to arise primarily when the woodland is flooded (and have not so far been estimated).

The value of this erosion control service depends partly on whether the total downstream deposition of sediment (including that from the rest of the catchment) is sufficiently high for dredging to be considered necessary (and not ruled out on wider environmental grounds). Few studies exist that have estimated the benefits of controlling soil erosion in the UK (see Inman, 2006). For the purposes of this appraisal, very rough indicative estimates of the potential annual value of the riparian woodland planting for erosion control are assumed based upon valuing the above range of the potential reduction in sediment delivery to the watercourses using a dredging cost of £14/m^3. The latter is taken from the mid-point estimate of unit dredging costs that are reported to have applied in the Norfolk Broads in 2005/6.[20] The maximum reduction in sedimentation is assumed to occur 10 years after planting, with a linear increase from zero in year zero. The approach implies that the maximum annual benefits of £221/yr (central estimate) and £441/yr (high estimate) apply from 2023 (i.e. year 12) onwards.

Education & Knowledge

The Slowing the Flow project is expected to create opportunities for educational visits to find out about flood risk management using woodland creation and other measures.

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[18] There is fishing in the Pickering Beck primarily for trout, and also grayling (see: http://www.pickeringfishery.co.uk/index.html), but no estimates are available of the impact of sediment loads on species abundance or the value of this fishery.

[19] These estimates are based upon Environment Agency national maps of predicted sediment delivery to watercourses for 1 in 1 year and 1 in 10 year events at a 1 km grid scale, and estimated upslope land areas draining to potential riparian woodland planting sites in the Pickering Beck catchment (the annual level is combined with the ten year level by dividing the latter by 10).

[20] This is based upon the mid-point of the reported range of £13-£15/m^3 - see: http://www.broads-authority.gov.uk/broads/live/authority/meetings/navigation-committee/2005/09-08/%5Breport%5D%20Dredging%20programme%202005-06-Update.doc.

It is anticipated that this will result in between two and five education-related visits per year by schools/colleges and professional groups to the area for the first five years of the project. This number is thought likely to drop to between one and three visits per year in the subsequent five years, and to one visit per year thereafter (depending on how many similar demonstration projects are initiated).

Although there appears to be no well established methodology for estimating associated values at present, a simple approach used in some previous studies is to consider cost savings associated with visits to the new site compared to existing alternatives.[21] It is unclear at present what cost savings might arise associated with visits to the site. However, potentially cost savings could be quite significant for some of the professional group visits (if one considers, for example, that the main alternatives where similar measures have been implemented to date are some distance away – e.g. in Wales).

For the purpose of providing tentative indicative estimates, it is assumed that the education and knowledge mean value per visit (in terms of avoided costs) ranges between zero (minimum estimate) and £200 (maximum estimate), with a central estimate nearer the lower end (£40). It is further assumed for the central estimate that there are three visits a year in the first 5 years, two a year in the following 5 years, and one every two years thereafter. As they account for about half the measures envisaged, forestry measures are assumed to account for half the total education and knowledge benefits associated with the project. This approach implies aggregate annual values of £60 (central estimate) and £500 (high estimate) in years 0-4 years, declining to £40 and £300 respectively in years 5-9, and £10 and £100 respectively from year 10 onwards.

Social Relations

Over the period June 2009 to March 2011 inclusive, volunteers have contributed a total of 68 person days to the Slowing the Flow project, with the 160 participants in each of the two Community Engagement Days held having spent at least an additional 22 person days. Increased social networking, social capital and community cohesion are viewed as important benefits of the participatory nature of the project. These have arisen partly as a result of greater understanding of how land-use can contribute to flood risk management and provide additional ecosystem services, as well as greater community cooperation in the genesis and evolution of the project.

It is not immediately clear how best to value such benefits, nor to what extent they might have been realised through different activities had the project not gone ahead. However, Volunteer England (a charity and membership organisation concerned with volunteering in England) note that the simplest approach is to multiply the total number of volunteer hours by an average hourly wage.[22]

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[21] A different approach based upon valuing investment in human capital is understood to be adopted in a study undertaken as part of the UK National Ecosystem Assessment (Mourato, et al forthcoming). However, as this has yet to be published, it could not be used as a basis for estimating indicative values for the Slowing the Flow project.

[22] See: http://www.volunteering.org.uk/resources/goodpracticebank/Core+Themes/Volu

For the purpose of providing rough indicative estimates, for the high estimate it is assumed that the same levels of volunteering as experienced to date (around 49 person days, or 363 person hours a year) continues in the future. As some activities (such as the Community Engagement Days) are likely to be discontinued, lower levels of volunteering are assumed for the central estimate (25 person days). Volunteer time is then valued either at the main national minimum wage of £5.93/hr (central estimate),[23] at the gross mean wage rate in 2010 in Ryedale Council district in North Yorkshire of £11.48/hr (high estimate),[24] or no monetary benefit is assumed (low estimate) as the time volunteered might have been put to an equally good use for the community in the absence of the project. Accounting for about half the measures envisaged under the project, forestry measures are assumed to contribute around half the total community development benefits. This approach implies indicative annual benefit estimates ranging from zero (low estimate) to £549 (central estimate) and £2,085 (high estimate).

