Economic Valuation of the Effect of the Shortlisted Tidal Options on the Ecosystem Services of the Severn Estuary

FINAL TECHNICAL REPORT

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EXECUTIVE SUMMARY

ES.1 OBJECTIVES

This research was commissioned by the Department of Energy and Climate Change (DECC) to estimate the economic value of the ecosystem changes due to the Severn Estuary Tidal Power options being considered.

The key objective of this project is "*to value the net ecosystem effects that result from changes in the environment or in key species associated with the Severn Tidal Power (STP) scheme*" the methodology of which must be consistently applied to each of the shortlisted STP options. The research is split into four key components:

1. The definition of an ecosystem services framework to account for all of the services provided by all habitat types that will be affected by the decision to use tidal power for electricity generation.
2. An assessment of the provision of compensatory measures through the valuing the change in ecosystem services such action may provide.
3. Valuing all of the changes in the estuary ecosystem services as a result of each of the short listed STP options through the application of a value transfer based on the available qualitative assessment of environmental change as defined by the Strategic Environmental Assessment (SEA), where quantitative evidence is unavailable a qualitative assessment is made.
4. Recommendations that identify where there are gaps in scientific or valuation literature and how these may be addressed through primary valuation study(ies) in the future.

ES.2 STUDY CONTEXT

The Severn Estuary covers the upper reaches of the Bristol Channel on the west coast of Britain, between South Wales and the South West of England. The Estuary provides support for many wildlife species as a result of its 12 metre tidal range, i.e., the vertical distance between the highest high tidal and the lowest low tide one of the largest in the world. As a result of this tidal range the Estuary could prove a significant resource for generating low carbon energy through tidal power. However, the Estuary's unique nature (designated Ramsar site, Special Area of Conservation (SAC), i.e., Severn Estuary/Môr Hafren, under the European Habitats Directive, and Special Protection Area (SPA) under the European Birds Directive) means that there are potentially significant environmental and social effects which may arise as a result of the construction and operation of a tidal power scheme.

The key concepts that underlie the evaluation of STP options include:

Ecosystems services approach: this is a framework to assess the goods and services provided by ecosystems where environmental effects relate to a loss or gain of one, a group, or all of the services of the ecosystem. The services covered are provisioning, regulating, cultural and supporting services.

Economic value: is a concept that underpins valuation and measures changes in wellbeing via the trade-off between money and changes in the quality or quantity of a resource, as revealed by the preferences of individuals (so-called willingness to pay or willingness to accept).

Value transfer: allows for existing economic value evidence to be used to estimate the monetary value of environmental effects of STP options. While used extensively and a valuable input to appraisal, it is subject to limitations. Its robustness depends on 'matching' suitable existing valuation evidence to the context of the Severn Estuary. Two approaches are used: (i) bundled approach which uses the change in the area of habitat affected as a proxy for all ecosystem services provided and (ii) single ecosystem service approach which values individual services separately. Currently, only the changes in annual CO_2 equivalent flux are possible within the latter approach.

The flow chart below provides an overview of the value transfer process used in this research. It also shows the key stages in which inputs from the strategic environmental assessment (SEA) team are used.

ES.3 RESULTS

Environmental Change

The data on the environmental change as a result of the STP scheme are based on the final outputs of the SEA process as of 1st March 2010. There has since been an update to these figures released on 16th March 2010. To account for this update the main results tables have been updated throughout the report. However, sensitivity analysis relating to habitats estimates (Section 10) have not been re-analysed following the production of the new intertidal estimates due to insufficient resources in the project budget (and because the changes are minor and do not change the overall conclusions). Data for CO_2 emissions is based on that provided by SEA team on the 23rd March 2010. The, information reported here was gathered through published SEA work and consultation with the SEA team.

The level of reported environmental change as a result of the STP scheme to the area of intertidal, saltmarsh and grassland habitat in the Estuary ranged from a maximum decrease of 16,230ha and 210ha for intertidal and saltmarsh habitat respectively; to a maximum increase of 530ha and 250ha for grassland and saltmarsh habitats respectively. There was no decrease in grassland area with the smallest increase in grassland area across STP options estimated as 50ha. In contrast, there was no increase in intertidal area with the smallest decrease across STP options estimated as 2,790ha however; each of the measures relating to habitat change is still to be approved by the Environmental Workstream of the SEA which is as of 29th March 2010 currently reviewing theme and topic papers. In terms of the central estimate of total flux in annual CO_2 equivalent emissions, values ranged from -376 to -4,139 tCO_{2e} per year across STP options and are subject to differing error bands depending on the habitat change seen with the introduction of each option. The negative sign means decreases in emissions. It is worth noting that all estimates relate to the immediate effect of each option (a single year value for 2020 only). In addition, these estimates are based on the comparison of different optimisation strategies within STP options and do not include the following processes: changes relating to the Nitrogen cycle; the effects of the loss of sequestered carbon as a result of a change in intertidal habitat, saltmarsh and grassland; and ecological changes that are likely to take place an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.

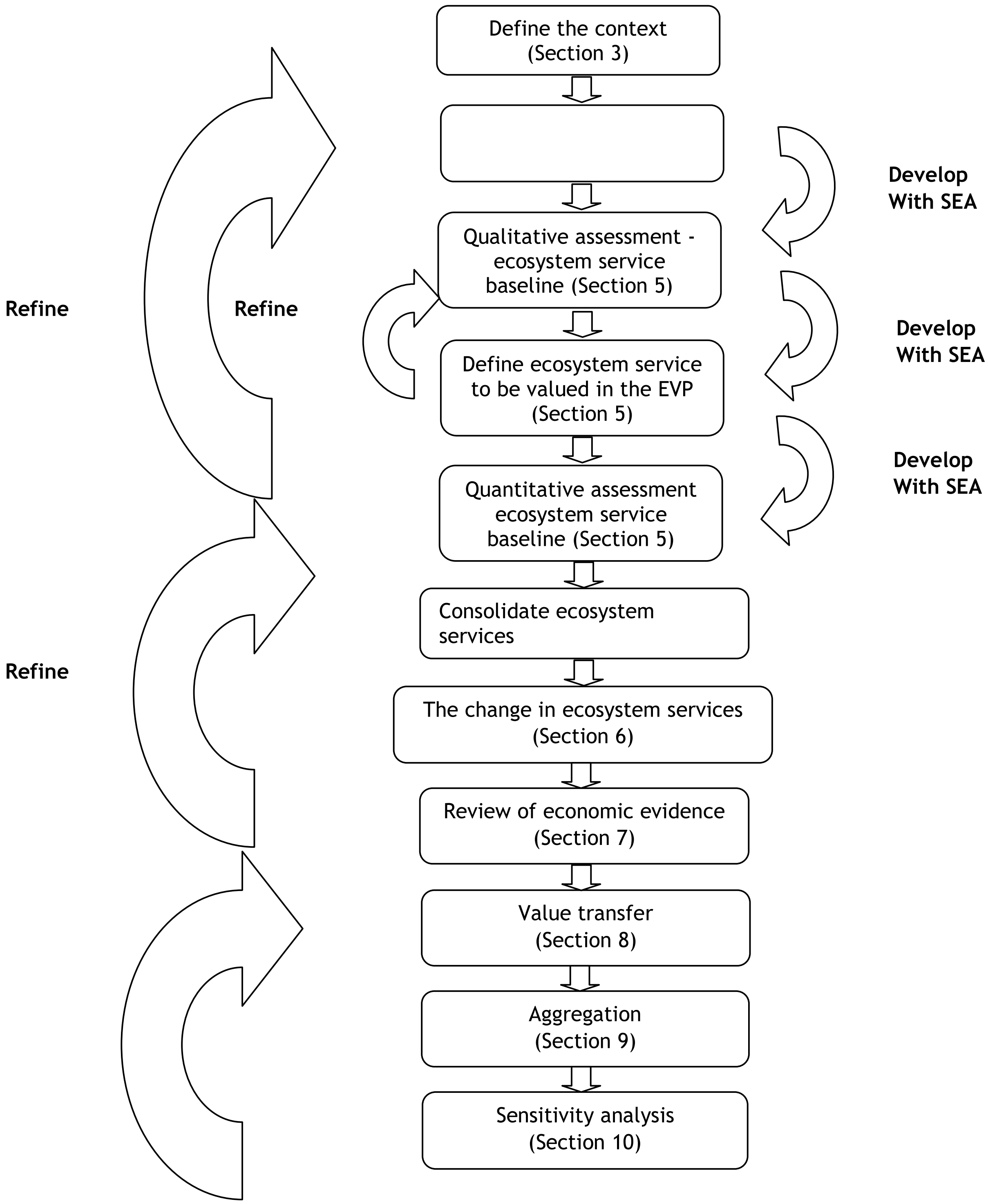
Monetary Values

Monetising the initial estimates of environmental change detailed above through the application of several value transfers led to the estimation of the change in total economic value following the introduction of an STP scheme in 2020 for the lifetime of the STP project assumed to be 120 years. Only rudimentary estimates of total recovery were available in relation to the total change in habitat over 120 years and as such the effect of recovery associated with each option over the lifetime of the project is not evaluated. The total change in economic value ranges from an approximate loss in present value (PV) terms of between £8 and £223 million across the schemes over a project lifetime of 120 years (these results exclude carbon costs). Table E.1, summarises the main results of the study including those currently available in relation to the economic value change for CO_2 equivalent emissions. Including carbon emissions within the calculation for total value change results in a net gain in PV terms from approximately £2.55 to £6.18 million in PV terms at the lowest cost of emissions and a net gain of £10.28 to £23.46 million at the highest cost of emissions. However, given the uncertainty relating to the CO_2 equivalent emissions data these results cannot be used within the decision making process. In addition, to scientific uncertainty there are a number of assumptions and caveats in relation to the application of the value transfer within this particular study (these are listed below), which also add to the uncertainty around the results generated.

Table E1: Summary of present values of selected environmental impacts of STP options in the Bristol Channel (applying standard discount rates, HMT, 2003 in £ millions, rounded to the nearest £10,000)					
Habitat - value type	**Immediate Effect (~2020)**				
	Brean Down to Lavernock Point Barrage (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
MAIN ESTIMATE	PV over the project lifetime £ million (120 years)				
Saltmarsh: low-high	(-2.40) - (-19.17)	+1.51 - (-19.05)	+0.87 - (-19.07)	+0.87 - (-19.07)	+2.66 - (-19.01)
Intertidal mudflat: low-high	(-69.73) - (-203.63)	(-13.61) - (-201.85)	(-11.41) - (-201.78)	(-29.52) - (-202.36)	(-10.93) - (-201.77)
Grassland	+0.07	+0.01	+0.01	+0.01	+0.01
Total change in habitats: low-high	(-72.06) - (-222.73)	(-12.09) - (-220.89)	(-10.53) - (-220.84)	(-28.68) - (-221.42)	(-8.26) - (-220.77)
Carbon costs: low-high	+2.55 - +10.60	+6.18 - +23.46	+2.96 - +11.23	+5.02 - +19.05	+0.56 - +2.13
TOTAL - MAIN ESTIMATE RANGE: low-high	**(-69.51) - (-212.13)**	**(-5.91) - (-197.43)**	**(-7.57) - (-209.61)**	**(-23.66) - (-202.37)**	**(-7.70) - (-218.64)**
Included:	Change in the area of saltmarsh, intertidal and grassland habitats and CO_2 equivalent flux. Saltmarsh and intertidal habitats (which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle) represents area between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT). The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post STP scheme. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. The estimates of CO_2 equivalent flux include: The effect of the loss of potential carbon sequestration, i.e., the change in the amount of habitat (ha) is assumed to lead to a year on year loss of the ability to sequester carbon, Siltation (averaged over the project lifetime to obtain an annual value), and Methanogenesis				
Excluded:	Saltmarsh and Intertidal habitat estimates do not include intertidal areas of sub-estuaries and changes arising from long term morphological processes. Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by each STP scheme. The following factors that are likely to have an effect on the unit economic value estimate but are excluded from the analysis due to lack of data:				

Table E1: Summary of present values of selected environmental impacts of STP options in the Bristol Channel (applying standard discount rates, HMT, 2003 in £ millions, rounded to the nearest £10,000)	
	• Ecosystem services of archaeology and health effects of wetlands, • Population (users and non-users) outside the 50 km diameter area, and • Far field effects (beyond Bristol Channel). Ecosystem services excluded because STP scheme is likely to lead to no change or no significant change in an ecosystem service include: habitat provision for bees, subsistence cropping, subsistence shell fishing and catch, wildfowling, water for industrial cooling, air quality, other recreation, and renewable energy (i.e., fuel for biomass). Ecosystem services included within other technical reports (i.e., aggregate extraction and navigation/port services) are excluded here. The total flux in annual CO_2 equivalent emissions exclude: • Any changes as a result of the Nitrogen cycle, • The loss of sequestered Carbon as a result of a change in intertidal, saltmarsh and grassland, and Ecological changes that are likely to take place where an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.
Caution:	Caution should be used if comparing values between STP options as these represent estimates for the comparison of different optimisation strategies within STP options. As such these values maybe subject to different levels of reliability. In addition different design factors may have been taken into account for different options and current optimal solutions may change. The effects on sequestration and methanogenesis are extremely sensitive to ecological factors which could be altered by different design options/optimisation for each option. Values relating to the total flux in annual CO_2 equivalent emissions should be used with caution as they are subject to high levels of uncertainty. Negative values relating to total flux in annual CO_2 equivalent emission relate to decreases in emissions. The unit values presented here relate to habitat information obtained from the SEA on the 16th March 2010; and CO_2 emission estimates from 23rd March 2010. The values obtained on the 16th March 2010 were updated after the original project cut-off date for inputs, the impact of this update was to change the total value of the change associated with intertidal habitats by +0.2% - -1.6% across STP Options. The affect of these changes has been documented here and within the technical report as the accompanying sensitivity analyses relating habitat estimates have not been updated within the technical report due to the magnitude of the associated change (Steering group meeting 23rd March, 2010).
Sources:	Table 13.1

Ecosystem Valuation Process



Assumptions and caveats

Estimates of intertidal habitat (Black and Veatch, 2010)

All estimates relating to the immediate effect of STP scheme on habitat have been obtained from the SEA team the following assumptions relate to these estimates:

- Total intertidal represents area between the Highest Astronomical Tide (HAT) and the Lowest.
- Astronomical Tide (LAT) and includes saltmarsh, and mudflat which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle.
- Estimates do not include intertidal areas of sub-estuaries.
- Estimates do not include changes arising from long term morphological processes.
- The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post scheme.

Economic values

The key economic value evidence used (Brander et al. 2008) is based on a European wide dataset but not specifically for wetlands in the UK or within the Severn Estuary area. Therefore, the key assumption that had to be made for this value transfer is that the Severn Estuary is a typical European wetland. This is clearly incorrect with the implication that given the unique characteristics of the Severn, the results reported here are significant underestimates. Primary value data fitting the context of the Severn Estuary and the STP options are needed to compare the value transfer results in order to estimate the error bands. In the absence of such data, it is not even possible to know what the appropriate error bands are.

Despite this overarching and crucial caveat, we have undertaken the analysis described above and the following list is the individual assumptions and caveats related to the implementation of the value function. As part of sensitivity analysis, lower and upper bound unit values are estimated using different values for the above factors for intertidal and saltmarsh valuation and also for the CO_2 equivalent flux.

The lower bound estimate comes from the 'low damage scenario' in which all relevant factors are defined so that the current unit value of the Severn Estuary is a lower bound estimate and the unit value of change under each STP option is also a lower bound estimate. In the 'high damage scenario', both the current unit value and the unit value of change are at their highest. In other words, the low damage scenario shows the case of losing a small value from an already low value resource, and high damage scenario shows the case of losing a high value from an already high value resource.

The two scenarios used for unit economic value estimates are defined as follows:
The LOW damage scenario (lower bound damage estimates):

- There are wetlands available within the 50km diameter of the Estuary that could function as substitutes to the Severn Estuary.
- The affected population considered within this estimate relates to the 'local' population only, i.e., towns along the estuary up to Minehead on the English coast and Cardiff on the Welsh coast including: the local and unitary authorities of Cardiff, Newport, Bristol and Bath, and N.E. Somerset.
- The 'average' value estimates are used within the calculation of value change.

- The habitats that remain unaffected in the 'with STP option' case provide all the services they provide today, i.e., each 1 ha of a given habitat that remains continues to provide all its services.
- Central CO_2 equivalent flux in tonnes per year are valued at the lowerbound DECC non-traded unit value in £ per tonne.

The HIGH damage scenario (upper bound damage estimate):

- There are no substitute wetlands available within the 50km diameter area.
- The affected population considered within this estimate relates to the 'regional' population, i.e., the South West Region for England and E. Wales.
- The 'marginal' value estimates are used within the calculation of value change.
- The habitats that remain unaffected in the 'with STP option' case do not provide any of the services they provide today, i.e., due to the changes to the complex nature of the Severn Estuary that exist today, remaining habitats also lose their ecosystem services.
- Central CO_2 equivalent flux in tonnes per year are valued at the upperbound DECC non-traded unit value in £ per tonne.

For the unit values in the current situation, 'low damage' scenario has the same definition as it has for STP options. This is evident in similar unit values for current situation and the individual options, which only differ because of the change in the area of each habitat under the current situation and each STP option. As for the 'high damage' scenario, ecosystem services continue to be provided in the current situation (without the STP option) but are entirely lost in all STP Options. All other parameters of high damage scenario apply in the same way for the current situation as listed above for the STP options. Both damage scenarios use the same unit economic value for grassland. Other sensitivity analyses were also implemented during the study.

Types of habitats and services covered

- Only intertidal (includes: mudflat, sandflat, rock and shingle), saltmarsh and grassland are included in the 'bundled' approach – other potential (positive or negative) effects are excluded due to lack of scientific or economic data. The quantitative assessments of change used for the habitats covered have not been finalised or ratified by the steering group – the implication is that the results are likely to be underestimates;
- The future baseline is assumed to remain unchanged as there is currently only a qualitative description within Black and Veatch (2010) and there is no scientific data relating to the value of potential ecosystem services that maybe provided (without STP) in the future – the implication is that the results are likely to be underestimates;
- There are no specific variables that account for human health values of wetlands archaeological or agricultural values within this function. In the case of the former two services however, both have been identified as less likely to change significantly following the STP scheme, while scientific or other economic data are also lacking for human health values – the implication is that the impact on results is likely to be insignificant;
- Commercial hunting is not present within the Severn Estuary, given that there is only a single coefficient for commercial fishing and hunting –the implication is that the contribution of fishing maybe overestimated but this overestimation is likely to be insignificant;
- The most conservative (lowest) economic value estimates are selected for the Severn Estuary to feed into the function used to estimate of the monetary value of the change in both intertidal and saltmarsh habitat within the Severn Estuary as a result of STP scheme within the 'low' scenario. The (highest) values 'ecologically' are inputted into the function used to estimate of the monetary value of the change in both intertidal and saltmarsh

habitat within the Severn Estuary as a result of STP scheme within the 'high' scenario. – Despite the provision of a range it likely that both results sets will be underestimates; and

- The WTP estimate remains constant over the lifetime of the project. Sensitivity analysis tests this assumption by assuming GDP growth from 2020 to 2140 which therefore increases the per-hectare per year value of both intertidal and saltmarsh habitat over time. The implication for the results reported above is that they are underestimates. The per-hectare per year value of grassland is not changed overtime.

Affected population and its characteristics

- The approximate population within 50 km of the wetland site are accounted for by looking up the populations associated with the main unitary authorities and counties for both the 'local' and 'regional' estimates – in reality there are likely to be further population in the area – the implication is that the results are underestimates;
- The study area is a 50km circle centred in the Severn Estuary. This area was chosen in order to meet the criteria of the Brander et al. (2008) function. However, this is smaller than the SEA team's study area as defined within the initial SEA Scoping report as downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and River Usk. This definition has since been extended in Black and Veatch (2010), however, the exact study area will vary by topic (see pg. 20 Black and Veatch, 2010, for study area definitions for each SEA topic) – the implication is that the results are underestimates (excluding other likely affected population – potentially national population);
- This limitation of the population in both sensitivity analysis scenarios also means that the non-use values are underestimated in the results. Given the uniqueness of the Severn Estuary, exclusion of even a part of non-use values means that the results are underestimates; and
- GDP per capita of the UK in 2020 is used within the calculation (see calculating GDP section), based on an assumed growth in GDP from 2009 to 2020 and constant after that. Although, the starting value is slightly lower than that for the South West (however, the latest data available for this is 2006 on the Eurostat website) and thus a slight underestimate, the 2.5% (EIU, 2009) annual growth rate maybe optimistic leading to a slight overestimate.

Estimates of CO_2-e flux

- The estimate has an error band of that depends on the amount of habitat lost (see Section 10 for additional information relating calculations) the implications of which are that estimations with the highest emission predictions dominate the habitat values calculated within this study.
- In addition, the estimates do not include any changes as a result of the Nitrogen cycle and neither do they include the loss of currently sequestered carbon as a result of a change in the following habitat types, intertidal habitat, saltmarsh and grassland. The results also exclude any ecological changes that are likely to take place when an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration. The implication for the results is that they are likely to be significant underestimate of the carbon emission to the atmosphere.

Construction Impacts

- Construction impacts are excluded from the estimates. Similar economic valuation analysis for large scale water infrastructure projects has shown that construction impacts are a small fraction of the overall environmental and financial costs of a those projects.

However, it is not clear how comparable those infrastructure projects are to the STP options and hence it is not possible to make a comment on the size of this gap in the analysis.

Aggregation

- Assuming that the habitat area will remain at the levels seen immediately following the introduction of an STP scheme and that they will remain constant over time means that potential recovery within the Severn Estuary is unaccounted for within the valuation. Despite this, the aggregated results are still likely to be underestimates given that the environmental change as a result of STP will be irreversible and continue into perpetuity. Rudimentary estimates of recovery are available however, as they cannot be separated into different habitat types, i.e., intertidal, saltmarsh and grassland, these values are not used within our calculations.
- The aggregation over time assumes that the change in habitats and annual CO_2 equivalent flux starts 2020 at the end of the construction period. Thus, until then the value (cost or benefit) of change is assumed to be zero. This is a conservative assumption since the damage in particular will start as soon as the construction starts. The implication for the aggregate results is are underestimates.
- The lower discount rate recommended by the Green Book for intergenerational effects is used in sensitivity analysis (see Section 10). The implication for the above results is that they are underestimates.

Sensitivity Analysis

Given the wide number of different caveats, assumptions and uncertainties listed above a thorough sensitivity analysis was carried out and the following sensitivity tests were completed:

1. The application of an alternative value transfer function for intertidal and saltmarsh habitats;
2. Setting alternative values for: GDP and the population within 50km of the Severn Estuary habitat;
3. Determining the affect of substitute inclusion on values;
4. Comparing the effect of the removal of different ecosystem services following the introduction of an STP option within the Brander et al. (2008) function;
5. Determining the affect of using either the ‘marginal’ or ‘average’ values for habitat change within the Brander et al. (2008) function;
6. Comparing the combined value change estimated for intertidal and saltmarsh habitats to that generated by applying the mean per hectare per annum estimate reported by Brouwer et al. (1999) and Ghermandi et al. (2008); and
7. Varying economic value over time by increasing GDP at 2.5% per year from 2009;

In addition two further sensitivity tests relating to all three habitats included within the ‘bundled’ valuation approach, i.e., intertidal mudflats, saltmarsh and grassland, are:

8. The application of an alternative discount rate, and
9. Estimating the predicted effects of STP scheme on intertidal, saltmarsh and grassland habitats if damage estimates were increased / decreased by 10%.
10. Estimating error bars for CO_2 emissions under differing assumptions for siltation, methanogenesis and annual sequestration.

Of the sensitivity tests completed those in which lower discount rates are applied, affected estimates most with increases in the value of change in excess of 180% for the ‘high’ scenario.

In addition, the application of the Ghermandi et al. (2008) meta-analytic function or the values derived within Brouwer et al. (1999) rather than those derived from Brander et al. (2008) results in increases in per hectare per year values of between 30-70% for the 'low' scenario and an increase of up to ten times when applying the Ghermandi et al. (2008) meta-analysis for the 'high' scenario, this increase is largely down to the fact that ecosystem services are assumed to be unavailable following the STP scheme in the 'high' scenario. Sensitivity analyses conducted in addition to the differing assumptions relating to the 'low'/'high' scenarios affected estimates by less than 10%.

ES.4 COMPENSATORY MEASURES

Currently, only an introduction to the processes associated with the use of different resource equivalency methods which can be used to derive compensatory measures is discussed in this report. Section 11 provides further detail on the ecological and economic methods that are used to assess equivalency between compensatory measures and environmental damage, and how they do or do not apply in the context of the Habitats Directive.

ES.5 CONCLUSIONS

The two main conclusions from the analysis above are that:

- All five shortlisted STP options results in net environmental costs. However, because of all the caveats listed above, what can be estimated here given the currently available quantitative impact and economic value data is very likely to be a significant underestimate, and
- Most importantly, the value transfer and sensitivity analyses are based on the initial assumption that the Severn Estuary is like a typical wetland which is clearly not the right assumption.

This project is possibly the most extensive value transfer applied in the UK. There are, however, several significant caveats that make the results insufficient (on their own) as input to final decision making. The appropriate input for any further analysis should come from a primary valuation study. The recommended approach would be the stated preference method.

1 INTRODUCTION

1.1 Background

The Severn Estuary covers the upper reaches of the Bristol Channel on the west coast of Britain, between South Wales and the South West of England. The estuary provides support for many wildlife species as a result of its 12 metre mean spring tidal range[1] which is one of the largest tidal ranges in the world. As a result of this tidal range the Severn estuary could prove a significant resource for generating low carbon energy through tidal power (potentially contributing 5% of the UK's energy demand (Parsons et al., 2008) and thus helping the UK government make inroads into its ambitious carbon reduction targets[2]. However, the Estuary's unique nature means that there are potentially significant environmental and social effects which may arise as a result of the construction and operation of a tidal power scheme in the Severn Estuary.

The estuary supports populations of wild birds that are of European importance[3] and contains several areas of habitat that are of international importance. These features are recognised by the designation of the estuary as a Special Area of Conservation (SAC), i.e., Severn Estuary/Môr Hafren, and as part of the Natura 2000 Network and also a Special Protection Area (SPA) under the Birds Directive[4]. In addition to these designations the estuary is a Ramsar site due to the importance of the area for migratory fish, its unusual estuarine communities and for supporting important populations of waterfowl[5]. In addition to these and other individual features, the complexity of the entire Estuary system itself makes it a unique environment.

The Sustainable Development Commission (SDC) has examined options for generating electricity from the Severn Estuary tidal resource (see Black and Veatch et al., 2007) and subsequently commissioned the 'Severn Estuary Tidal Power Feasibility Study'[6]. The purpose of the feasibility study is to identify a preferred tidal energy option following an assessment of the costs and benefits (including environmental, social, regional, economic, and energy market effects). In conjunction with public consultation, it will then be determined whether the UK Government could support a tidal energy project in the Severn Estuary and on what terms.

To date an initial assessment of potential tidal power options has been completed with the identification of a set of short-listed options. In conjunction with this a draft version of the 'Severn Tidal Power Strategic Environmental Assessment (SEA) environmental report' being available. In addition a first phase report, the Severn Tidal Power Strategic Environmental

[1] Tidal range – vertical distance between the highest high tidal and the lowest low tide. http://severntidalpowerconsultation.decc.gov.uk/feasibility_study_overview - SDC Report 2007
[2] Specifically an 80% reduction in greenhouse gas emissions by 2050. In addition the draft EU Renewable Energy Directive (CEC, 2008) will require 15% of UK energy generation to come from renewable sources by 2020.
[3] http://www.jncc.gov.uk/page-23
[4] Bird species of importance include; Bewick's swan, Shelduck, Dunlin, Redshank, European white-fronted goose, Gadwall and Internationally important assemblage of wintering waterfowl.
[5] The Ramsar Convention (The Convention on Wetlands of International Importance, especially as Waterfowl Habitat) is an international treaty for the conservation and sustainable utilization of wetlands, i.e., to stem the progressive encroachment on and loss of wetlands now and in the future, recognizing the fundamental ecological functions of wetlands and their economic, cultural, scientific, and recreational value. It is named after the town of Ramsar in Iran. http://www.ramsar.org/about
[6] See: http://severntidalpowerconsultation.decc.gov.uk/ for the feasibility study and consultation.

Assessment Scoping Report[7] focused on setting the context and objectives and establishing the scope and baseline for the SEA of short-listed options.

There are several options for tidal generation in the Severn Estuary. The feasibility study is currently assessing a large barrage, 2 smaller barrages and 2 lagoons. As part of the feasibility study each of these options are being evaluated in terms of their environmental, social, regional, economic, and energy market effects. A number of 'embryonic technologies' are also being assessed. However as these fall outside of the strategic environmental assessment, they are not being considered within this economic valuation study.

The objective of this technical report is to document the research to date on the economic valuation of the effects of the shortlisted options on the ecosystem services of the Severn Estuary. In order to ensure that information from the SEA ahead of their 2010 report was incorporated into this project, two workshops attended by the SEA theme leads, eftec and the project Steering Group were organised in April and July 2009 and further one-to-one contact between the SEA and economic valuation teams was maintained throughout the project.

1.2 Objectives

The key objective of this project (hereto called the ecosystem services valuation project (EVP)) is "*to value the net ecosystem impacts that result from changes in the environment or in key species associated with the Severn Tidal Power (STP) scheme*" the methodology of which must be consistently applied to each of the shortlisted STP options. This work is split into four key components:

1. The definition of an ecosystem services framework (encompassing key species but not limited to them) that accounts for all of the services provided by all habitat types that will be affected by the decision to use tidal power in the Severn Estuary;
2. An assessment of the provision of compensatory measures through valuing the change in ecosystem services such action may provide;
3. Valuing all of the changes in the estuary ecosystem services as a result of each of the short listed STP options: this includes key aspects such as determination of affected populations, the use of value transfer, and treatment of risk, uncertainty and errors. The quantitative information on ecosystem effects comes from the SEA work, and
4. Recommendations that identify where there are gaps in scientific or valuation literature and how these may be addressed through primary valuation study(ies) in the future.

This report presents the work and findings in all these four components as much as the scientific and economic data currently available allow. Minor changes will be possible as further SEA data on the effects become available. However, no new economic value evidence is expected unless a purpose-designed primary valuation study is implemented.

1.3 Structure of technical report

Following this introduction, the rest of the report is organised to reflect the individual steps of the methodology used in this study. The report contains both conceptual discussion (updated as relevant from Interim Report 1) and implementation process and results.

Section 2: Overview of the project methodology - describes the concepts underpinning the EVP work and includes economic valuation, ecosystem services and the value transfer process designed for this study. The section distinguishes two approaches to value transfer used here:

[7] See Severn Estuary Tidal Power Feasibility Study supporting documents – Annex 2: Severn Tidal Power Strategic Environmental Assessment Scoping Report.

(i) the bundled approach which assumes the size (and economic value) of habitats is a proxy for all services that are affected and (ii) single ecosystem service approach which tries to value each service affected.

Section 3: The decision making context – sets out the key objectives for the project in terms of how this project will contribute to the appraisal of the STP options.

Section 4: The definition of the good and the affected population – describes the current and future environmental baseline of ecosystem services of the Severn Estuary and the population likely to be affected by the changes.

Section 5: Qualitative assessment of the change in the provision of ecosystem services – provides a qualitative assessment as to the change in ecosystem services as a result of the STP scheme.

Section 6: Quantitative assessment of the change in ecosystem services- provides the currently available quantitative estimates of ecosystem services which are only available for change in the size and type of habitat change and in the annual carbon flux.

Section 7: Economic value evidence – summarises the studies from the literature that are relevant and indicates which studies are selected for this value transfer and why.

Section 8: Valuing the ecosystem changes for Severn Estuary Tidal Power Options – applies the bundled and single ecosystem service approaches to value transfer using the currently available data.

Section 9: Aggregation – aggregates the annual values from the previous section across the impact types and time.

Section 10: Sensitivity analysis – tests some of the key assumptions and data inputs to the value transfer. This is not a complete sensitivity analysis at present.

Section 11: Introduction to the valuation of compensatory measures – details the different approaches to equivalency that can be used to define compensatory measures.

Section 12: Construction effects – presents the quantitative impact and economic value data on construction effects.

Section 13: Conclusions and Recommendations – summarises the value estimates, lists the caveats and presents some basic design elements of a primary valuation study.

Annex 1: (SEA – EVP) Workshop questions

Annex 2: Updated mapping SEA Receptors: part of (SEA – EVP) workshop 2 presentations

Annex 3: Initial value transfer mapping

Annex 4: Summaries of value evidence used in the value transfer

Annex 5: Single service approach – affected population

A separate summary report is also presented.

2 OVERVIEW OF THE PROJECT METHODOLOGY

The methodology adopted here is a combination of economic valuation and ecosystem services approaches. This Section presents the key concepts in each approach and also sets out the design of the value transfer methodology for the EVP which the rest of the report follows.

2.1 Economic Value

Economic analysis is concerned with measuring the ***wellbeing*** of individuals and overall society. Trade-offs made between different goods and services reveal the value that is placed on those goods and services and their contribution to wellbeing. The existence of a trade-off is the key point; economic value is concerned with what is 'given up' (or 'foregone' or 'exchanged') in order to obtain a good or service, rather than seeking to estimate the absolute value for a resource.

Environmental resources contribute to human wellbeing in several ways and individuals have several motivations for placing a value on these resources. One typology of such values is the Total Economic Value, the components of which are shown in Box 1.

Use value involves some interaction with the resource, either directly or indirectly:

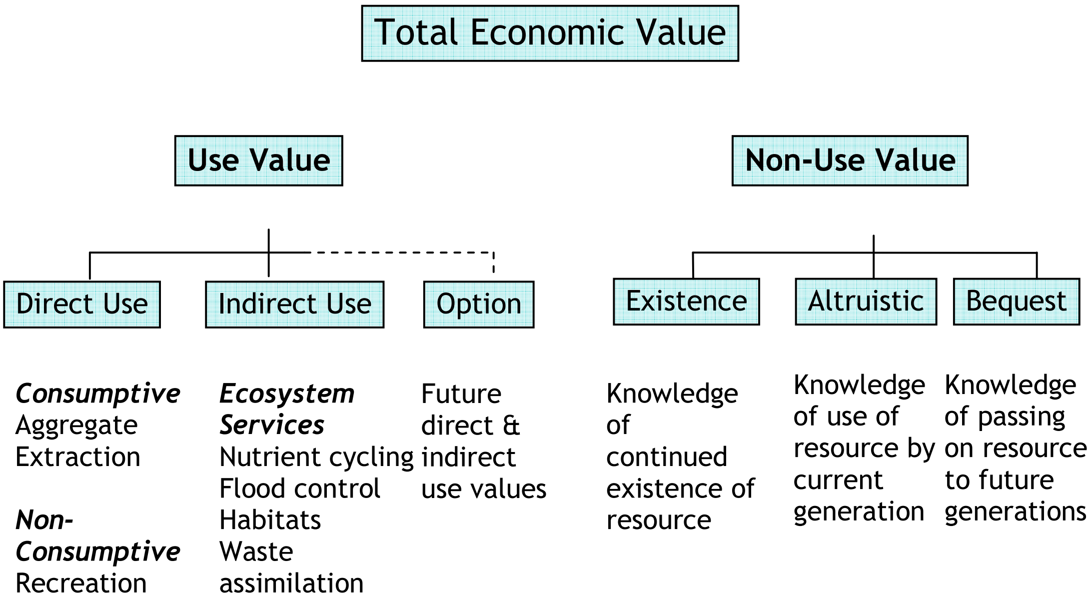
- *Direct use value*: e.g. the use of the estuary in either a consumptive manner, such as industrial water abstraction or in a non-consumptive manner such as for recreation (e.g. fishing).
- *Indirect use value*: The role of the estuary in providing or supporting key (ecosystem) services, such as nutrient cycling, habitat provision, climate regulation, etc.
- *Option value*: Not associated with current use of the estuary but the benefit of keeping open the option to make use of estuary resources in the future. A related concept is ***quasi-option value*** which arises through avoiding or delaying irreversible decisions, where technological and knowledge improvements can alter the optimal management of a natural resource.

Non-use value is associated with benefits derived simply from the knowledge that the natural resources and aspects of the natural environment are maintained, i.e., it is not associated with any use of a resource. For example, individuals place a value to knowing that iconic locations such as the Severn Estuary will be protected even though they have no intention to visit or make any other direct or indirect use. Non-use value can be split into three parts:

- *Altruistic value*: Derived from knowing that contemporaries can enjoy the goods and services related to the estuary.
- *Bequest value*: Associated with the knowledge that the estuary as a resource will be passed on to future generations.
- *Existence value:* Derived simply from the satisfaction of knowing that the estuary continues to exist, regardless of use made of it by oneself or others now or in the future.

Many forms of cultural and spiritual value that may be attributed to resources such as the Severn Estuary are also largely included in this typology through non-use values.

Box 1: Total Economic Framework (TEV)



Economic analysis is ordinarily concerned with a ***marginal change*** in the provision of a good or service. It goes without saying that for a resource such as water its 'total value' is infinite since it is essential for supporting all life. The same is true for many other resources and services supplied by the natural environment. However it is the marginal value of a natural resource (e.g. the ecosystem services provided by the Severn Estuary) that is of relevance when considering trade-offs relating to competing uses of a resource (e.g. supplying habitat for fisheries, the production of renewable energy etc.) and also services that generate wellbeing that rely on the Estuary (e.g. functioning of ecosystems, recreation). The marginal value of an ecosystem service provided by the Severn Estuary is the additional economic value that is generated by the last unit of the services provided by the estuary e.g. water in a particular use, such as abstraction for agricultural use.

When considering trade-offs between different goods and services, if the resource that is given up is money it is possible to express economic value in monetary terms. Money therefore is a 'unit of measure' that enables a common comparison of outcomes in economic analysis; for example comparing the financial cost of measures to reduce diffuse pollution to the benefits of improved water quality.

The trade-off between money and changes in the provision (quantity or quality) of goods and services, i.e., their economic value, is defined through individuals' ***willingness to pay*** (***WTP)*** for securing a gain or avoiding a loss, or their ***willingness to accept compensation*** (***WTA***) for foregoing a gain or tolerating a loss.

2.2 Economic valuation methods

The following valuation methods have been developed to quantify the total, or components of the total, economic value in monetary units:

- ***Market prices***;
- ***Revealed preference methods***; ***and***
- ***Stated preference methods***.

These are appropriate differently for market and non-market goods and services and are outlined briefly below.

Market goods and market prices

Many goods and services, including some provided by the ecosystem services of the Severn Estuary, are ***market goods***. The ***market price*** at which a good is exchanged reveals some information on its economic value. In particular, for the buyer of a good, the price reveals the amount of money the buyer is at least willing to give up to obtain the good. For the seller, the price reveals the amount of money the seller is at least willing to accept as compensation for giving up the good.

Market price information, however, is an imprecise measure of the economic value of a particular good since it may not fully reflect WTP or WTA. For example, many buyers may be willing to pay more than the market price to obtain the good. The difference between the maximum amount a buyer is willing to pay and the actual price paid is termed ***consumer surplus***, reflecting the element of benefit from obtaining the good that is 'gained for free'. Similarly the seller of the good may be willing to accept a lower amount than the market price to give up the good. The difference between the minimum amount a seller is willing to accept and the actual price received is termed ***producer surplus***, reflecting the additional benefit in exchange gained (in effect 'economic profit'). Overall, in the case of market goods and services, economic value (WTP or WTA) is reflected by the market price paid or received plus any consumer or producer surplus.