Agricultural production

Current land uses expected to be converted into woodland comprise rough grassland used mostly for sheep grazing in the case of the riparian woodland, arable crops and improved grassland in the case of the floodplain woodland, and a mix of arable crops and improved grassland for farm woodland. It is unclear to what extent agricultural production values will fall on local farms where areas are planted with woodland. However, for the purpose of providing rough indicative estimates, it is assumed that farm gross margins (low estimates) or net farm income (high estimate) or intermediate values closer to the former than the latter (central estimates)[25] based upon those in McBain and Curry (2010) apply. For floodplain woodland minimum and maximum values (-£820/ha and -£280/ha) are from figures for cereal farms in England, and those for farm woodland (-£542/ha and -£72/ha) from figures for lowland cattle and sheep farms in England. As planting is likely to be on relatively steep ground with limited existing access and only half expected to be fenced to keep animals out, the values for riparian woodland (-£163/ha and -£20/ha) are assumed to be half the figures for cattle and sheep in less favoured area farms in England (In each case these figures are in 2007/8 prices and are reflated to 2011/12 prices using the Treasury GDP deflator). This approach implies that the central estimate for the total value of lost agricultural production changes from -£3,771 in 2011 to -£15,085 in 2012, then stabilising at -£32,056 from 2013 onwards.

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nteer+Managers+and+Coordinators/Is+there+any+way+of+measuring+the+economic+value+of+the+work+our+volunteers+are+doing.htm.

[23] See: http://www.direct.gov.uk/en/Employment/Employees/TheNationalMinimumWage/DG_10027201. (The minimum wage is lower for workers under 21).

[24] This is from the 2010 Annual Survey of Hours and Earnings published by the Office of National Statistics. See: http://www.statistics.gov.uk/statbase/Product.asp?vlnk=1951.

[25] They include three-quarters of the difference between the gross margin and the net farm income (reflecting the idea that machinery and other costs may not be reduced much at the margin by farming a smaller area of the farm).

Discussion

As noted above, the value of most of the ecosystem service impacts can be expected to vary over time and to be sensitive to a range of underlying assumptions. Minima, maxima and means for each of the indicative central estimates for each of the impacts are summarised in Table 1 below.

Table 1: Indicative annual ecosystem service values: Central estimates

	Minimum (£/yr)	Maximum (£/yr)	Mean (£/yr)
Habitat creation	£0	£138,514	£121,524
Flood regulation	£4,200	£6,000	£5,964
Climate regulation	-£18,241	£317,943	£107,035
Erosion Regulation	£0	£221	£205
Education and knowledge	£10	£60	£14
Community development	£549	£549	£549
Agricultural production	-£32,056	-£3,771	-£31,604
Total	-£42,653	£431,180	£203,687

These estimates suggest that habitat creation and climate regulation are by far the largest benefits, while the loss of agricultural production could be a significant disbenefit. Although sensitivity analysis (low and high estimates are shown in Tables 4 and 5 in the Annex) also supports this conclusion, it could conceivably change with further refinement of the approach (e.g. were other elements such as 'peace of mind' associated with reduced flood risk also included) or the estimates.

The ecosystem service benefits considered thus far are gross values not allowing for the costs of the forestry measures implemented. Indicative costs of implementing the woodland creation measures are shown in Table 2. The high estimates assume that many of the tasks are done by volunteers, while the low estimates do not take account of any reduction in costs arising from the use of volunteers.[26] The central estimates are mid-point values.

Table 2: Indicative costs of implementing the forestry measures (£/ha)

	Riparian and farm woodland			Floodplain woodland		
Year	Low	Central	High	Low	Central	High
0	-£6,031	-£4,687	-£3,343	-£6,724	-£5,337	-£3,950
1	-£893	-£684	-£475	-£1,069	-£840	-£611
2	-£568	-£431	-£295	-£643	-£500	-£357
3	-£502	-£302	-£102	-£515	-£315	-£115
4	-£320	-£160		-£320	-£160	
5	-£80	-£40		-£80	-£40	
Total	-£8,395	-£6,305	-£4,216	-£9,351	-£7,192	-£5,033

[26] As of the beginning of April 2011, it is understood that volunteers had spent 70 person hours on such tasks to date.

In addition, the cost of building each of the large woody debris dams is estimated to range between -£110 and -£55, with a central estimate of -£80 (with the variations relating to the extent to which apprentices are used to construct the dams). This gives an estimated total cost for constructing all 150 woody debris dams under the project ranging from -£16,500 (low estimate) to -£8,250 (high estimate), with a central estimate of -£12,000. The combined total cost for all the forestry measures is estimated to range from around -£0.8m to -£0.4m.