Where resource inputs are required to produce a market good or service a further concept of economic analysis, termed ***opportunity cost***, is of relevance. The opportunity cost of a resource is the value of the next best alternative use of resource. This concept is central to the notion of ***economic efficiency***, where scarce resources are employed in uses that generate the highest (social) wellbeing.

Non-market goods

Many uses and services supported by environmental resources are not traded in markets and are consequently 'un-priced'. However for ***non-market goods*** the metrics of WTP and WTA are still those of interest. The contrast with market goods is that since there is no price paid for the non-market resource, WTP and WTA are composed wholly of consumer surplus.

The appropriateness of different methods is varied, with some providing estimates of economic value that are more accepted than others. For instance, using ***market prices*** to assess benefits of increased fish stocks in terms of increased revenue from commercial fish catch may be relatively straightforward. But this will also under-estimate the economic value of this benefit, since no account is made for any excess willingness to pay over market price, for the fish themselves, for non-use value reasons or other recreational benefits such as angling.

The following paragraphs describe the types of valuation that can be used along with how they might be applied in the context of evaluating STP options within the Severn Estuary.

- ***Revealed preference methods***: Indirectly estimate the use value of non-market goods and services by observing behaviour related to market goods and services. A classic example is valuing the water environment through the cost (both money and time) incurred in undertaking water-based or water-affected recreation activities, valuation methods include;

- ***Hedonic pricing method*** estimates the use value of a non-market good or service by examining the relationship between the non-market good and the demand for some market-priced complementary good. For example, statistical comparison of the prices of properties located in the area affected by the STP (e.g. landscape or flood risk changes) with identical properties located elsewhere could show the affect of the STP on these properties. Unfortunately, this method requires the change to have taken place previously in order for its effect to be reflected in house buying behaviour and hence is not deemed appropriate in this context.

- ***Travel cost method*** is a survey based technique that uses the cost incurred by individuals travelling and gaining access to a recreation site. For example, travel costs of individuals visiting and participating in recreation (e.g. angling on the Severn Estuary) as a proxy for the recreational use value of that site. In part, travel costs determine the number of visits an individual may undertake and may be seen as the 'price' of a recreational visit to a particular site.

- ***Stated preference methods***: Can estimate the total economic value of non-market goods and services by directly asking individuals, via questionnaire surveys, what they would be willing to pay or accept for a specified change in the provision of the good (note that use value or non-use value components of TEV can be estimated separately or in combination) valuation methods include;

  - ***Contingent valuation:*** a survey-based approach to valuing non-market goods and services. The approach entails the construction of a hypothetical, or 'simulated', market via a questionnaire where respondents answer questions concerning what they are willing to pay (or willing to accept) for a specified environmental change (the trade-offs respondents make constitute the simulated market). In the case of the Severn Estuary one might ask respondents what they would be willing to pay to protect some aspect of the estuary that may be adversely affected by STP.

  - ***Choice modelling*** covers a variety of questionnaire based methods that infer WTP (or WTA) indirectly from responses stated by respondents. Instead of directly asking these measures as in a contingent valuation survey, choice modelling questionnaires present respondents with choices between different options for delivery of a good or service characterised by different levels of a set of 'attributes'. If each option has a 'price' attached (e.g. in terms of increased bills, municipal taxes, entrance fees, etc.), subsequent analysis of respondents' choices reveal their willingness to pay (or accept) for each of the attributes presented to them. For example one might ask respondents to trade-off different 'future' estuary scenarios in which different STP options had been implemented or where none of the options had been implemented.

An alternative to these methods that can be used for primary research is value transfer which is the method used in this study. ***Value transfer*** is defined as the transposition of economic values estimated at one site (the 'study' site) to another site (the 'policy' site). The study site refers to the site where the original study took place, while the policy site is a new site where information is needed about the economic value of similar benefits. In the context of this project, the policy site is the Severn Estuary. The rationale for value transfer is that using previous research results saves effort and expenditure involved in undertaking original research. The result will never be as good as an original valuation study, and the key to its application therefore is to assess acceptable errors and the impact thereof on the CBA outcome.

In practice, there are two main approaches to value transfer, which differ in the degree of complexity, the data requirements and the reliability of the results, namely:

(i) Unit value transfer	***(ii) Value function transfer***
value estimate [e.g. £/ha] ⇨ STP option appraisal [£/ha]	valuation function [e.g. £/ha = f (X_{SS})] ⇨ STP option appraisal [£/ha = f (X_{PS})]

Where X is a set of factors that are found to statistically influence economic value, PS is the policy site, i.e., the Severn Estuary, SS is the study site and f signifies 'function', the coefficients of which show the scale and direction of the relationship between individual factors in the set X and the value estimate (here £/ha but can be in other units). Both approaches are applied here.

Unit value transfer

Unit value transfer can take one of three forms:

- *Unadjusted unit value transfer from a single study*: typically a mean WTP estimate and confidence intervals are transferred. A range of values from a study are used to predict the economic value of the change in provision of the policy good. Ideally the selected study focuses on the same good and is carried out at the same location although at a different point in time. However, and more commonly, studies from a different yet comparable location and time are used for such transfers.
- *Unadjusted unit value transfer from multiple studies*: mean WTP estimates (and confidence intervals) from two or more studies may be used to specify a range of values or calculate an average value for the change in the provision of the policy good. This can include the use of mean values from a meta-analysis study, which summaries economic value estimates across multiple studies.
- *Adjusted unit value transfer*: mean WTP is adjusted to account for the differences between the study and policy goods with regards to one or more factors that are expected to influence economic value estimates of the policy good. A common adjustment factor is the ratio of income of the population at study and policy sites. Income is used as it is known to be a significant factor and relatively easy to find data on.

Here we collated value estimates for most of the individual ecosystem services likely to be affected by the STP options. However, due to gaps in quantitative effect data, these are not yet used. Further revisions will be provided when relevant new effect data become available.

Value function transfer

Value function transfer allows the analyst to control for a set of factors found to explain variation in economic values (for the study good), such as the socio-economic characteristics of the affected population, characteristics of the good, the change in its provision and the availability of substitutes:

- *Value function:* is transferred from the study good context to predict mean value for the policy good. The coefficients of the explanatory variables in the study good value function are multiplied by the average values of these factors in the policy good context to predict an average value. Adjusted value function approaches are also possible where the function coefficients can be based on multiple data sources (e.g. coefficient values are drawn from multiple studies).

- *Meta-analysis function*: is estimated on the basis of results from multiple valuation studies. This approach accounts for a broader base of evidence in predicting the value of the change in provision of the policy good. As with value function transfer, the average values of the explanatory factors in the policy good context are multiplied by the meta-analysis function coefficients.

In adopting a unit value transfer approach, analysts assume that the preferences of the average individual for the change in provision of the study good are an adequate description of the preferences of the average individual in the policy site context. This is clearly a simplifying assumption and, in practice, a series of factors is expected to influence economic values in a specific circumstance including:

- The characteristics of the good and the level of its provision;
- The characteristics of the affected population;
- The availability of substitutes for the good; and
- The context in which the good is provided (the 'market construct').

Not controlling for differences in the above factors between the policy and study goods will likely imply a greater uncertainty in the accuracy of the results of value transfer. Whether a higher level of uncertainty can be accommodated depends on the requirements of decision-context.

Where there is the need to control for multiple factors in value transfer, an appropriately specified and executed function transfer approach can be the most appropriate method. Value function transfer applies information from the study good context to the policy good context regarding the relationship between economic value and a number of explanatory factors. For example, a WTP function relates WTP to parameters such as the characteristics of the good and the change in its provision, socio-economic and demographic characteristics of the affected population, patterns of use and the availability of substitutes:

$$WTP_{PG}\,(£/hh/yr) = \alpha_{SG} + \beta 1_{SG}\, X1_{PG} + \beta 2_{SG}\, X2_{PG} + \ldots + \beta n_{SG}\, Xn_{PG}$$

The α and the βs are coefficients from the WTP function estimated for the study good. The Xs are the values of the explanatory variable for the policy good (e.g. average household income, distance from site, number of substitutes, etc.). The values of explanatory variables should be derived from the supporting data for the policy good.

Although value transfer is used extensively in practice and is certainly a valuable input to appraisal, its limitations should be recognised. The robustness of value transfer depends on the success of the 'matching' of the Severn Estuary in terms of its environmental and socio-economic circumstances to an appropriate study site and the quality of the original economic valuation study. Where there are significant differences between the study site and the Severn Estuary, a number of strategies may be employed that 'adjust' economic value estimates accordingly including for example accounting for differences in income.

Section 2.4 shows how value transfer is designed for this study.

2.3 Ecosystem Services

The ***ecosystem services approach*** is a term that has come to describe a basis for analysing how individuals are dependent upon the condition of the natural environment. The approach explicitly recognises that ecosystems and the biological diversity contained within them contribute to individual and social wellbeing and that this contribution extends beyond the provision of goods such as fisheries or water for use in agricultural and industry to services which support life by regulating essential processes such as climate. Ecosystem services are commonly divided into four categories (Defra, 2007):

- ***Provisioning services***: refers to products that are obtained from ecosystems. In the case of the Severn Estuary these might include fish, grazing areas for sheep and cattle, shell fish, aggregates, and water for abstraction. In the context of STP, provisioning services include the following:

    - Food - commercial fish catch; shellfish catch; grazing for cattle and sheep; subsistence level fishing & cropping; arable land; and wildfowling.
    - Fibre/materials - that can be used within manufacturing or to produce final products such as clothing etc. for example, reeds, wood, leather, aggregates.
    - Land - arable land, development land – land that could be used for the development of buildings (any type) and developed land – land in an advanced state, i.e., used to locate buildings, or cultivated in some way, i.e., changed from its original state.
    - Fuel - renewable energy - energy from a natural resource that is replaced naturally or controlled carefully allowing for its continual use without depletion.
    - Water – water for industrial usage; water for agricultural use; regenerative services, – i.e., used to develop and grow e.g. plants; maintenance of surface fresh water stores, e.g. the replenishment of ponds and still water bodies during high tides; groundwater replenishment – for example the leaching of water through the soil at periods of high tide.
    - Natural medicine – products existing in nature e.g. plants used to treat or potentially treat illness and injuries.
    - Biochemicals and genetics – study of living organisms and their properties and biological characteristics.
    - Ornamental resources – resources that are used as decoration rather than for a practical purpose.

- ***Regulating services***: refers to the benefits obtained from the regulation of ecosystem processes e.g. carbon sequestration, flood protection, waste management, and erosion control.

    - Climate/climate change - the regular pattern of weather conditions (or change) including carbon sequestration - The natural removal of carbon from the atmosphere by the soil and plants.
    - Air quality – i.e., the potential of increases in emissions from increased congestion as a result of construction.
    - Water regulation - flood prevention and aquifer recharge.
    - Water purification & waste management - filtration of water; detoxification of water and sediment – to remove toxins from or purify water &/ or sediment, i.e., removal of harmful chemicals or sewage.
    - Erosion regulation – regulation of soil destruction through wind, rain and waves.
    - Pollination – putting pollen into plants or flowers to produce seeds including habitat for bees (contribute to the pollination process) – self explanatory.
    - Bioremediation of waste - Waste settling on the seabed is stored, assimilated, diluted and recycled through chemical re-composition.

- ***Cultural services***: refers to the non-material (use and non-use) benefits that individuals obtain from ecosystems, for example through recreational use, heritage assets and practices or cognitive development.

    - Spiritual, religious, cultural heritage - archaeological ruins (both on land and in water), (historical not recreational value) - the remains of buildings and objects of past cultures and heritage fishing – fishing with 'traditional' techniques.
    - Recreation and tourism – activities that individuals do for enjoyment & business activity connected with providing accommodation, services and entertainment for people who are visiting a place for pleasure including angling (freshwater migratory and coarse, estuarine and sea), bird watching – self explanatory, hiking, scuba diving – self explanatory, sailing, canoeing windsurfing etc., holiday destination – visitation of a particular area as part of a holiday, visiting archaeological ruins (both on land and in water), (recreational value) – visitation of the remains of buildings and objects of past cultures, golf courses on dunes – self explanatory.
    - Landscape and amenity - views and visiting the Severn bore, – i.e., visiting the strong, high wave that rushes along the estuary from the sea at particular times of the year

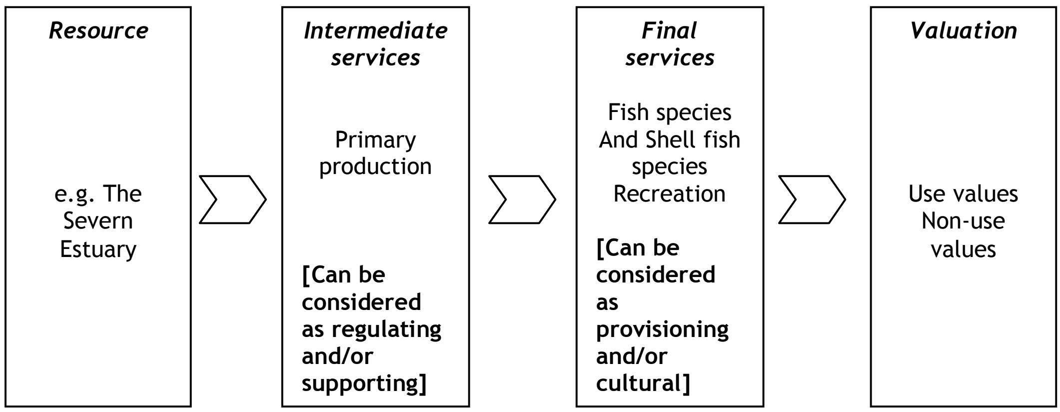
- ***Supporting services***: refers to services that are necessary for the production of all other ecosystem services. They differ from the other services in that their impacts on people are either indirect (via provisioning, regulating or cultural services) or occur over a very long time. Examples of these services include soil formation, nutrient cycling, and primary production. How these relate to further services can be shown by considering the services of 'nutrient cycling' which can result in the outcome of clean water. But while nutrients cycling and clean water provision are processes, only the latter is also a benefit (e.g. for household drinking water supply, abstraction for industry or agriculture and so on).

    - Soil formation and retention – the production of soil and the process by which it is held in place.
    - Cycling processes e.g. nutrient cycling or the movement of nutrients through an ecosystem.
    - Primary production - primary production is the production of organic compounds from atmospheric or aquatic carbon dioxide.
    - Habitat provision - the supply of vital habitat for different species.

The example of supporting services highlights the need to distinguish between services in themselves (***intermediate services***) and outcomes that affect wellbeing (***final services***), particularly with respect to the risk of 'double-counting' (or 'over-valuation'). When considering ecosystem services, in the context of evaluating STP options for the Severn Estuary this project will focus on outcomes in terms of benefits to human populations, rather than services and functions that contribute to those outcomes (see Box 2.1 for an example of this approach). The focus within this study is on the 'final' services that directly impact on individuals' wellbeing and that are perceptible to them. This does not mean that intermediate services, such as regulating and supporting services, do not have economic value. The analysis is organised so that the contribution of these intermediate services to final services is identified and included in the valuation of the latter (Section 5).

Box 2.1: Applying an ecosystem services approach to the valuation of STP options

Luisetti et al. (2008a) provide an example of how an ecosystem services approach can be used to establish the benefits to user and non-user populations that arise from services and functions provided by the natural environment. The framework applied distinguishes between intermediate services and final services or outcomes that generate economic value ('benefits' to human populations), which is particularly important with respect to avoiding double-counting when valuing ecosystem services. The diagram below shows the example of fish and shellfish provided within the Severn Estuary.



Source: adapted from Luisetti et al. (2008a).

2.4 Value transfer for the STP options

Whether it is a unit or a function transfer, value transfer involves a number of steps. The following steps are taken from the ongoing value transfer guidance work for Defra (forthcoming 2009) and also form the basis of the process used for this project as shown in Figure 2.1. The 'good' in this context refer to the ecosystem goods and services of the Severn Estuary.

<u>Step 1: Establish the decision-context (Section 3 of this report):</u> establishes why a valuation approach should be used within the context of comparing STP options.

<u>Step 2: Define the good and affected population (Section 4):</u> relates to the identification of ecosystem services that are provided by the Severn Estuary both currently (the status quo – the current baseline) and those that might be provided in the future under a dynamic baseline. This step also defines how to define and account for the affected population.

<u>Step 3: Define and quantify the change in the provision of the good (Section 5 & 6):</u> identifies the expected scale and direction of the change in ecosystem service provision under the STP options compared to, ideally, a dynamic baseline.

<u>Step 4: Identify and select monetary valuation evidence (Section 7):</u> reviews the existing literature and selects the appropriate valuation evidence (unit values or value functions).

<u>Step 5: Transfer evidence and estimate monetary value (Section 8):</u> combines the data on the change in ecosystem services and economic value evidence to estimate the value of the environmental effects of STP options.

Step 6: Aggregate values (Section 9): estimates the value aggregated over different environmental effects, affected population and over time.

Step 7: Conduct sensitivity analysis (Section 10): tests the influence of the key assumptions made in all the steps above on the value estimates in Steps 5 and 6. Uncertainty surrounds both scientific and economic data and hence assumptions for both need to be tested.

Step 8: Reporting (Section 13): presents the overall process and results. The entirety of this report and its Annexes are the product of this step.

This approach to value transfer combines the ecosystem services and economic valuation (value transfer) approaches. Figure 2.1 shows the above steps in the form of a flow chart to show the iterative nature of the approach. An initial look at the ecological evidence allows for the definition of an ecosystem services framework and typology in which qualitative effects of STP options can be described. These effects are then quantified through further review of data and expert workshops.

Scientific input for the project came mostly from consultation with the SEA team mainly through two workshops: on April 21st and July 3rd 2009. Annex 1 presents further detail on these workshops. Table 6.2 shows a list of all data of interest to the EVP and its current and future availability following the SEA. The team provided inputs directly via the use of spreadsheet templates through several iterations of the project. The collaboration between the SEA and EVP teams has given the EVP the opportunity to ensure that the SEA information is in a form that can feed into ecosystem services and value transfer frameworks. In fact, such close consultation between the technical and economics experts is necessary even if the mismatch of their respective work programmes is not an issue.

Quantitative impact information is then matched to the economic value evidence available from the literature. The matching of the quantitative evidence on effects and economic value evidence from the literature is done at two levels:

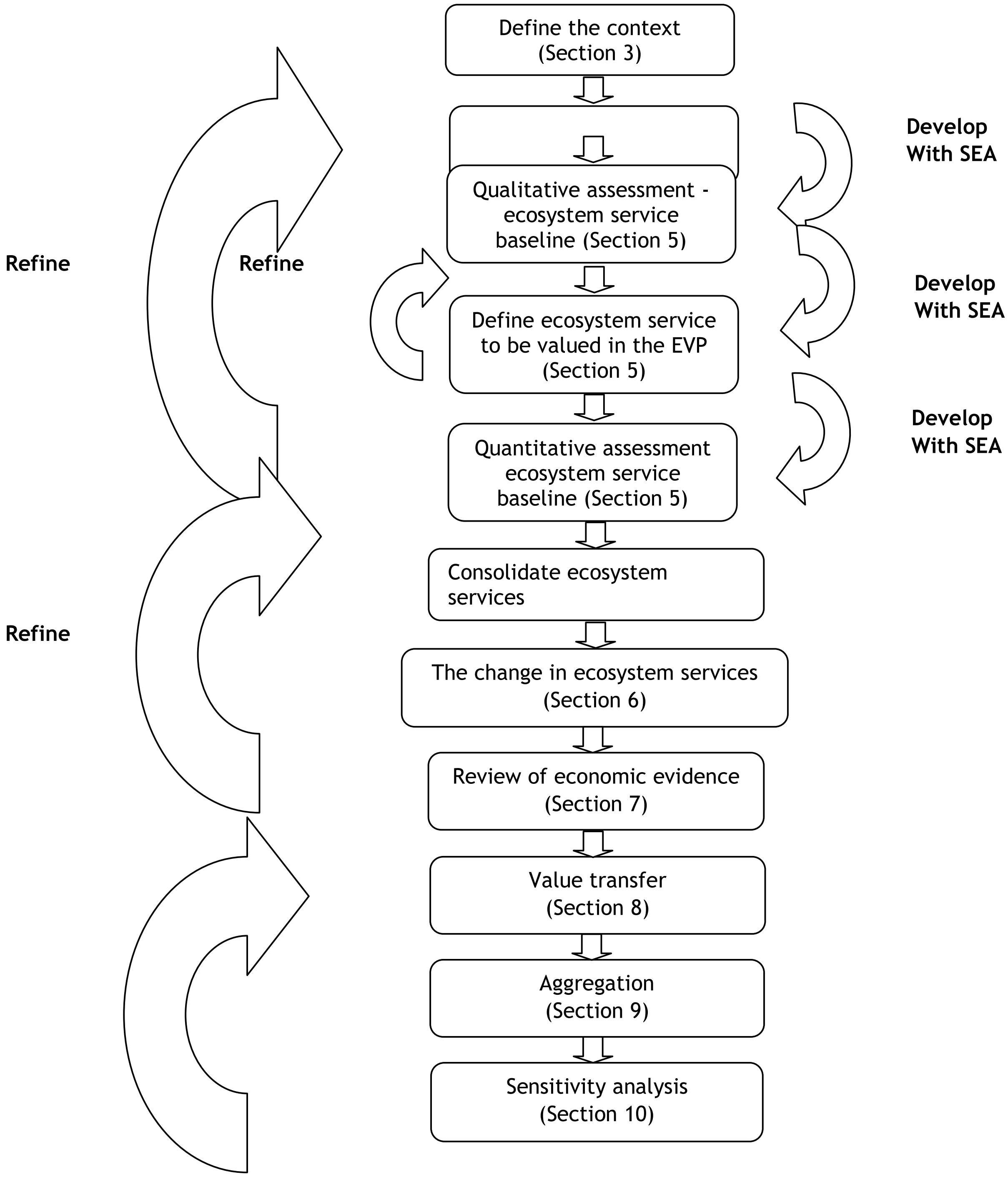
(1) **the 'bundled' approach** uses the size of each habitat type impacted on as a proxy for the value of the effects on all ecosystem services provided by that habitat. The valuation literature used for the 'bundled' approach tends to rely on studies that consider the ecosystems in their entirety rather than the valuation of specific ecosystem services.

(2) **the 'single service' approach** considers the value of each ecosystem service separately which requires economic valuation evidence for each 'final ecosystem service' within a particular habitat type. Here, only the change in the annual CO_2 equivalent flux is possible to estimate and value separately as a single service.

There are advantages and disadvantages associated with each approach. The bundled approach may potentially over simplify the 'policy good' due the reliance on generic economic values associated with particular habitats. Alternatively, the single service approach may potentially double count and the reliance on patchy economic value evidence could potentially over estimate values.

Thus to ensure the most robust value transfer, both approaches are investigated in this study. The former is more complete since there is more economic value evidence available and quantitative effects at the ecosystem service level are currently unavailable (see 6.2 in Section 6 for details regarding the timing for information at the ecosystem service level).

Figure 2.1: Process of Ecosystem Valuation for Severn Estuary Tidal Power Options



3 DECISION MAKING CONTEXT

The UK became the world's first country to put in place legally binding carbon budgets in order to commit to the reduction of the UK greenhouse gas emissions by 80% by 2050. Given the large tidal range of the Severn Estuary, the area has the potential to contribute significantly to the UK government's target of producing 15% of all energy from renewable sources by 2020[8]. However, the Estuary also provides many other ecosystem services. Therefore, the decision as to whether to go ahead with tidal power requires trading off pros and cons of different options and the baseline (current or dynamic future).

'Typical' and inter-related decision-making questions that might arise in relation to such a trade off include:

Policy and project (infrastructure) appraisal

(i) Is STP worthwhile?

(ii) If so, which STP option should be chosen among the set of alternatives?

Prioritization issues

(iii) How important is the generation of low carbon energy relative to biodiversity conservation?

Assessment of Environmental Damage

(iv) What is the value of environmental damages that might result from the STP scheme?

(v) What scale of compensation (or compensatory measures) for damage is justified?

The first two questions are also those that ***cost benefit analysis*** as recommended by HM Treasury Green Book (HM Treasury, 2003 and subsequent updates) is designed to address. The damage assessment category is an input to cost benefit analysis. There may also be scope to use this work as an input to determining the appropriate type and scale of compensatory measures as they are defined in the Habitats Directive. However, it is important to note that any measures will need to be compliant with the relevant directives and legal frameworks.

EVP is designed to produce economic value of the environmental effects of the STP to assist with answering the above questions, of which only (iv) can be directly answered in this study. The other questions require further data (e.g. capital and operating costs of STP for (i) and (ii)).

EVP uses the environmental impact information related to the following five specific STP options are being considered[9]:

1. **Shoots Barrage** (B4) – located near the Severn road crossings;
2. **Beachley Barrage** (B5) – slightly smaller and further upstream than the Shoots Barrage (and upstream of the Wye);
3. **Welsh Grounds Lagoon (L2) -** an impoundment on the Welsh shore of the Estuary between Newport and the Severn road crossings;

[8] http://www.decc.gov.uk/en/content/cms/news/pn047/pn047.aspx

[9] http://severntidalpowerconsultation.decc.gov.uk/news/severn-tidal-power-consultation-launched

4. **Bridgwater Bay Lagoon** (L3d) – an impoundment on the English shore of the Estuary between Hinkley Point and Weston Super Mare; and
5. **Brean Down to Lavernock Point Barrage** (B3) - located between Brean Down and Lavernock Point (also known as the Cardiff to Weston Barrage).

The titles and the codes in brackets used above match the titles used in the SEA reports. The change in the size of the affected habitat types (for the bundled value transfer) and the change in the annual CO_2 equivalent flux are possible to differentiate.

4 DEFINITION OF THE GOOD AND THE AFFECTED POPULATION

This section defines the good (the Severn Estuary and the ecosystem services it provides) and the population affected by the changes to the Estuary's ecosystem services due to STP options.

4.1 The good

The ecosystem services framework presented in Section 2 is populated here using the data from the SEA phase 1 documentation and consultation with the SEA team (see Table A3.1 in the Annex 3 for SEA receptor and ecosystem services mapping) to identify the current and potential 'final' ecosystem services that the Severn Estuary provides.

The habitats which are likely to be impacted by the STP options are the following:

- Wetlands (inc. lakes, ponds, reed bed, bog) - Wetlands are defined as areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing. In this typology we only consider freshwater wetlands[10] (saltwater wetlands are covered under the intertidal category), along with lakes and ponds.

- Freshwater rivers and streams – bodies of fresh water flowing in channels regardless of their size.

- Intertidal habitat: ecosystems between the low and high tide lines, e.g. mudflat etc. Highly productive areas which support large numbers of predatory birds and fish[10]. *"Mudflats are sedimentary intertidal habitats created by deposition in low energy coastal environments, particularly estuaries and other sheltered areas. Their sediment consists mostly of silts & clays with a high organic content. Towards the mouths of estuaries where salinity and wave energy are higher the proportion of sand increases. Mudflats are intimately linked by physical processes to, and may be dependent on, other coastal habitats such as soft cliffs and saltmarshes. They commonly appear in the natural sequence of habitats between subtidal channels and vegetated saltmarshes. In large estuaries they may be several kilometers wide and commonly form the largest part of the intertidal area of estuaries".*"[11]

- Saltmarsh habitat: *"Coastal saltmarshes in the UK (also known as 'merse' in Scotland) comprise the upper, vegetated portions of intertidal mudflats, lying approximately between mean high water neap tides and mean high water spring tides. For the purposes of this action plan, however, the lower limit of saltmarsh is defined as the lower limit of pioneer saltmarsh vegetation (but excluding seagrass Zostera beds) & the upper limit as one metre above the level of highest astronomical tides to take in transitional zones. The development of saltmarsh vegetation is dependent on the presence of intertidal mudflats"*[12].

- Grassland habitat: Only grassland habitat change is included within the terrestrial habitat category (which also includes dunes, cliffs and woodland) as this was the only habitat type likely to change as a result of the STP scheme (see Section 6). Grasslands are defined as a combination of lowland dry acidic and lowland calcareous grassland – *"Lowland calcareous grasslands are developed on shallow lime-rich soils generally overlying limestone rocks,*

[10] http://www.naturalengland.org.uk/ourwork/conservation/designatedareas/ramsars/default.aspx
[11] http://www.ukbap.org.uk/library/UKBAPPriorityHabitatDescriptionsfinalAllhabitats20081022.pdf
[12] http://www.ukbap.org.uk/library/UKBAPPriorityHabitatDescriptionsfinalAllhabitats20081022.pdf

including chalk. These grasslands are now largely found on distinct topographic features such as escarpments or dry valley slopes and sometimes on ancient earthworks in landscapes strongly influenced by the underlying limestone geology. Lowland acid grassland typically occurs on nutrient-poor, generally free-draining soils with pH ranging from 4 to 5.5 overlying acid rocks or superficial deposits such as sands and gravels. It often occurs as an integral part of lowland heath landscapes"[13].

- Water column & Sub-tidal (inc. reefs, sandbanks, sea grass) – habitat which is covered by water.

Table 4.1 shows the status quo (current and potential) of the ecosystem services provided by these habitats. The table uses the following notation:

(●) indicates that a service is provided and currently of importance;
(o) indicates a potential service;
(-) indicates that a services is not provided, and
(?) where whether a service is provided or not is not known.

The table represents the typology of ecosystem services that are taken into account in the ***environmental baseline***, i.e., the important ecosystem services provided in the status quo. In fact, in addition to the status quo, the environmental baseline should also include information about what will happen in the future *with* and *without* the STP options.

Without the STP some services could improve, some decline and some services that are currently not provided may become available or vice versa. For the without case we assume that the status quo continues into the future. We do not have enough data and what there are, are surrounded by huge uncertainty about what will happen into the future without STP so we assumed that the status quo will continue as is. This means that if a service that is currently not provided becomes available in the future (without the STP), the loss of this potential service is not included in the impact assessment of the STP options.

We also do not know what the baseline (without STP) will be when the effects of climate change and the effects of current nature or other management and action plans are taken into account. However, the SEA for the effects of the STP options (the 'with STP' case) takes note of these in estimating a 'net' effect (see Section 5).

[13] http://www.ukbap.org.uk/library/UKBAPPriorityHabitatDescriptionsfinalAllhabitats20081022.pdf

Table 4.1: Ecosystem services within the Severn Estuary: typology

Ecosystem services		FW Wet-lands	FW Rivers & Streams	Inter-tidal	Salt marsh	Sub-tidal	Terrestrial
PROVISIONING							
Food	Commercial fish catch (F)	-	●	○	-	●	-
	Shellfish catch (F)	-	-	○	-	○	-
	Grazing for cattle and sheep	-	-	-	●	-	○
	Subsistence level fishing & cropping (F)	○	○	○	○	○	○
	Wildfowling	-	-	●	●	-	●
Fibre/ materials	Fibre and construction prods (e.g. reeds, wood, leather, aggregates)	○	○	○	○	●	○
	Arable Land	-	-	-	-	-	●
	Development Land	-	-	-	-	-	●
	Developed Land	-	-	-	-	-	●
Fuel	Renewable energy (F)	○	○	○	○	●	●
Water	Water for industrial usage	-	○	-	-	-	-
	Water for agricultural usage	○	●	-	-	-	-
	Regenerative services	○	○	○	●	●	●
	Maintenance of surface FW stores	○	○	-	-	-	-
	Groundwater replenishment	○	○	-	-	-	-
Natural medicines	Natural medicines	○	○	○	○	○	○
Biochemicals	Biochemicals and genetics	○	○	○	○	○	○
Ornamental resources	Ornamental resources	○	○	○	○	○	○
REGULATING							
Climate/climate change	C sequestration (F)	○	○	○	●	●	●
Air quality	Air quality	-	-	-	○	○	○
Water reg.	Flood protection	●	●	●	●	-	○
Water purification & waste management	Filtration of water	●	●	○	●	●	○
	Detoxification of water and sed.	●	●	●	●	●	-
Erosion regulation	Erosion regulation	-	○	●	●	●	●
Pollination	Habitat for bees	○	○	-	●	-	●
Bioremediation of waste	Beach cleaning? (F)	-	-	○	○	-	-
CULTURAL							
Spiritual, religious, cultural heritage	Archaeological ruins (F - historical not recreational value)	●	-	●	?	-	●
	Heritage fishing	-	●	-	-	●	-
Recreation and ecotourism	Freshwater angling (migratory)	-	●	-	-	-	-
	Freshwater angling (coarse)	-	●	-	-	-	-
	Estuarine & sea angling	-	-	●	-	●	-
	Bird watching (F)	●	●	●	●	-	●
	Hiking	●	●	●	●	-	●
	Diving	-	-	-	-	○	-
	Sailing, canoeing, surfing etc	-	●	-	-	●	-
	Holiday destination (incorporates views) (F)	●	●	●	●	●	●
	Archaeol. ruins (F - rec.value)	●	-	●	-	-	●

Table 4.1: Ecosystem services within the Severn Estuary: typology

Ecosystem services		FW Wet-lands	FW Rivers & Streams	Inter-tidal	Salt marsh	Sub-tidal	Terr estri al
	Golf courses on dunes (F)	-	-	-	-	-	○
Landscape and amenity	Views (part of rec. above) AAF	●	●	●	●	●	●
	Visiting the Severn Bore	-	-	-	-	●	-
SUPPORTING							
Soil form. & retention	Soil formation and retention	○	-	-	○	○	●
Cycling processes	Cycling processes	●	●	●	●	●	●
Primary production	Primary production	●	●	●	●	●	●
Habitat provision	Habitat provision	●	●	●	●	●	●

F – Final service, AAF – Already accounted for elsewhere in the table, FW – fresh water.

4.2 Defining the affected population

Determining the population which will be affected by a change in the provision of the goods and services of concern is crucial for estimating the aggregate economic value of environmental costs and benefits. In fact, even if it is not possible to estimate the monetary value of a change in provision, consideration of the affected population (e.g. the number of households or visitors) can be valuable for providing an indication of the significance of gains and losses in social wellbeing. In accordance with the TEV framework, two principal population groups may be identified:

- ***Users***: often this population group is readily identified as it consists of those making direct use of a resource, for example all visitors to the Severn Estuary (so long as visit data are recorded). It also includes those deriving indirect use values, for instance in terms of flood protection benefits within the area. Different elements of use value can be relevant at different spatial scales; recreation values may only be relevant at a local level, while others such as flood protection may confer benefit on a larger regional scale. Indirect use values in terms of carbon storage and sequestration are relevant at a global scale; that is reduction of carbon emissions benefits not only a regional and national population but the global population.

- ***Non-users***: this refers to the population group that derives some wellbeing from a resource even though they do not make direct or indirect use of it. Instead economic values are associated with altruistic, bequest and existence value motivations. The Severn Estuary for example provides habitats for many migratory fish and important bird species for which individuals may hold non-use values. Indeed, there may be non-use values associated with the Severn Estuary itself. There are no rules for determining who is likely to hold non-use values and hence it is usually not possible to define non-user population ex ante. It is an empirical finding.

Combining affected users and non-users results in the identification of the ***economic jurisdiction*** that is relevant to a given decision-making situation. The economic jurisdiction is a spatial area the population of which is found to hold positive economic values for the good in question, i.e., the Severn Estuary in this case. This jurisdiction may not necessarily match well with administrative boundaries. However, since the emphasis of the EVP is to account fully for use and non-use values; economic jurisdiction is the relevant consideration when establishing the extent of the affected population.

Given the scale of the Severn Estuary, it is likely that the affected population will be the entire UK population which may hold non-use values. Given the lack of theoretical certainty about the size of non-use population, this is an empirical issue which needs to be address by a primary valuation study, if one is undertaken.

Both the bundled and single service approaches require a more specific definition of the affected population and in doing so create the potential for both under and over estimation. These are further discussed in Section 6.

5 QUALITATIVE ASSESSMENT OF THE CHANGE IN PROVISION OF ECOSYSTEM SERVICES

This section presents the initial qualitative assessment of the changes in the ecosystem services provided by the Severn Estuary. This leads to a consolidation of the ecosystem services due to some services not being present or not being affected by STP. It is this consolidated list that is taken forward for value transfer.

5.1 Qualitative assessment and changes over time

Following the outputs of workshop one with the SEA team, theme leads reviewed the qualitative scale and direction of excepted ecosystem service provision change under the assumption of STP with 'engineering' mitigation such as the provision of locks, but without the provision of offsetting and compensatory measures. The main areas of uncertainty with regard to ecosystem service provision relate to some of the following issues.

i. The difference between up and downstream effects, and
ii. Assumptions relating to environmental quality following the STP scheme.

The Table 5.1 (in the Table 5.2.xls spreadsheet) identifies the changes in final ecosystem service provision qualitatively using the following categories to describe the direction of the affect on ecosystem services and the scale of the impact, with a positive sign indicating that the impact will result in a higher level of ecosystem service provision and a negative sign indicating that the level of service provision is expected to decrease. This spreadsheet represents the early indications of the likely impact and is not approved by the statutory advisors.

The effects of the STP options will have a changing profile over time involving potentially significant effects during construction, decommissioning and operation periods (Black and Veatch, 2010). The time profile discussed with the SEA team in our second joint workshop includes the following:

2009:	Current situation – ecosystem service provision at today's levels
2014 onward:	Future baseline – ecosystem service provision without the STP scheme.
2014 – 2020:	Construction phase – effects during construction.
2020 - 2140:	Operation phase - immediate effects once construction is completed in time reaching a new equilibrium
> 2140:	Decommissioning

Each period defined above is subject to uncertainty. The start and end of the construction period will depend on a number factors such as the timing of decisions relating to the STP scheme, the particular STP option chosen and any issues regarding the potential for a public enquiry. Thus the suggested timing for immediate impact may also move in any such scenario. The time taken to reach a new equilibrium and the nature of that equilibrium will depend on the ability of the ecosystem to recover.

Within this study we assume that there is no ecosystem recovery during the lifetime of the STP project. The main reason for this assumption is that there are currently only rudimentary estimates on the expected habitat at the end of the projects lifetime (see Table 6.2 for current data availability).

Despite the relative detail of the above timeline, the current level of data availability (both scientific and economic), mean that we do not differentiate the effect/value of implementing STP in as much detail as that shown, obviously this does have implications for uncertainty and the resulting values calculated this point is covered further within Section 10 (sensitivity analysis).

The effects of any STP option will also be influenced by external impacts like climate change. These have been incorporated into the SEA assessments based on the UKCP09 projections (see Box 5.1 below).

Box 5.1: Summary of current climate change predictions used within the SEA following UKCP09 recommendations

The latest climate change predictions for the UK were realised on 18/06/2009. The response of key variables to climate change including annual rainfall, temperature etc. are covered by this latest release. UKCP also gives details on the probability of each set of predictions given for a particular variable. Climate change scenarios are considered as part of the SEA estimates on the potential effects of the introduction of STP options in the Severn Estuary.

The SEA process incorporates these predictions into each topic paper specifically considering predictions with a 'medium' probability and at 50% emissions level. Apart from in the case of flood risk where data from Defra 2006 Guidance for sea level rise is incorporated to maintain consistency between the Severn Estuary Flood Risk Management Strategy and the Update to the Shoreline Management Plan (see 121320 STP Climate_change_scenarios_15-07-09.doc for discussion on UKCP09 use within the SEA). In addition the SEA team use UKCP's predictions for emission scenarios with probabilities of 10% and 90% within sensitivity analyses.

The variables for which predications are available include: temperature, precipitation, air pressure, cloud, humidity, sea level rise, storm surge, sea surface and sub-surface temperature, salinity, currents, and waves (ukcp09.defra.gov.uk).