The estimates considered so far have not accounted for the timing of the costs and benefits (i.e. their distribution over the selected 100 year period) in making comparisons. Both cost and timing aspects are accounted for in Table 3, where each 100 year flow of annual values has been converted into a present value by discounting based upon the Treasury Green Book protocol and then summing. Aggregating gives a net present value (NPV) ranging from around £0.8m (low estimate) to £9.6m (high estimate), with a central estimate of £4.3m. The positive NPV in each case indicates that the sum of the present value of the ecosystem service flows exceeds that of the cost of implementing the forestry measures. This suggests that from a societal perspective the public benefits outweigh the costs. However, the indicative estimates imply that it is unlikely that the benefits will invariably outweigh the costs for private landowners. For example, if also based upon Treasury Green book discount rates, the estimates suggest present values of expected woodland grant payments (ranging from £4,515/ha to £6,780/ha),[27] would only partly cover those for forestry costs (£4,200 to £8,200/ha) and for lost agricultural production (£3,600/ha to £13,100/ha).

Table 3: Indicative ecosystem service present values (£k at 20011 prices)

	Low (£k)	Central (£k)	High (£k)
Habitat creation	£1,630	£2,773	£4,459
Flood regulation	£88	£175	£292
Climate regulation	£923	£2,800	£5,464
Erosion Regulation	£0	£5	£10
Education and knowledge	£0	£1	£6
Community development	£0	£16	£62
Agricultural production	-£1,113	-£911	-£306
Forestry Costs	-£710	-£539	-£369
Net Present Value	£819	£4,321	£9,618

Based upon the approach recommended in current government guidance on estimating cost-effectiveness in appraisal and evaluation (DECC & HM Treasury, 2010),[28] the approach indicates that the forestry measures are highly cost-effective

[27] The grant rate for planting the woodland is expected to be £3,800/ha, which is assumed to be supplemented by annual payments averaging around £250/ha a year for floodplain and farm woodland, and £60/ha a year for riparian woodland, for the first 15 years.

[28] This recommends deriving the cost-effectiveness (CE) of a measure by dividing its NPV (excluding the present value of the carbon benefits) by the total tonnes of carbon dioxide equivalent saved. The carbon benefits excluded are either those in the traded sector (i.e. covered by the EU ETS) or those in the non-traded sector

from both a climate change mitigation and habitat creation perspective. In terms of the former, they suggest indicative estimates for delivering carbon savings of between -£61.61/tCO_2 (low estimate) to £2.85/tCO_2 (high estimate), with a central estimate of -£28.83/tCO_2 (Negative values indicate a net benefit, while positive values indicate a net cost per tonne of carbon dioxide saved).

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(i.e. not covered by the EU ETS), depending whether the impact being investigated is in the traded or non-traded sector. Values for 2011 recommended for the non-traded sector range from £30-£90/tCO_2 at 2011 prices (being higher in subsequent years).

Annex: Sensitivity Analysis and initial Scoring of potential Impacts

Table 4: Indicative annual ecosystem service values: Low estimates

	Minimum (£/yr)	Maximum (£/yr)	Mean (£/yr)
Habitat creation	£0	£130,861	£91,909
Flood regulation	£2,100	£3,000	£2,982
Climate regulation	-£9,288	£107,942	£33,584
Erosion Regulation	£0	£0	£0
Education and knowledge	£0	£0	£0
Community development	£0	£0	£0
Agricultural production	-£39,150	-£4,606	-£38,597
Total	-£45,180	£167,520	£89,878

Table 5: Indicative annual ecosystem service values: High estimates

	Minimum (£/yr)	Maximum (£/yr)	Mean (£/yr)
Habitat creation	£0	£190,639	£176,796
Flood regulation	£7,000	£10,000	£9,940
Climate regulation	-£26,900	£614,147	£211,830
Erosion Regulation	£0	£441	£411
Education and knowledge	£100	£500	£130
Community development	£2,085	£2,085	£2,085
Agricultural production	-£10,776	-£1,268	-£10,623
Total	-£21,521	£806,637	£390,568

Table 6: Scores assigned to likelihood of impact of project measures on ecosystem services

	Bunds	Woodland creation	Stream/drain restoration	Farm Measures	Combined
Provisioning					
Fresh water	0	0	0	+	+
Food	0	-	0	0	-
Fibre & Fuel	0	+	0	0	+
Genetic	0	0	0	0	0
Biochemicals	0	0	0	0	0
Ornamental	0	0	0	0	0
Regulatory					
Air quality	0	+	0	0	+
Climate	(-)	+(+)	+	0	+
Water/flood	++	++	++	++	++
Natural hazard	0	+	0	0	+
Pest	0	0	0	0	0
Disease	0	0	0	0	0
Erosion	++	++	++	++	++
Water quality	+	+	0	++	+
Pollination	0	0	0	0	0
Cultural					
Heritage	0	0	0	0	0
Recreation	++	+	+	+	++
Aesthetic	0	+	+	0	+
Spiritual	0	0	0	0	0
Art/folklore	0	0	0	0	0
Social relat.	++	++	+	+	++
Education	++	++	++	++	++
Supporting					
Soil	0	+	0	+	+
Primary prod.	0	+	0	0	+
Nutrient cycl.	0	0	0	0	0
Water recycl.	0	0	0	0	0
Photosynth.	0	0	0	0	0
Habitat	0	++	+	+	++