In addition to climate change the effects of management strategies such as the Severn Estuary Shoreline Management Plan (SMP), Salmon Action Plans (SAP) and Coastal and Habitat Measurement Plan (CHaMP) (See Box 5.2), are taken into account when assessing the cumulative effects of each STP option along with other development activities for a full list see <<Cumulative Effects Consequential Developments (V13) 28-09-09(TrkCh).doc>>, part of the outputs from the SEA team.

Box 5.2: The Severn Estuary Management Plans and the cumulative effects

Coastal Habitat Management Plan (CHaMP): are used to recommended measures to prevent future losses of habitat and to quantify habitat change (www.eclife.naturalengland.org.uk).

Salmon Action Plans (SAP's): are part of the National Salmon Strategy, launched in1996, the strategy sets out the main objectives for improving the survival of Salmon populations via catchment based plans, i.e. SAP's (ea-transactions.net).

Shoreline Management Plans (SMP's): - are large-scale assessments of the risks associated with coastal processes and their management (www.environment-agency.gov.uk).

The current level of data availability (both scientific and economic) means that the results cannot differentiate the effect/value of implementing STP in as much detail as the detailed timeline above may imply. This does have implications for uncertainty and the resulting values calculated this point is covered further within Section 7.

5.2 Consolidation of ecosystem services

Following the qualitative assessment of ecosystem service change across habitats, the original list of ecosystems services was consolidated and categorised into final services, i.e., those that have a direct effect on human wellbeing and contributing ecosystem services to each 'final ecosystem service' (see Table 5.1). This consolidation makes value transfer more suitable and show how many ecosystem services contribute to final services[14]. The following identifies which ecosystem services have been taken out of the value transfer phase of the EVP as a result of this consolidation and the rationale behind each.

On the basis of the initial qualitative analysis, if an STP option is likely to lead to no change or no significant change in an ecosystem service, that service is dropped from further analysis. These include:

- Habitat for bees, (there is also currently no/very low service provision of this service within the Severn estuary);
- Subsistence cropping;
- Subsistence shell fish & catching;
- Wildfowling – birds caught & sold;
- Water for industrial cooling;
- Recreational coarse fishing is not expected to be affected by the STP scheme as these species remain within fresh water – change in service provision may occur if flow rates were to decrease substantially with the introduction of STP however, this effect is not expected;
- Recreational heritage fishing: all heritage fishing within the area is commercial, thus recreational heritage fishing is removed from the 'final ecosystem services' table;
- Part of the recreational water sports: scuba diving is removed as a consideration within this ecosystem services as currently no scuba diving takes place within the estuary due to low visibility and dangerous currents;

[14] The number of ecosystem services included within the value transfer has decreased from 43 in the initial typology description to 23.

- Other recreation – this is to be removed as visits to attractions within the Severn Estuary area including stately homes, parks and gardens are not expected to change as a result of STP scheme;
- Air Quality – this is has been removed as the main effects of the STP options on air quality (noise and increased air pollution as a result of increases in road congestion) are during the construction phase and are covered separately; and
- Renewable energy, (in this case – the use of fuel for biomass production), is also considered to be of low importance as the vegetation within the estuary is not suitable for use within biomass production.

The following list of ecosystem services were removed from the 'final ecosystems services' table as they do not currently provide a service at the moment, these are also not covered within the scope of the current SEA process.

- Natural medicines;
- Biochemicals and genetics, and
- Ornamental resources.

Finally, services of the estuary relating to ports and navigation have also been removed to avoid the duplication of effort as they are part of the regional economic report.

All other services are still within the scope of the value transfer either by the virtue that they contribute to the list of 'final ecosystem services' to be valued or, have been amalgamated into a single higher level service, i.e.:

- Flooding: includes fluvial and coastal
- Grazing: includes grazing for sheep and cattle and the provision of agricultural land, however, there is currently low service provision of this service within the Severn estuary;
- Waste Water: includes detoxification of water & sediment along with waste remediation and beach cleaning

Table 5.1 also gives details on the units of change used within the economic literature when valuing the change in provision of each service. For example, a decrease in the number of fish within the estuary and tributary rivers result in less angling and therefore a change in the number of visitor days. The table also summarises the 'scale' of the population affected by each service.

Table 5.1: Final Ecosystem Services

Ecosystem Service	Contributing Ecosystem functions	Final Service	Econ. Ev	Units	Population
Food	Primary production, habitat provision, nutrient cycling, water quality, nursery functions	Commercial fish catch	**MP**	**Kg**	Local
		Value of recreational fish catch inc. heritage catch	**MP**	**Kg**	
		Commercial Shell fishing	**MP**	**Kg**	Local
	Habitat provision (e.g. arable land), water for agricultural use, soil formation & retention	Grazing for cattle and sheep*	**MP**	**Ha**	Local
Water	Cycling processes, water quality	Water for agriculture	**MP**	**m^3**	
	Cycling processes, water quality	Aggregates	**MP**	**kg**	Local/Regional
	Bioremediation of waste, nutrient cycling	Waste disposal, (inc. detoxification of water & sediment)	**MP**	**m^3**	Regional
Climate change & regulation	Cycling processes, soil formation & retention	CO_2 emissions	**SPC**	**ha**	Global[15]
Water regulation	Soil formation & retention	Flood protection (indirect use values)	**NM**	**No of properties at risk**	Local/Regional
Water purification	Cycling processes, Soil formation & retention	Drinking water quantity and quality	**MP**	**m^3**	Local/Regional
Spiritual, Religious & heritage	Soil formation & retention	Archaeological ruins*	**MP, NM**	**Visitor days**	Local/Regional/National /Global[16]
	Primary production, habitat provision, nutrient cycling, Water Quality	Commercial Heritage fishing (non-use values)	**NM**		Local
Recreational values	Primary production, habitat provision, nutrient cycling, water quality, landscape, biodiversity.	Freshwater angling (migratory)	**EXP, NM**		Local visitors & (specialist)
		Estuarine & sea angling*	**EXP, NM**		Local visitors & (specialist)
		Bird watching (F) – v. few all wrong country apart from service value ones	**EXP, NM**		Local visitors & (specialist)
		Hiking	**EXP, NM**		Local visitors & (specialist)
		Water sports[17] - not including scuba diving	**EXP, NM**		Local visitors / Regional[18]
		Wildfowling recreation	**EXP, NM**		Local visitors & (specialist)
		Beach recreation	**EXP, NM**		Local/Regional/National
	As above & all recreational activities defined	Holiday destination (exc. all recreational values & views mentioned above and below)	**EXP, NM**		Local/Regional/National /Global[19]

[15] As a result of global risk of climate change
[16] This depends on the particular archaeological site in question
[17] e.g. sailing, canoeing, wind surfing, surfing.
[18] These are not specialised activities & are therefore not considered to be of National and Global importance
[19] Many towns along the estuary are visited by international travellers (International visitor survey, 2009)

Table 5.1: Final Ecosystem Services

Ecosystem Service	Contributing Ecosystem functions	Final Service	Econ. Ev	Units	Population
Landscape	Habitat provision	Landscape (inc. only value to local residence)	**MP, NM**	**No. of households**	Local (within 30 miles of each shortlisted site -
		Landscape (non-use values)	**NM**		Local/Regional/National /Global[20]
Habitat provision	Habitat provision	Biodiversity (non-use values)	**NM**	**Change biod****	Local/Regional/National /Global[23]

NOTES:

Econ. Ev. – Economic evidence,
U – use,
NU – non-use,
MP – Market price,
NM – Non-market,
EXP – expenditure data,
SPC – Shadow price of Carbon

** Change in biodiversity – this can be represented in a number of different units including changes in the features affected, amount of designated area, numbers of different species affected.

Local population – defined as towns along the estuary up to Minehead on the English coast and Cardiff on the Welsh coast including: the local and unitary authorities of Cardiff (305,350), Newport (137,017), Bristol (380,340) and Bath and N.E. Somerset (169,045)

Regional population – includes the South West Region for England (4.9mn) and E. Wales (includes: Cardiff (305,350), Newport (137,017), Bridgend (128,645), Monmouthshire (84,885) and the Vale of Glamorgan (119,292)

National population - includes England (51mn) & Wales (2.9mn)

Global population is an estimation of the current global population = 61bn

[20] The area has obtained a Ramsar designation and provides habitat for a number of endangered species including the Sea Lamprey.

5.3 Differentiation between STP options in data terms

During the SEA a process of optimisation for each of the shortlisted STP options, i.e., the Shoots Barrage (B4), Beachley Barrage (B5), Welsh Grounds Lagoon (L2), Brean Down to Lavernock Point Barrage (B3), and Bridgwater Bay Lagoon (L3d) (Discussed during workshop 2) was conducted. The optimisation results have been used to show that the following ecosystem services are likely to be affected differently by each of these generic services:

- Habitat change (ha) – used as a proxy for all ecosystem services provided across habitat types;
- Archaeological ruins, i.e., the location of STP options may affect archaeological sites differently;
- Landscape effects;
- Commercial fishing;
- Recreation fishing (migratory fish);
- Aggregates, – i.e., due to the effect of STP options on the geomorphology of the estuary aggregate extraction maybe affected in terms of aggregate quality and changes in the access to aggregate deposits;
- Water quality and water quantity relating to the level of water; and
- Recreational opportunities – Bird watching and tourism.

Out of this list, currently only the first one (habitat change) can be incorporated into value transfer (the 'bundled' approach).

6 QUANTITATIVE ASSESSMENT OF THE CHANGE IN ECOSYSTEM SERVICES

This Section presents the quantitative assessment of the change in the provision of the Severn Estuary ecosystem services due to STP options. The changes are presented both for the bundled and single ecosystem services value transfer.

6.1 Quantitative assessment of change – input to the bundled ecosystem services value transfer

Following the second joint SEA-EVP workshop conducted on July 3rd, 2009 the SEA theme leads were asked to provide a quantitative assessment of the environmental change associated with the introduction of each of the short listed STP options in terms of the change in habitat area and the provision of the final ecosystem services. This has since been updated through a further quantitative assessment conducted by the SEA team and following steering group meeting in 12th November 2009. The final data provided by the SEA team were obtained from the final versions of both the Marine Ecology and Air & Climatic Factors topic papers (25th February 2010). The assessment of the data used the optimisation work undertaken as part of the SEA. The estimates relating to habitat change and changes in CO_2 equivalent flux are presented in Table 6.1. Unfortunately, data relating to the future baseline were unavailable with only broad estimates available in relation to the future equilibrium state. The CO_2 equivalent flux data relate to a 'single' ecosystem service but since this is the only one for which data are available, it is reported in this table.

The bundled approach applied within this study uses estimates of the affected population as part of the calculation process (see Section 8) however, the main focus of the approach relates to the size of the area of habitat affected by each STP option using evidence expressed in terms of £ per ha of habitat.

6.2 Quantitative assessment of change – input to the single ecosystem service value transfer

Data matching the criteria required for value transfer (see Table 5.1 for types data measures required for each service) and relating to the change in the provision of individual final ecosystem services across STP options are currently unavailable (except for CO_2 equivalent flux which is presented in Table 6.1). Table 6.2 below provides information on the level of data produced by the SEA Phase 2 process on its completion.

The population affected by each ecosystem service is also mostly identified. However, due to lack of quantitative data on the change in each ecosystem service, the details for the population analysis is presented in Annex 6 rather than in the main part of the report. Pertinent information is summarised at the beginning of each sub-section within the 'single' services approach detailed in Section 7.3.

The future baseline values are set to equal the current values of intertidal and saltmarsh habitat, the future trend is one of deterioration however, the aims of the CHaMP are to avoid further deterioration and the SEA assumes that this target is met (Black and Veatch, 2010), and therefore the status quo is assumed to continue as is meaning that the baseline remains static.

Table 6.1: The change in the habitats and total flux in equivalent carbon dioxide emissions affected by the STP options

Habitat	Units	Current Level	Future Baseline (2020-2050) NO STP	Immediate Effect (~2020)				
				Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Intertidal habitat (mudflat, sandflat, rock and shingle)	Ha	**30,370**	**30,370**	**13,950**	**26,850**	**27,460**	**22,920**	**27,580**
Saltmarsh (&other types of marsh)	Ha	**990**	**990**	**780**	**1,130**	**1070**	**1,070**	**1,240**
Fresh water wetland	Ha	Unavailable - likely to be limited to qualitative assessment						
Grassland habitat	Ha	**60**	**60**	**590**	**110**	**120**	**110**	**140**
Total Flux in annual carbon (equivalent) emissions	change in tCO_2e per annum	n/a	n/a	**-1,706**	**-4,139**	**-1,981**	**-3,360**	**-376**
Included:	Change in the area of saltmarsh, intertidal and grassland habitats and CO_2 equivalent flux. Saltmarsh and intertidal habitats (which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle) represents area between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) . The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post STP scheme. The estimates of CO_2 equivalent flux include: • The effect of the loss of potential carbon sequestration, i.e., the change in the amount of habitat (ha) is assumed to lead to a year on year loss of the ability to sequester carbon, • Siltation (averaged over the project lifetime to obtain an annual value), and • Methanogenesis							
Excluded:	Saltmarsh and Intertidal habitat estimates do not include intertidal areas of sub-estuaries and changes arising from long term morphological processes. Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by each STP scheme. The following factors that are likely to have an effect on the unit economic value estimate but are excluded from the analysis due to lack of data: • Ecosystem services of archaeology and health effects of wetlands, • Population (users and non-users) outside the 50 km diameter area, and • Far field effects (beyond Bristol Channel).							

	Ecosystem services excluded because STP scheme is likely to lead to no change or no significant change in an ecosystem service include: habitat provision for bees, subsistence cropping, subsistence shell fishing and catch, wildfowling, water for industrial cooling, air quality, other recreation, and renewable energy (i.e., fuel for biomass). Ecosystem services included within other technical reports (i.e., aggregate extraction and navigation/port services) are excluded here. The total flux in annual CO_2 equivalent emissions exclude: • Any changes as a result of the Nitrogen cycle, • The loss of sequestered Carbon as a result of a change in intertidal, saltmarsh and grassland, and • Ecological changes that are likely to take place where an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.
Caution	Caution should be used if comparing values between STP options as these represent estimates for the comparison of different optimisation strategies within STP options. As such these values maybe subject to different levels of reliability. In addition different design factors may have been taken into account for different options and current optimal solutions may change. The effects on sequestration and methanogenesis are extremely sensitive to ecological factors which could be altered by different design options/optimisation for each option. Values relating to the total flux in annual CO_2 equivalent emissions should be used with caution as they are subject to high levels of uncertainty. Negative values relating to total flux in annual CO_2 equivalent emission relate to decreases in emissions. The unit values presented here relate to habitat information obtained from the SEA on the 16th March 2010; and CO_2 emission estimates from 23rd March 2010.
Data sources and other notes:	The values obtained on the 16th March 2010 were updated after the original project cut-off date for inputs. The affect of these changes has been documented here and within the technical report as the accompanying sensitivity analyses relating habitat estimates have not been updated within the technical report due to the magnitude of the associated change (Steering group meeting 23rd March, 2010). Intertidal area has been rounded to the nearest 100 ha. Saltmarsh area has been rounded to the nearest 10Ha. Grassland area has been rounded to the nearest 10Ha.

Table 6.2: State of SEA information on single ecosystem services

Ecosystem Service	Baseline data availability	Data available on effects of STP alternative options	Further Comments
Commercial Fish	Economic valuation of commercial fisheries provided within Migratory & Estuarine Fish Topic Paper	Effects upon commercial fishing addressed in Migratory & Estuarine Fish and Communities Topic Papers.	Desk based assessment and modelling. Key migratory fish species life-cycle modelling including age/stage structured matrix populations. No new surveys.
Nursery	Baseline with regards to juvenile fish included in Migratory & Estuarine Fish Topic Paper.	Effects upon juvenile fish included in Migratory & Estuarine Fish Topic Paper.	Desk based assessment and modelling. Key migratory fish species life-cycle modelling including age/stage structured matrix populations. No new surveys.
Recreational fish catch	Economic valuation of recreational fishing provided within Migratory & Estuarine Fish Topic Paper	Effects upon recreational fishing addressed in Migratory & Estuarine Fish and Communities Topic Papers.	Desk based assessment and modelling. Key migratory fish species life-cycle modelling including age/stage structured matrix populations. No new surveys.
Heritage catch	Economic valuation of heritage fishing (elvers) provided within Migratory & Estuarine Fish Topic Paper	Effects upon heritage fishing (elvers) addressed in Migratory & Estuarine Fish	Desk based assessment and modelling. Key migratory fish species life-cycle modelling including age/stage structured matrix populations. No new surveys.
Shellfish	Swansea Bay South (site suitable for the harvesting of shellfish) addressed in Marine Water Quality Topic Paper.	Quantitative effects on water quality in Swansea Bay South addressed in Marine Water Quality Topic Paper.	Desk based assessment and modelling. No new surveys.
Grazing land for sheep & cattle	SEA does not have an Agriculture topic.	Not available	-
Water for agriculture	Freshwater Environment & Associated Interfaces Topic Paper addresses existing surface water and groundwater abstractions and the future baseline of these abstractions.	Qualitative assessment with regards to effects on abstractions available in Freshwater Environment & Associated Interfaces Topic Paper.	Desk based assessment using output from Hydraulics & Geomorphology, Marine Water Quality and Flood Risk & Land Drainage Topics.
Waste disposal	Waste water treatment addressed in Marine Water Quality and Other Sea Uses Topic Papers. Waste disposal addressed in Resources & Waste Topic Paper.	Effects upon waste water treatment addressed in Marine Water Quality and Other Sea Uses Topic Papers. Effects upon waste disposal addressed in Resources & Waste Topic Paper (desk based qualitative assessment).	
Carbon sequestration	Baseline within Air & Climatic Factors Topic Paper	Carbon Flux provided by the SEA in the affected habitats table	Carbon flux calculations based on Air & Climate Factors Topic Paper
Air quality	Baseline within Air & Climatic Factors Topic Paper	Emissions modelling presented in Air & Climatic Factors Topic Paper.	

Table 6.2: State of SEA information on single ecosystem services

Ecosystem Service	Baseline data availability	Data available on effects of STP alternative options	Further Comments
Flood protection & flood risk	Baseline and future baseline taking into account sea level rise is within Flood Risk & Land Drainage Topic Paper.	Use of simplified 1D models. Requirements for measures to prevent or reduce significant effects on flood risk and land drainage provided.	Takes into consideration flood defences, erosion protection and pumping of outfalls. Wetland function meta analysis will be covered as part of the EVP process.
Drinking water quality & quantity	Freshwater Environment & Associated Interfaces Topic Paper addresses existing surface water and groundwater abstractions and the future baseline of these abstractions.	Qualitative assessment with regards to effects on abstractions available in Freshwater Environment & Associated Interfaces Topic Paper. Other Sea Uses Topic addresses effects upon Water Treatment Works.	
Archaeological ruins	Archaeological sites and monuments, evidence for past environments, historic buildings and structures, historic landscapes and artefacts and structures related to seafaring are provided in the Historic Environment Topic Paper.	Effects upon the historic environment in the sub-tidal, intertidal and terrestrial zones are addressed in the Historic Environment Topic Paper.	Effects may occur during construction, operation and decommissioning.
Heritage fishing (non-use value)	Economic valuation of heritage fisheries (elvers) provided in Migratory & Estuarine Fish Topic Paper	Effects upon heritage fishing (elvers) provided in Migratory & Estuarine Fish Topic Paper	Data available in economic valuation literature
Freshwater angling (migratory)	Economic valuation of recreational fishing provided within Migratory & Estuarine Fish Topic Paper	Effects upon recreational fishing addressed in Migratory & Estuarine Fish. Communities Topic Paper addressed effects on recreation and tourism and employment.	
Estuarine & sea angling	Economic valuation of recreational fishing provided within Migratory & Estuarine Fish Topic Paper.	Effects upon recreational fishing addressed in Migratory & Estuarine Fish. Communities Topic Paper addressed effects on recreation and tourism and employment	
Bird watching	Tourism and recreation of Severn Estuary and surrounds presented in Communities Topic Paper and Other Sea Uses Topic Paper. This includes bird watching.	Qualitative assessment of effects upon nature based tourism included in Other Sea Uses Topic Paper.	
Hiking	Not explicitly addressed in any topic papers.	Not explicitly addressed in any topic papers.	Tourism and recreation of Severn Estuary and surrounds presented in Communities Topic Paper and Other Sea Uses Topic Paper.

Table 6.2: State of SEA information on single ecosystem services

Ecosystem Service	Baseline data availability	Data available on effects of STP alternative options	Further Comments
Water sports	Tourism and recreation of Severn Estuary and surrounds presented in Communities Topic Paper and Other Sea Uses Topic Paper. This includes sailing, boating, windsurfing, canoeing, surfing, bore surfing, bathing and diving.	Qualitative assessment of effects upon water sports based tourism and recreation included in Other Sea Uses Topic Paper. Quantitative effects upon tourism and recreation based economy included in Communities Topic Paper.	Scuba diving removed from EVP
Wildfowling recreation	Tourism and recreation of Severn Estuary and surrounds presented in Communities Topic Paper and Other Sea Uses Topic Paper. This includes wildfowling.	Qualitative assessment of effects upon nature based tourism included in Other Sea Uses Topic Paper.	
Beach recreation / holiday destination	Tourism and recreation of Severn Estuary and surrounds presented in Communities Topic Paper and Other Sea Uses Topic Paper. This includes beach recreation.	Qualitative assessment of effects upon tourism included in Other Sea Uses Topic Paper. Quantitative effects upon tourism and recreation based economy included in Communities Topic Paper.	
Landscape	New field surveys were undertaken to establish the existing landscape and seascape character and existing visual amenity. This is presented in the Landscape & Seascape Topic Paper.	Zone of visual influence of each alternative option defined. Qualitative assessment of effects on existing landscape and seascape features and visual amenity.	
Non-use value of landscape			
Biodiversity (non-use values)	Qualitative and quantitative data on baseline provided for marine ecology (habitats and species), migratory and estuarine fish, waterbirds and terrestrial & freshwater ecology.	Modelling of effects upon marine ecology (habitats), migratory and estuarine fish and waterbirds presented in relevant Topic Papers. Qualitative effects on marine ecology (habitats and species) and terrestrial & freshwater ecology also presented in relevant Topic Papers.	Waterbirds baseline included new survey work.

7 ECONOMIC VALUE EVIDENCE

This section provides an overview of current best practice in terms of the application of value transfer to a specific project. The section also summarises the main points to consider when deciding which piece(s) of economic literature can provide the 'best value estimate' for a specific ecosystem service or habitat change, where the 'best value estimate' can be described as a study in which the good valued is similar to that being valued by the project and the study is itself of good quality (see Section 7.1). The discussion in Section 7.1 applies to both bundled and single service value transfer. Sections 7.2 and 7.3 detail how the approach has so far been applied in the context of the Severn Estuary in terms of selecting the appropriate value evidence in the case of the 'single' ecosystem service and the 'bundled' ecosystem service approaches respectively.

An initial summary of the relevant literature was presented in interim report 1, which is repeated in Annex 4. Given the different approaches to the application of value transfer within the EVP several literature reviews at the 'single' ecosystem service level have been completed (see Section 7.2) along with a literature review accounting for the valuation of groups or 'bundled' ecosystem services (see Section 7.3).

7.1 Selection of the economic value evidence

An important consideration to be kept in mind when assessing the merits of different study site values is the expectation that, WTP for a particular good will differ between different locations. Therefore, in order to minimise concerns relating to the validity and reliability of transferred values, it is important to select the most appropriate WTP estimate from the most appropriate study site or good. A valuation study is suitable for value transfer in this context, if (Bateman et al., 2002):

i. The ecosystem/ecosystem services valued in the study and the ecosystem/ecosystem service subject to change within the Severn Estuary is the same or differences accounted for;
ii. The change in the provision of ecosystem/ecosystem services valued in the study is similar to those of the Severn Estuary;
iii. The affected population both in terms of its characteristics and geographical extent in the study is similar or accounted for when transferring the values of one study to the Severn Estuary context;
iv. Ideally, the study describes the functions used of mean values calculated in enough detail that their results can be used within the context of the Severn Estuary EVP;
v. The study is of good quality; and
vi. The property rights across the site studied is similar to those across areas of the Severn Estuary affected.

In theory, adhering to these conditions enables a suitable 'match' to be made between the policy site good to be valued in this case the Severn Estuary and its associated appraisal context and a suitable existing valuation study from which to source WTP information. While not explicitly mentioned above (but embodied within criteria (ii) and (iii)), location is a particularly important consideration in assessing the appropriateness of a study for transfer purposes. For instance, 'similar' wetlands, or estuaries may be distinctly different between different countries due to differences in the provision of ecosystem services across specific habitat types or cultural associations. In addition socio-economic characteristics typically vary between different countries, most notably when comparing developing to more developed countries.

(i) The characteristics of the good

As the previous discussion highlighted, the typical heterogeneity of estuary habitats and the ecosystem services they provide is an important consideration in relation to the reliability of transferring economic values from another context to that of the Severn Estuary. The main issue is that some economic values associated with specific ecosystems services or habitat types maybe highly site and good-specific. Without a high degree of similarity between the study good and the policy good (in conjunction with a similar change in provision of the good as discussed below) it is unlikely that value transfer will provide an accurate proxy of economic value at the policy site.

From a practical point of view, this implies that the economic values sought for the environmental change associated with the STP scheme in the Severn Estuary rely on studies that have considered the benefits of similar ecosystems or ecosystem services. However, further difficulty can be envisaged since clearly no two wetland or estuary ecosystems are identical. This point is particularly pertinent, given the unique scale and nature of the Severn Estuary which as a whole displays distinctive features that are unmatched elsewhere, be they in terms of physical characteristics (e.g. geomorphologic landscape, or the collection of heritage landscape) or in terms of biodiversity value (e.g. Severn Estuary is a designated Ramsar site).

Several papers review a number of valuation studies to derive meta-analytic functions that cover a broad range of habitat types within the 'wetlands' (Brander et al 2008; Ghermandi et al., 2008; Brander et al., 2006; Brouwer et al., 1999; Woodward & Wui, 2001), where the size of a particular habitat type (i.e., hectares) acts as a proxy for the value of all of the ecosystems services that an area provides. However, this can still lead to issues in terms of matching the good as the valuation studies covered can include a broad spectrum of objectives and disparate goods. Nevertheless, such studies can help address the issue of the scalability of transfer functions especially where valuation studies are used to derive meta-analytic functions for resources at the global or continent level.

In addition to habitat and ecosystem service characteristics of wetlands may be described through designations e.g. Ramsar. These characterisations account for landscape settings, and also ecological and wildlife considerations along with the scale of a site and its rarity. Although valuation literature exists for specifically, protected areas, i.e., Jacobs (2004); these tend to be highly specific studies that are difficult to use within the context of value transfer as many have been designated for their unique features. It is also worth noting that sites that are designated for their natural characteristics and unique futures tend to have high economic values. However, the designation per se does not have an economic value. It is the presence of unique (or sufficiently important) ecosystem services that attracts both designation status and high economic value.

(ii) The change in the good

The change valued could include:

a. The value of the restoration of a habitat area from one state to another;
b. The value of preventing further habitat change;
c. The value of a particular ecosystem service, i.e., flood control at varying levels;
d. The cost associated with increased ecosystem service loss, i.e., money needed for flood defences following the removal of wetlands, and
e. The value of a particular habitat area.

By and large, these actions amount to marginal changes to the current state of a habitat. In these cases it is most likely that the appraisal context will be that of cost-benefit analysis where the intention would be to compare the cost of the action to the perceived benefits of the action. Bullet point (e) covers studies that seek to generate the TEV of an entire area, as described in the site/good characteristics section above many meta-analytic analyses seek to determine this (see Box 7.1 below). Any study used within the evaluation of ecosystem service change within the Severn Estuary as a result of the STP scheme must be shown to value a change in an ecosystem/ecosystem service that is comparable in both its nature (e.g. increase or decrease) and magnitude.

(iii) Affected population

Valuation evidence sourced from existing studies should correspond to the affected population identified for the Severn Estuary context. For example economic value estimates for specific user groups (e.g. specialist groups such as anglers and bird-watchers) should not be transferred to estimate use values held by local residents (a population group of which specialist users will only comprise a small proportion). Likewise use value estimates should not be transferred to estimate non-use values held by the general public.

In addition to comparing types of affected population, the characteristics of the affected population (e.g. socio-economic, frequency of use, etc.) should also be compared to the characteristics of the population sample for the study good. An exact match between the all the characteristics is not required since some differences (e.g. in income and other significant determinants) can be controlled for by adjustments to the transferred value evidence from the selected study (or set of studies). Here supporting data that has been collated can input to adjustments in the transfer process (see Section 8).

Again it is the case that some judgement will be needed to determine how similar the study sample population and the policy good population, i.e., those affected by STP scheme are, and whether any differences between these two populations would be expected to lead to significant differences in WTP estimates between the sites.

(iv) Willingness to pay (WTP) functions

In undertaking a value transfer, it is important to establish that WTP values sourced from a valuation/meta-analysis follow distinguishable patterns which conform to the prior expectations of economic theory. In essence, this is a form of 'quality control' which can assess the validity and reliability of the values obtained by study.

One way to do this is to consider empirical (econometric) analysis, presented by the valuation study, which seeks to determine the relationship between WTP and a number of explanatory variables. For a comprehensive discussion concerning such aspects of stated preference studies see Bateman et al. (2002). Similar discussion with regards to the travel cost method is provided by Ward and Beal (2000).

Such explanatory variables typically include income, socio-economic characteristics, attitudes towards the good and its change in provision, use and distance from the good, will influence an individual's WTP for resource. With regards to income, in most cases, it is expected that wealthier individuals will be more inclined to have higher WTP (all else being the same). Hence in a WTP bid or meta-analytic function, the coefficient on income (which measures the impact of the change in income on WTP) should have a positive sign. In the case of a variable such as distance from the resource (or price/cost, or the number of substitute sites), it would be reasonable to expect a negatively signed coefficient, implying that as distance from the resource (or price, or the number of alternative sites to visit) increases WTP decreases.

It is also important to consider the statistical significance of these coefficients. Statistical significance tests are applied to see whether a coefficient is statistically different from zero or not. If the coefficient is found not to be statistically different from zero, then the implication is that the variable has no influence on WTP. The studies that estimate significant coefficients for (with expected signs – positive or negative) key variables mentioned above should be preferred for value transfer.

Aside from considering the influence of individual variables it is also necessary to consider the explanatory power of the whole WTP function. This can help establish that WTP estimates for the study good population are not completely random. A parameter known as the R-squared statistic (or pseudo

R-squared depending on the form of the WTP bid or meta-analytic function), which is often denoted as R^2, provides a measure of the explanatory power of an estimated bid function. The larger the R^2 statistic, which takes a value between zero and one, the greater is the assumed explanatory power of the model. Unfortunately there is no commonly accepted threshold value for the R^2 statistic that denotes a function as having an acceptable power of explanation. However, at lower values (perhaps around 0.1) conclusions may be drawn that the WTP values from the sample population show very little in the way of distinguishable patterns (Bateman et al., 2002).

Thus for the purposes of value transfer, transferred WTP information will be more appropriate if it is sourced from a study that demonstrates robust empirical results, both in terms of the individual variables and WTP values and overall WTP functions.

(v) Quality of the study

The robustness of evidence sourced from existing studies is a key when determining whether a study can be used for value transfer. Studies that are judged to be of poor quality should not be used for value transfer even if the match between the policy good context and study good context is favourable.

An assessment of study quality can be made from:

- The study reporting; for example methodological and validity of result issues may be reported;
- Reference to guidance documents for economic valuation methods; and
- The interpretation and explanation of results (as discussed in (iv) above)

The condition that studies considered for value transfer exercises should themselves be sound follows on closely from (iv) and the robustness of WTP values and functions. Here a number of issues relating to stated preference studies which are used in this value transfer are listed:

- Elicitation effects – are concerned with whether or not a respondent will answer truthfully (i.e., state their 'true' WTP amount). Crucially this may depend on the way in which the valuation question is framed. Overall, there are four main ways in which a WTP question may be framed (see Bateman et al. 2002).
- Payment vehicle effects – are concerned with the way in which respondents would have to pay for the good which is of interest in the valuation scenario. Typical payment vehicles include donations to charitable bodies, payments to specific trust funds, increases in either national or local taxes, or entry fees.
- Information effects – empirical evidence suggests that as the amount of information provided to respondents increases, so do elicited WTP values. However, it is likely that this relationship applies to all goods and services.
- Interviewer and respondent bias – CV studies may also be influenced by aspects relating to the interviewer (e.g. their appearance or accent may cause the respondent to behave in a particular way) or the respondent. For example, in surveys administered by mail, only those with a strong interest in the good may return questionnaires, leading to sample self-selection (sample bias). Whether a survey sample is representative of the population of interest to the good in question is important when aggregating WTP amounts.

In addition to the influence that the survey instrument may have on WTP responses, much debate surrounding CV has centred on whether estimated values are invariant to the magnitude or scope of the good being valued (and therefore in violation of the underlying principles of economic theory on which valuation methodologies are based). This debate concerns 'scope sensitivity', 'embedding' and 'part whole' effects:

- Scope sensitivity - testing for scope involves observing whether WTP increases with the size of the good (i.e., WTP for a larger wetland area should be greater than WTP for smaller areas in isolation). Insensitivity to scope is often termed as an 'embedding effect'.

- Part-whole effects – are an allied concept to scope insensitivity. Here when a set of goods (the 'parts') are valued individually the sum may exceed that for the same set of goods valued together (the 'whole'). This effect is particularly relevant to the valuation of wetland assets. For example, when considering a number of ecosystem services within an area, part-whole effects suggest it may be difficult to extrapolate the value of preserving one service from the value of preserving all services (Ragkos et al., 2006).

The existence of the any of the above, from elicitation effects to part-whole effects, may lead to questions concerning the 'soundness' of valuation studies, and hence would bring into question the appropriateness of using WTP information sourced from these studies in value transfer exercises. These points have been considered as part of this value transfer process.

(vi) Property rights should be the same across the sites

This final condition concerning property rights relates to the change in wellbeing that is to be assessed in the policy good context, here the Severn Estuary, and how this compares to the change in wellbeing that was considered for the study site good. There are four types of benefit measure that may be estimated by valuation studies:

- WTP to secure a gain (e.g. an improvement in the condition of a wetland resource);
- WTP to avoid a loss (e.g. preventing deterioration of a wetland resource);
- WTA to tolerate a loss (e.g. compensation for experiencing deterioration of a wetland resource); and
- WTA to forego a gain (e.g. compensation for not receiving an improvement a wetland resource).

In valuation studies the choice of benefit measure may depend on the property rights structure and the type of change from the status quo position. This is particularly difficult in the case of the Severn Estuary as different areas within the estuary are subject to different property rights. Some areas with high conservation value will be publically owned while other areas (possibly used for wildfowling or farming) maybe privately owned. Thus how to account for the value of ecosystem services over the whole area or within a specific part will be handled differently and require different valuation studies/evidence for use within the value transfer.

7.2 The bundled ecosystem services value transfer

Overview of the available value evidence

A number of studies world-wide have sought to estimate the value of wetlands (including intertidal and saltmarsh areas), i.e., the amount/size of a habitat as a proxy for all of the ecosystem services that they provide. As there is data available in terms of the potential change in the size of habitats as a result of the STP scheme (Table 6.1), the bundled approach can be used within this study to value the change in wetland habitat.

The following discussion details the principle findings from the valuation literature. In conjunction with the summary table of recent applicable studies, the intention of this review is to assess the potential scope for the bundled value transfer application.

The survey of studies undertaken for this report has found 22 studies which consider ecosystem services as a whole for the types of habitats that will be affected by STP and have been reported in publicly accessible formats. All of the studies summarised within **Table 7.1** report mean WTP for either a bundle of wetland services or a per hectare value for a wetland habitat type that can be used as a proxy for the value of these services. The valuation methods used to collect data include choice experiments (4), contingent valuation studies (12), and replacement cost (1). Five of the studies are meta-analyses.

Table 7.1: Summary of the existing economic valuation studies that can be used in the bundled value transfer approach

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Birol & Cox (2009)	Benefits of different wetland management schemes CE	marginal WTP per respondent per km2 created wetland	Severn Estuary, UK	£13.80 CI 95% 9.1-18.5 n=100 individuals
Brander et al. (2008)	Study to calculate the per heactaare value of different wetland habitat types Saltmarsh Intertidal mudflats MA	Value per ha per year	European wetland types	£2008 per hectare per year Function described by Brander can be used within a function transfer for the policy site and a per ha value derived. n=166 studies yielding 264 observations)
Brander et al. (2006)	Meta-analytic study used to determine the per hectare value of different wetland habitat types unvegetated sediment Salt/brackish marsh MA	Per hectare value of wetland type	Global source of studies	£2008 per hectare per year Unvegetated sediment: Median £238 Saltmarsh: Median £104 n=80 studies
Brouwer et al. (1999)	wetland MA of CVM studies	Mean WTP for all wetland functions relating to freshwater wetlands	USA and other developed countries	£2008 Mean WTP for Salt and fresh water wetlands = £327 per hectare Broad meta-analysis that derives values for specific wetland functions and wetland types n=30 studies
Carson, R.T., L. Wilks and D. Imber.	Preservation value of a conservation zone CV.	Mean WTP for different impacts scenarios	Australia	Australian dollars per year (million) (a. Value represents a conservative estimate of the aggregate annual WTP for preserving the KCZ National Park: 435; Australian dollars per year per person (b. Value represents the sample median annual WTP per person to avoid the major impact scenario (for total national sample). The major impact scenario is designed to describe a realistic worst case from mining operations in the KCZ: 143.26.

Table 7.1: Summary of the existing economic valuation studies that can be used in the bundled value transfer approach

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Dalecki, et al. (1993)	Examination of Early, Late, and Non-respondents WTP for wetland preservation CV	Wetland preservation	USA	US$ per person per year (a. Individual median WTP estimate for wetland preservation of the first wave (response rate = 24%): 24.4; (b. Individual median WTP estimate for wetland preservation of the fourth wave (response rate = 67%): 6.54.
Ghermandi et al. (2008)	Study to calculate the per heactaare value of different wetland habitat types Estuarine habitat MA	Value per ha per year	Based on global studies	Mean values not reported but function is available
Goodman et al. (1998)	The non-use value of the coastal environment are investigated CV	WTP additional taxes for a conservation programme for the entire British coast	UK	Mean WTP for environmental protection: 21.84 per household per year n=766 individuals
Heimlich, R.E.	Study looks at the Costs of an Agricultural Wetland Reserve RC	Wetlands converted from cropland.	USA	US$ per acre (1982) (a. Value is the high estimate of the marginal costs of 5 million acres of wetland reserve: 1184; (b. Value is the high estimate of the total average cost (in $/acre) that minimizes reserve costs for wetland reserve of 1 million acres: 286.
Jacobsen et al. (2008)	This study looks at the biodiversity value of Danish grasslands CV and CE	The WTP for the preservation of a grassland is valued by both describing generic species traits and the iconic species that occur with the grassland	Denmark	No WTP values are reported however, functions for grassland preservation are defined variables include number of species present, or alternatively a description of iconic species occurrence along with access. The more generic model could be applied to the Severn estuary case study i.e., WTP = (ßAreaGrassland/ßPrice) +(ßSpecies in Grassland/ßprice) + ßAccess/ßprice) Facilities attribute set to zero and thus not included above (depends on an assumption with regard to the number of species represented, does not include Socio-economic values)

Table 7.1: Summary of the existing economic valuation studies that can be used in the bundled value transfer approach				
Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Kuriyama (2000)	Value of forest around the Kushiro Marsh CE	Wetland area protected (26861) Wetland area protected (31361) Wetland area protected (51361) Wetland area protected (91361) Wetland area protected (515361)	Kushiro Marsh, Japan	WTP for each size of protected area estimated ($2000) per household per year $0 CI. 95%:0 $12 CI. 95%:10-14 $51 CI. 95%: 43-58 $97 CI. 95%: 82-110 $137 CI. 95% 116-156 n = 670, individuals response rate 79.29%
Luisetti et al. (2008b)	This study determines the value of saltmarsh characteristics for new areas of salt marsh created CE	WTP for saltmarsh characteristics including the number of birds observed, size of the saltmarsh, access to the saltmarsh, and distance to the nearest site	Essex, UK	A mean per hectare value is not specified, however, a WTP function is specified to determine aggregate WTP for different sized wetlands within the Essex area i.e., WTP = (ßAreaSaltmarsh/ßPrice) +(ß Bird Species /ßprice) + (ßAccess/ßprice) – (ßDistance/ßprice) Socio-economic variables not included, only relates to saltmarsh
Milon & Scorgin (2006)	A latent class choice model is used to evaluate the effect of alternative ecological charicteristics of wetland functions on WTP CE	Evaluation of preferences for the restoration of the Greater Everglades	USA	Mean WTP from MNL model for Full restoration was estimated as $29.33 (range:-$29.37-$195.27, with different groups) n=480
Pate, J. and J.B. Loomis.	This paper examines the issue of geographical distance to determine if distance negatively affects willingness to pay values. CV	A Case Study of Wetlands and Salmon in California	USA	US$ per person per year Total benefits (aggregate in millions): 1a $175; 1b $2, 2357; 1c $81; 1d $203; 1e $102; 2a $190; 2b $2,490; 2c $62; 2d $175; 2e $105.

Table 7.1: Summary of the existing economic valuation studies that can be used in the bundled value transfer approach

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Poor, J.	The Value of Additional Central Flyway Wetlands in Nebraska's Rainwater Basin Wetland Region CV	The objective of this study is to apply the CVM to estimate the value to the people of Nebraska, of government acquisition and/or management programs to increase the current amount of Rainwater Basin (RWB) wetlands.	USA	Mean WTP: $126.79 per year
Oglethorpe & Miliadou (2000)	Valuation of non-use attributes of wetland: Lake Kerini CV	WTP for the protection of the lake	Lake Kerini Greece	Mean WTP per capita per year across the sample £15.24 n=250 individuals
Oglethorpe (2005)	Values for health and grass.land habitat VT	ELF model – uses the results of previous studies to estimate the per hectare value of changes in health/grassland	UK	£2008 Mean value in £/ha Mean (lower/upper bands) for the South West of England £5.74 (3.21-7.86)
Ragkos et al. (2006)	Value for all functions of a Greek wetland CV	WTP for specific functions of Zazari-Cheimaditida wetland	Greece	£2008 Mean WTP £94.43 CI95%: £74.25-£154.08 n = 174 individuals
Steever, WJ., M. Callaghan-Perry, A. Searles, T. Stevens and P. Svoboda.	This study looks at Public Attitudes and Values for Wetland Conservation in New South Wales, Australia CV	Wetland conservation.	Australia	Australian dollars per person for 5 years (a. Value represents median WTP for the pooled sample. Value from the pooled sample omits those respondents who did not express WTP: 100; (b. Value represents aggregate value for wetlands in New South Wales, Australia, assuming a WTP per household of A$17.10 and 2.23 million households in the state: 38.
Stone, A.	Valuing wetlands: using a contingent valuation approach CV	Mean annual WTP for wetland protection.	Australia	£85-109. per hectare

Table 7.1: Summary of the existing economic valuation studies that can be used in the bundled value transfer approach

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Whitehead, J.C., T.J. Hobans and W.B. Clifford.	Improved water quality.	Dollars per person per year.	USA	(a. Value is expected WTP to protect the Albemarle-Pamlico Estuarine System. Uses interval data regression with a quadratic functional form. Upward biasing effect of starting point bias corrected in the estimation: 23.55; (b. Value is expected WTP to protect the Albemarle-Pamlico Estuarine System. Uses interval data regression with a linear functional form. Upward biasing effect of starting point bias is corrected in the estimation: 27.05.
Whitehead, J.C.	Measuring Willingness to Pay for Wetlands Preservation with the Contingent Valuation Method. CV	Preservation of a bottomland hardwood forest wetland.	USA	$ per household per year Value measures mean WTP for wetland preservation estimated from log-linear form of model: 6.31.
Whitehead, J.C.	Environmental Interest Group Behaviour and Self-Selection Bias in Contingent Valuation Mail Surveys CV	Wetland preservation.	USA	$ per person per year (a. Value is the average WTP per person/ year in the general sample for the preservation of the Clear Creek wetland area (assuming 15% of the general population belongs to an environmental interest group): 4.12; (b. Value is the average WTP per person/year in the environmental interest group sample for the preservation of the Clear Creek wetland area: 42.83.
Willis, K.G.	Valuing non-market wildlife commodities: An evaluation and comparison of benefits and costs CV	WTP for the preservation of the current state of the wetlands.		£ per hectare (a. total use value: 44; (b. total non-use value: 807.
Woodward & Wui (2001)	A meta-analytic study to value single ecosystem finctions within wetlands MA	Value of single wetland functions only	North American and European studies	$ per hectare (2001) Wetland Habitat $756 Lower & upper bound (235-2424) n=39 studies

VT - Value transfer; CE – Choice experiment; CV – Contingent valuation; MA – Meta analysis; RC – Replacement cost.

Several of the studies listed above relate to particular wetland resource, i.e., Kuriyama (2000), Ragkos et al. (2006), Oglethorpe & Miliadou (2000), Milon & Scrogin (2006), Poor (1997), Whitehead (1991a) the results of which are driven by specific attributes of the local wetland making them less desirable for inclusion within a value transfer.

A number of studies value wetlands in different countries e.g. Kuriyama (2000), Milon & Scrogin (2006), Oglethorpe & Miliadou (2000), Pate & Loomis (1997), Poor (1997), Ragkos et al. (2006), and Whitehead (1991a and b) etc. While this in itself is not necessarily a problem, there are differences between the wetland ecology of resources in the study sites, the affected populations and their socio-economic characteristics and those of the population within the Severn Estuary thus these studies do not make a good match.

The contexts of the studies in Table 7.1 vary widely with some exploring methodological effects of different analyses with a wetlands example, i.e., Dalecki et al. (1993) and Whitehead (1991b).

A series of meta-analysis studies (see **Box 7.1**) have been undertaken in recent years to draw to the findings and implications of the widespread empirical literature concerned with the valuation of wetland and floodplain benefits including: Brouwer et al. (1999), Woodward & Wui (2000), Brander et al. (2006), Brander et al. (2008), Ghermandi et al. (2008). Of these Brander et al. (2008) and Ghermandi et al. (2008) update the older studies mentioned and each is useful with regard to the use here as each report mean per hectare values. The key difference between Brander et al. (2008) and Ghermandi et al. (2008) is that the former (264 observations) estimates a meta-analysis function for a sub-sample of CORINE[21] land cover classes only; the latter (383 observations) is based on all observations in the dataset, including wet forests, forested floodplains, estuaries and lagoons which are excluded from the CORINE dataset (and covering both temperate and tropical wetlands).

Evidence relating to grassland is much less prevalent. However, there are two potential studies of relevance. The first is the ELF - Environmental Landscape Features Model which includes a per hectare value for heath land in the South West of England (Oglethrope, 2005) and the second relates to the outputs of a choice experiment that value the biodiversity of Danish grassland (Jacobsen et al., 2008).

[21] CORINE land cover 2000 is part of the European Commission programme to COoRdinate INformation on the Environment (CORINE). It provides consistent information on land cover changes during the past decade across Europe: http://dataservice.eea.europa.eu/dataservice/

Box 7.1: Meta-analysis studies

Meta-analysis is defined as "the statistical evaluation of summary findings of empirical studies, helping to extract information from large masses of data in order to quantify a more comprehensive assessment" (Brouwer *et al.*, 1999; p48). Essentially they collate information from multiple studies and provide a quantitative synthesis of existing literature. In the context of economic valuation, this enables the investigation of the range of economic value estimates from the same or similar good from different studies, producing summary statistics such as mean value, median value, confidence intervals etc., as well as identifying the key factors that influence estimated economic values via a meta-analysis function.

A **meta-analysis function** relates economic value estimates (the 'dependent variable') from various studies to explanatory variables, such as wetland type, size, provision of ecosystem services, socio-economic characteristics of the affected populations, availability of substitutes etc. as well as study characteristics and methodology.

A typically meta-analysis function can be expressed as (see Brander et al., 2008):

$$v_i = \alpha + \beta_S X_{Si} + \beta_W X_{Wi} + \beta_C X_{Ci} + u_i$$

Where:

- The index *i* relates to observations of economic value estimates in the sample (i.e. n = 1,…, *i*).
- The *β*'s correspond to vectors of coefficients for the explanatory variables.
- A constant term *α* is estimated.
- A set of study characteristic variables are included in X_S: e.g. valuation method, year of publication, authors, etc.
- The characteristics of the good are included in X_W: e.g. wetland type (coastal, inland, etc.) size, ecosystem services provided, etc.
- Context variables are included in X_C; e.g. socio-economic characteristics of the affected population, availability of substitutes, etc.

A meta-analysis function that includes such a range of variables will enable the analyst to adjust economic value estimates to the policy good context. In general use of a well specified and robust meta-analysis function is recommended over the simple transfer of estimated mean economic values from a meta-analysis study, which risks significant over or under-estimation of economic values by not controlling for the specific details of the policy good context.

Selecting the appropriate evidence

The ideal economic valuation study to select for a value transfer is one that is conducted for the same good, sufficiently similar change and the same location as that affected by the policy of interest. The studies reviewed in Table 7.1 are compared to the Severn Estuary and the STP context to see if any one or more of them can be used to provide 'generally applicable' unit value estimates or meta-analyses functions that can be applied here.

In terms of the good – the Severn Estuary, Table 7.1 shows that there is a recent study available on the Severn Estuary (Birol and Cox, 2009) which applies a choice experiment to value different management scenarios for the Severn. Therefore, the change in the good is not sufficiently similar to the context of EVP. In terms of methodology, the sample used for the study is extremely small and localised and the WTP function derived does not include any variables relating to socio-economic characteristics, making the study unsuitable for EVP. However, the study may be of use in designing a primary valuation study for EVP if such a study goes ahead.

Given that there are no other studies in the literature about the Severn Estuary or about as large scale a change the STP options are likely to effect, we choose to use the study that is most similar (still far from the ideal as the caveats surrounding the results in Section 9 show) and that is methodologically the best. This study is the Brander et al. (2008). It is limited to temperate European wetlands and the meta-analysis function permits the estimation of the economic value of ecosystem services associated with an area of wetland (one hectare). This matches the habitat changes due to STP options reported in **Table 6.1.** The Brander et al. (2008) function also allows for the adjustment of socio-economic characteristics, substitutes and spatial factors within the meta-analytic function derived.

Two other functions are used for sensitivity analysis (Section 10). Ghermandi et al. (2008) and Luisetti et al. (2008b). As stated, above Ghermandi et al. (2008) drive a meta-analytic function and report mean per hectare value across different habitat types, estuarine being the habitat of interest here. The main difference in the function is the consideration of a wider set of habitat types and the use of 383 world-wide data observations to derive the function rather than the European subset. Lusetti et al. (2008) derive a WTP function to determine the value of saltmarsh habitat. While this function does include variables relating to the distance to the saltmarsh resource, access to the saltmarsh, saltmarsh size and the number of bird species that can be seen in the area the function does not include variables relating to the socio-economic characteristics of the affected population. A full summary of both Brander et al. (2008) and Ghermandi et al. (2008) is provided within Annex 5 for this document.

For the effect on grassland, we have chosen to use the outputs of the ELF model as they give specific values for the South West of England. The second study derives a WTP function that could be used in the design of compensation strategies that feature grassland where information relating to the number of species supported is available. A summary of the ELF project is given within the Annex 5 to this report.

The economic value evidence chosen for the CO_2 flux is presented in Section 8.2.

7.3 The single ecosystems services value transfer

This section summarises the economic value evidence found for individual ecosystem services affected by the STP options.

Commercial fish and shellfish catch (includes nursery functions):

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Commercial fish and recreational fish catch inc. heritage catch	-/--	Intertidal and rivers and streams
Commercial fish and recreational fish catch inc. heritage catch	-	Saltmarsh
Commercial fish and recreational fish catch inc. heritage catch	+/-	Water column (sub tidal)
Commercial Shell fishing	+	Intertidal
Commercial Shell fishing	+	Water column (sub tidal)

As the summary above shows the qualitative effect on each fisheries based ecosystem service is negative in almost all cases apart from shell fishing. Conceptually valuing the consumptive use-value of fish as a marketed food product, the result of commercial fishing activity, is relatively straightforward. In principle we seek an estimate of the sum of consumer and producer surplus and could derive this from knowledge of the demand curve and supply function for fisheries products. In practice calculating these may be difficult due to lack of data.

Assuming that impacted fisheries are a small contributor to overall supply in the fisheries market, with changes in supply from these fisheries having no impact on price, we can use the sale price of fish as an estimate of their value. In effect this assumes a zero consumer surplus for the marginal unit (avoiding the problem of not observing consumers' willingness to pay above market price paid). However this might not be acceptable for markets in which Severn Estuary fish plays a major part; for example the local restaurant trade may place a premium on local fish, and some estimate of this premium would also be required.

To derive an estimate of value, we need to subtract costs from sale price in order to estimate producer surplus. However cost data (for fishing, processing and marketing) is difficult to obtain, hence it may not be possible to estimate producer surplus, and as a consequence market values (sale price) are likely to over-estimate the value of fisheries in terms of providing a food source.

Actual information available on the value of commercial landings is not very closely related to the desired value estimate because it does not take account of costs, and looks only at the first point of sale, thereby ignoring any local premium.

Fish nursery functions fall into the category of intermediate functions and though we do need better information on them, in order to assess the effect on fisheries, we should not aim to value the function directly, thus the fisheries and shellfishery catch data as described above should incorporate these functions within their value estimates.

Finally, as noted above it is also not clear if commercial landings to ports in the Bristol Channel are the only aspect of interest in this regard. The key issue with respect to commercial landings is establishing the link between the effect of STP options and effects to fish stocks that are commercially exploited within the Severn Estuary area and beyond. Due to the uncertainty regarding the effect of the Severn Estuary on fisheries both within the Estuary area and beyond, along with the issue of determining where fish have been caught rather than landed, and the lack of information currently available with regard to the change in fish/shell fish provision as a result of the introduction of STP options it is not possible to link catch and market data to provide a proxy value estimate for the value of the fish, shellfish and fisheries and we are unable to provide a suitable estimate for the change in monetary value of commercial fishing and shell fishing for the STP scheme.

Currently reported values: The estimated value of fish and shellfish landings to ports in the Bristol Channel and Severn Estuary (see Other Sea Uses topic paper) is reported to have ranged between £2m to £4m for the period 1999 to 2003. Similarly the value of commercial eel fishing is estimated at £1.3 million on the basis of commercial exports.

Recreational catch values:

As for commercial fisheries described above, one can use a market price approach to value the recreational fish catch within the Severn Estuary area. Although, as for commercial fisheries using market price is likely to over estimate catch value as costs are not taken into account there are records detailing the number of Salmon caught and retained within England and Wales totalled 68.4t during 2008 (EA, 2008) River Wye had a reported average catch over 5 years of 2036 fish from 1992-1996 (EA, 1997) the reported value of which is estimated by multiplying the number of fish by the per fish value (£5,500) after Radeford et al. (1991) to obtain a value estimate. However, as with commercial fisheries above, the lack of information relating to the actual change in catch levels associated with the STP scheme along with the non-use values for angling is currently unavailable. Despite the popularity of shore and boat angling within the Estuary no details relating to Sea Angling catch are available.

Currently reported values: The Migratory & Estuarine Fish topic paper also reports the total value of the Severn Estuary salmon net fishery to fishermen (estimated by the Environment Agency as £96,200 in 2000). This is reported from the Severn Estuary SAP (EA, 2001) based on annual average catch for 1995-1999 and observed prices at the time of the report for salmon and sea trout, in conjunction with assumptions as to proportion of costs with respect to revenue in order to estimate net profit (producer surplus). Economic value estimates for salmon fisheries (comprising of recreation rod and commercial net fisheries) from Salmon Action Plans (SAPs) are reported for Rivers Severn (£1.1m), Wye (£22.4m) and Usk (£11m). These are reported as estimates of “minimum net economic value”, being the sum of: (1) market fishery value; (2) value to anglers; and (3) value to nets men (profit after sale of catch)[22]. Note these are total values, not annual.

Heritage fishery values – catch and non-use value

Net and fixed engine fisheries for salmon have been historically very significant in the Severn Estuary and its rivers. The fishery is now small, however the remaining fisheries are traditional and often unique and as such are of cultural and heritage importance. The heritage values of the River Severn Estuary and the Welsh coracle fisheries are discussed. Though minor in scale, they are traditional and locally unique, and so may have important heritage values. The total value of the Severn Estuary salmon net fishery to fishermen was estimated during 2000 to be £96,200 (EA, 2001)[23]. Only one applicable valuation study exists for valuing the non-use value of this highly specific resource. Simpson & Willis, (2004), used a stated preference study to determine the public WTP for maintaining a minimum level of activity within these fisheries. This study reported that the WTP to pay for the Welsh coracle fisheries[24] was £1.5 million and £5.3 million for the River Severn Estuary fishery. Note that this value is a total aggregate value based on a one-off payment; it is not an annual value.

Fishing (recreational and commercial) and Recreation

As the summary above shows the majority of effects expected with the introduction of the ‘largest barrage’ are negative for all recreational fishing apart from coarse fishing which is unlikely to be affected (this was removed in an earlier Section given the low likelihood of an effect of STP scheme). Other ecosystems service ‘effects’ vary over different habitat types.

Table 7.2 (at the end of this Section) shows the different studies that evaluate fishing and recreation. As with flood control and the ‘bundled’ services studies range in terms of location, the exact resource being valued and the nature of the conducted study. The meta-analytic studies are useful for both of these contexts however, as for flood control the use of these functions does not allow us to value a change in either of these services but rather the presence or absence of the service. Thus to determine the value of fisheries in the area the

[22] Details of the calculation are presented in the SAP documents. For example for the River Wye (EA, 1997) 5 year average rod catch (2036 fish for the period 1992-1996) is multiplied by the average capital value of rod caught salmon (£5,500 per fish, based on Radford et al., 1991) to give the market value. The estimate of consumer surplus to anglers is based on the expectation of a 1:1 ratio between the market value and consumer surplus (based on Radford, 1984). The market value (average catch × capital value per fish) is estimated to be approximately £11.2m; accounting for consumer surplus gives the £22.4m estimate.

[23] Note though that this value, which is reported in the Severn Estuary SAP, largely accords one commercial net fishery operator, rather than the heritage fishery – see also Section 4.1 and footnote 24.

[24] Valuations for Welsh coracle fisheries relate to the Rivers Tywi, Taf, and Teifi which do not flow into the Severn Estuary (although the Tywi flows into Carmarthen Bay).

ideal study would be one that focused on all of the values of all commercial fishery resources, likewise recreational fishing and recreation. Unfortunately, these are not available, however, Carlsen, (1985); Loomis, (1989); and Navrud (1988) allow for the valuation of changes in Salmon abundance while Lawrence (2005) and Söderqvist (2005) allow for us to value specific changes in abundance with regard to common sea fish in terms of recreational angling. This becomes more difficult for other recreational activities as while some values exist for canoeing (Jay, 1986) studies on windsurfers and surfers are unavailable. Similarly, specific studies on hiking are also difficult to track down although hiking is usually represented in studies of general recreation (Carlson et al., 2003).

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Commercial Heritage fishing (non-use values)	-/?	Rivers and streams
Freshwater angling (migratory)	-/?	Rivers and streams
Estuarine & sea angling	-	Saltmarsh and water column (subtidal)
Wildfowling	-	Intertidal and saltmarsh
Bird Watching	+/-	Intertidal
Bird Watching	-	Saltmarsh
Bird Watching	+	Water column (subtidal)
Hiking	-	Intertidal and terrestrial
Hiking	+/-	Saltmarsh
Sailing	+	Water column (subtidal)
Visiting archaeological ruin	-	Intertidal
Visiting archaeological ruin	?	Saltmarsh

There are, however, a few studies that relate to bird watching and wildfowling Kerlinger, (1992); Cooper & Loomis (1992), PACEC, (2004) and Luisetti et al. (2008b). Of these Luisetti et al. (2008b) specifically include 'bird species observed' as a variable to account for the non-use value of saltmarsh habitat and the PACEC wildfowling survey (2004) are the most appropriate to use within the Severn Estuary context. In addition, some estimates of expenditure, visitor numbers, bird watchers and wildfowling are available including approximate estimates of expenditure at two wetland reserve sites in the Severn area (see **Table 7.3** below).

It should be noted that the estimates collected in Table 7.3 represent a list of currently available information, some of which may not be used as part of the value transfer. For example, not all visitors to Slimbridge wetland centre will come to see birds; some RSPB members may join the organisation for other reasons such as for the group's lobbying work. To get an accurate estimate for the Severn Estuary area the number of visitors coming to the Severn and participating in recreational activities would need to be monitored. Thus the information in Table 7.3 acts as a guide rather than as an accurate representation of current visitor levels and visitor expenditure in the area. However, as with flood control below the change as a result of the STP scheme in the level of recreation (specific types), recreational angling and commercial fishing is highly uncertain and remains qualitative, thus a value transfer estimate of value is not possible.

Table 7.3: Summary of expenditure data and visitor estimates for bird watching, wildfowling and angling

Recreation type	Study	Area/data relating to...	Members/Visitor /shooting /angling days/yr	Value £/year in 2008 prices original year shown in brackets where not 2008
Bird watching	eftec, 2008	Titchwell	130,000	2,087,151 (2000)
Bird watching	eftec, 2008	Vare Farm Perthshire	58,000	291,791 (2000)
Bird watching	eftec, 2008	Freistone Shore	60,000	153,000 (2000)
Bird watching	Personal com. 2008	$Slimbridge_{SE}$	195,241	Adult entrance fee £8.75* Total entrance fees = 195,241 x 8.75 = £1,708,359
Bird watching	Personal com. 2008	Newport wetland $centre_{SE}$	54,725	- **
Bird watching	Personal com. – RSPB 2008	Total RSPB $members_{SE}$	20,545	Membership cost: £3/month Total membership cost/yr = 20,545 x 3 x 12 = 739,620
Wildfowling	PACEC, 2004	UK	$970,000_e$ – 19,000 of which are coastal wild fowling	750_emn (2004) on site exp by participants
Game fishing	EA, 2008	Annual game fishing licence UK	24,240	Annual licence cost = £68 Total licence cost = 24,240 x 68 = 1,648,320
Game fishing	EA, 2008	Short term game fishing licence UK	9739	Short term licence cost = 7.50 - 22.00 (1-8 days) 1day = 9739 x 7.50 = 73043 8 day = 9739 x 22.0 = 214,258 T. Cost Range = 73,043 – 214,258
Game fishing	Butler et al. (2009)	Salmon & Sea trout fishing in the Spey catchment Scotland	$40,544_e$	Expenditure/day = 228.44_e Total expenditure = 40544 x 228.44 = 9,261,871
Sea Angling	Drew Associates (2004)	Wales - residents Wales - visitors	$274,729_e$ (2000) $352,769_e$ (2000)	6.9_emn (2000) 21.8_emn (2000)
Sea Angling	Lawrence (2005)	South West	$750,000_e$	165_emn (2004)

Subscript SE – shows data relating to the Severn Estuary area; Subscript e – shows estimated data
* this estimate does not account for difference entrance fees for different individuals or that members of the wetlands trust have free entry
** There is no entrance fee at Newport wetland centre; however, there is a café and shop – expenditure unavailable

Agricultural land values:

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Grazing for cattle and sheep	**0/?**	Saltmarsh

As the above summary shows that the qualitative effect of the introduction of the 'largest barrage' is negative, however, any such effect is likely to be minimal (see Table 6.2). As with all market price estimates, this value does not account for the costs of grazing live stock on rough grazing land (see section on commercial fisheries above). However, agricultural land values can be used to determine the value of changes in the amount of rough grazing in the Severn Estuary area as a result of the STP scheme. Unfortunately agricultural land values tend to focus on the grade of land rather than what the land is used for; in addition the scale of the data available for rough grazing within the Severn Estuary area is at the county level meaning that any subsequent estimate of the rough grazing land would be an overestimate. Data relating to the change in amount of rough grazing land as a result of STP scheme is also unlikely to be available at the hectare level but rather as a qualitative measure (see Table 6.2 in section 6). This lack of information currently available means that it is not possible to link rough grazing land data and market data to provide a proxy value estimate of value.

Water abstraction and treatment (drinking water and agricultural use)

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Water supply: for cooling (in commercial factories)	+/-	Water column (subtidal)
Water supply: for disposal of waste	+/-	Water column (subtidal)
Water supply: agricultural use	+/-	Rivers and streams
Water supply: other (non-cooling) industrial use	?	Water column (subtidal)
Water purification & waste management: Filtration of water	-	Intertidal and saltmarsh
Water purification & waste management: Filtration of water	+/-	Water column (subtidal)
Water purification & waste management: Detoxification of water and sediment	-	Intertidal and saltmarsh
Water purification & waste management: Detoxification of water and sediment	?	Water column (subtidal)
Water purification & waste management: Disposal of waste	?	Intertidal and saltmarsh
Water purification & waste management: Disposal of waste	+/-	Water column (subtidal)

As the summary above shows both water quality and quantity are likely to be affected, in turn, having implications for the costs of water abstraction for different uses and treatment of water (both for public supply and other uses and wastewater treatment).

Abstraction

Water abstraction charges are calculated on a per m^3 basis and vary as to the nature of the abstraction, the resource used and the season abstraction occurs. The current annual charges with respect to water abstraction in the Severn Estuary area are calculated by:

Annual Charge = Standard Charge + Compensation Charge Eqn.1

= ((annual licensed volume '000m^3) x source factor x season factor x loss factor x SUC) **+ (**(annual licensed volume '000m^3 x season factor x loss factor x adjusted source factor x EIUC) + (Administration charges)

SUC = Standard Unit Charge (£/1000 cubic metres)
EIUC = Environmental Improvement Unit Charge (£/1000 cubic metres)
Annual licensed volume is the maximum amount that can be abstracted for a particular license

Assumptions:

1. The current charges with respect to agricultural and public water supply abstractions assume that all abstractions are annual, (season factor=1);
2. The loss factor is assumed to be high for all agricultural abstractions (i.e., that water does not return to any source directly/indirectly following use=1) and medium for water supply abstractions (i.e., =0.6);
3. The source factor is assumed to be unsupported (source factor=1);
4. The adjusted source factor is set to tidal or non-tidal as appropriate (0.2 or 1 respectively);
5. The SUC in the South West is £19.71/1000m^3;
6. The EIUC is set to £2.57 for non-water companies and £1.46 for water companies in the South West region; and
7. Finally each application has a £135 fee, along with £100 advertising administration fee and the minimum annual charge is £25.

Agriculture

Table 7.4 shows the abstraction charges related to agriculture for 2008 for the following Catchment Management Areas: Bristol Avon, Little Avon, Axe and North Somerset Streams, Rhymney, the Severn Vale, Taff and Ely, the Usk and the Wye. Charges do not include abstractions from boreholes, wells, ditches, lakes or pools but relate to rivers, streams, brooks and springs. The values for each area are calculated as (for each CAMS area – example below relates to line one in table 7.4):

Annual Charge = Standard Charge + Compensation Charge e.g. Bristol Avon, Little Avon, Axe and North Somerset Streams; Eqn. 1 for full definition of the terms.

= ((9862018/1000) x 1 x 1 x 1 x 19.71) **+ (**(9862018/1000) x 1 x 1 x 1 x 2.57) + 235

= £234,061 per year for Bristol Avon, Little Avon, Axe and North Somerset Streams CAMS Catchment

Thus the total cost of water abstraction related to agriculture (for all areas in Table 7.4) was approximately £1.1 million in 2008. Data relating to the amount of abstraction that are likely to be lost through the introduction of any STP option are unavailable (see Table 6.2). However, the STP scheme is not considered to cause a large change in terms of agricultural abstraction.

Table 7.4: Summary of abstraction charges relating to agriculture in 2008

Catchment Area Management Scheme (CAMS)	m^3/annum	Abstraction Charge £2008
Bristol Avon, Little Avon, Axe and North Somerset Streams CAMS Catchment	9862018	234061
Rhymney	1773548	40690
Severn Vale	4522131	209752
Taff and Ely	3476400	78394
Usk	1936472	47611
Wye	20146164	504671
Total for 2008	**41716733**	**1115179**

Abstraction charges are shown to the nearest £

Public Water Supply

Details relating to the abstraction of water for public water supply were unavailable due to national security considerations, thus calculation of the cost of abstraction could not be completed. If such data had been available Eqn. 1 defined above would be used to calculate the cost of abstraction. Black and Veatch, (2010), has recommended improved treatment at Weston WWTW (Wastewater Treatment Works) as a measure to prevent or reduce the effects on water quality for the L3d alternative only.

Sewage treatment

Sewage treatment costs in pence per m^3 during 2005-2006 are estimated in OFWAT (2006).

(Cost of operations per unit of volume + Cost of capital maintenance per unit of volume) x sewage volume

Discharge information relates to three water companies and relates to the maximum discharge consent except in the case of Welsh water – where one treatment plant is described as having in excess of 100,000 $m^3\ d^{-1}$.

Wessex Water: 560,000 $m^3\ d^{-1}$
Severn Trent: 105,000 $m^3\ d^{-1}$
Welsh Water: >210,000 $m^3\ d^{-1}$

Total Sewage treatment costs per day = (37 + 33) x 875000 = £612,500

Although we have current data relating to discharges from sewage treatment plants in the Severn Estuary area – we do not have an estimation of the sewage collected by each plant. Thus the estimate detailed here is very approximate. In, addition these values used for 'costs' are three years old and are likely to have increased over this period. The Potential change associated with the introduction of an STP option, is the possibility that the level of water is reduced within the estuary is reduced however, data relating to this information is currently unavailable from the SEA team (see Table 6.2).

Carbon emissions

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Carbon sequestration	-	Intertidal and saltmarsh
Carbon sequestration	+	Water column (subtidal)

As the above summary shows the qualitative effect on the carbon sequestration varies over different habitats following the introduction of the 'B3 - Brean Down to Lavernock Point Barrage. Given that emissions change in 2020 (and are assumed to stay the same for the duration of the project lifetime), the shadow price of carbon is calculated for 120 years to match SEA project lifetime. The price of non-traded carbon has been provided in DECC (2010). This new guidance provides carbon pricing up until 2100 after which the carbon cost is assumed to remain constant (approach approved by DECC via email on the 26th February 2010) (see main results, see Section 8), where the price of non-traded carbon is set as £25, £50 and £75 per tonne of emissions for low, central and high estimates. These values increase to a peak at approximately 2075 after which the value slowly begin to decrease and remain constant from 2100 until 2140. To calculate the value of the change in carbon flux each of the prices, i.e., low, central and high, is multiplied by the predicted emissions each year over the lifetime of the project and aggregated.

Flood Control

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Water regulation (flood prevention and aquifer recharge): protection from fluvial flooding	+/-	Rivers and streams
Water regulation (flood prevention and aquifer recharge): protection from coastal flooding	+/-	Rivers and streams, intertidal and saltmarsh
Erosion regulation: protection from flooding	+/-	Intertidal, saltmarsh and water column (subtidal)
Erosion regulation: protection from flooding	?	Terrestrial

As the summary above shows that the predicted qualitative effect of the introduction of 'B3 - Brean Down to Lavernock Point Barrage' is uncertain across ecosystem services relating to all aspects of flooding. The survey of studies undertaken for this report finds 18 studies which report values for the flood control services of wetlands and are applicable to the scope of this study and have been reported in publicly accessible formats. **Table 7.5a** provides a concise summary of studies.

All of the studies summarised within **Table 7.5a** report mean WTP for the flood control services for specific wetland habitat types. The elicitation methods used to collect data include choice experiments (1), contingent valuation studies (7), meta-analyses (6), hedonic pricing (2) and replacement cost (3).

Several of the studies listed below relate to particular resources, i.e., Bateman et al. (1991), Ragkos et al. (2006), and Luisetti et al. (2008b), the results of which are driven by specific attributes of the local wetland resource making them less desirable for inclusion within a value transfer. In addition, a number of studies value wetlands in different countries e.g. (Donnelly, 1989; Driscoll et al. 1994; Woodward & Wui, 2001). While this in itself is not necessarily a problem the wetland ecology of resources can vary across location furthermore the population and socio-economic characteristics of the respondents within these locations do not match that of the population within the Severn Estuary.

There are a number of meta-analyses that have taken place over the last few years in addition to the valuation of services as a 'bundle' of goods most of these studies are able to place values on specific ecosystem service functions including: flood control, recreation and fishing. The arguments for applying values derived from these studies have already made in Section 7.2, and as stated there these represent the most comprehensive studies for application to value transfer, thus Brander et al. (2008) is recommended as the study of choice for use in the evaluation of flood control services. Despite this, the change in the value of flood control services is dependent on understanding the change in flood risk associate which is currently unavailable, this also maybe at a too detailed level to determine the exact value of the change by using Brander et al. (2008) as this function is only able to value the flood control service in terms of its presence or absence. Thus the better alternative in this case maybe to use studies that determine the WTP for a change in the flood risk experienced by respondents. It is worth noting that as part of the SEA process the following flood risk management options were identified to reduce significant effects on flood risk and land drainage (see Table 7.5b).

Table 7.5b Draft requirements for measures to prevent or reduce significant effects on flood risk and land drainage

Alternative Option	Flood defences		Erosion protection		Pumping of outfalls	
	Total length (km)	Time frame of intervention	Total length (km)	Time frame of intervention	Area drained (ha)	Time frame of intervention
B3: Brean Down to Lavernock Point Barrage	44-87 far-field	Construction phase	135 ±50%	Year 5-50 repeated every 50 years	372	Construction phase
B4: Shoots Barrage	45 inner estuary 17 outer estuary	Construction phase	30 ±50% 41 ±50%	Year 10-20 repeated every 50 years Year 75-100	97	Construction phase
B5: Beachley Barrage	95 inner estuary 1.5 outer estuary	Construction phase	7 ±50%	Year 75-100	73	Construction phase
L2: Welsh Grounds Lagoon	0 inner estuary 24 outer estuary	Construction phase	19 ±50%	Year 5-50 repeated every 50 years	47	Construction phase
L3d: Bridgwater Bay Lagoon	0		37 ±50%	Year 75-100	243	Construction phase

Reproduced from: **Flood Risk & Land Drainage Topic Paper (2010)**

Landscape

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Views (part of recreation above)	--	Rivers and streams, intertidal, saltmarsh and water column (subtidal)

As the above summary shows qualitative effects on landscape are all predicted to be negative across all habitat types. Landscape will almost certainly play a part in many valuations relating to specific resources e.g. Kuriyama (2000), as it is part of the wider environmental context making it difficult to pick out the value associated with a site due to landscape considerations. Three recent studies relating to the value of landscape specifically have been conducted, two of which consider a particular context that cannot be transferred to that of the Severn estuary e.g. the effect of overhead cables on landscape (Navrud, 2008), and which are also conducted abroad, i.e., (Dymond et al. (2008) and Navrud, (2008)). Finally, González and León (2003) implement a choice experiment to determine the preferences for particular landscape attributes however; the context for this experiment (affect of landscape during bus excursions in Gran Canaria) cannot be matched to the context of the Severn Estuary. Once again the meta-analytic functions derived within Brander et al. (2008) and Ghermandi et al. (2008) account for an aesthetic service which may include landscape considerations; however, despite this the current studies available do not provide a suitable match to the Severn Estuary context given the scale of landscape change that may occur within the estuary, therefore the value transfer cannot be taken forward.

Biodiversity

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Habitat provision	+	Rivers and streams, water column (subtidal)
Habitat provision	-	Intertidal and Saltmarsh
Special birds – biodiversity value, non-use	+/?	Rivers and streams
Special birds – biodiversity value, non-use	-	Intertidal
Special birds – biodiversity value, non-use	-	Saltmarsh
Special birds – biodiversity value, non-use	-	Water column (subtidal)
Special fish species – biodiversity value, non-use	-	Rivers and streams, intertidal and saltmarsh
Special fish species – biodiversity value, non-use	+	Water column (subtidal)
Other species, biodiversity value, non-use	+/?	Rivers and streams
Other species, biodiversity value, non-use	-	Intertidal and saltmarsh
Other species, biodiversity value, non-use	+	Water column (subtidal)

As the above summary shows the predicted qualitative effects of implementing the 'B3 - Brean Down to Lavernock Point Barrage' in the Severn Estuary, as shown these predicted effects are uncertain across habitat types and all services relating to biodiversity. Studies relating to biodiversity tend to be of two kinds those that estimate generic values for the general biodiversity ecosystems service e.g. Jacobsen et al. (2008); or those that value particularly iconic species e.g. otters, White et al., (1999). However, studies relating to particularly iconic species can only be of use if the species concerned is represented within the Severn Estuary. In addition, there is the potential for double counting if each species is valued in isolation from other biodiversity considerations. In the case of the Severn Estuary it is no doubt preferable to consider a generic biodiversity value rather than one related to a specific or a few specific species, as with recreation and landscape above Brander et al. (2008) and Ghermandi et al. (2008) do consider this service as well as Woodward and Wui (2001). In addition, Jacobson et al. (2008) consider biodiversity value both in terms of iconic species and a generic value; Milon and Scrogin (2006) consider wetland species as a specific attribute within their WTP function and lastly Carlson et al. (2003) include generic biodiversity, fish and crayfish attributes within their choice experiment. The most relevant study to the Severn Estuary area in terms of biodiversity attributes is that of Birol and Cox (2009) who consider otter holt creation and protected bird species within their model of Severn Estuary management plans. However, as stated in the section on 'bundled' services above, this study relies on a small very localised sample making it inappropriate to transfer the resulting model to the wider Severn Estuary population.

One final option for considering biodiversity is to consider the value associated with sites designated in a particular way e.g. value of Natura or Ramsar sites (Jacobs, 2004 and Brander et al. (2006) respectively. However, the use of designation as a variable is fraught with difficulty as the sites valued within previous studies are designated for a number of differing reasons which may not match completely to those for used for the designation of Severn Estuary sites. In addition, site designation in itself cannot be considered an ecosystem service rather the ecosystem services of biodiversity, landscape etc. contribute to the reasons for site designation as without highly valuable habitat these service would be of low current value. As for the landscape ecosystem service above the current studies available do not provide a suitable match to the Severn Estuary context given the scale of biodiversity change that may occur within the estuary thus the value transfer cannot be taken forward.

Archaeological sites

Qualitative effects of single ecosystem services across habitats		
Ecosystem service	**Qualitative effect of STP scheme See Table 5.1**	**Habitat affected See Table 4.1**
Historical value of archaeological ruins	--	Freshwater wetlands, intertidal, saltmarsh and terrestrial

As the above summary shows the predicted qualitative 'effect' of introduction of the 'B3 - Brean Down to Lavernock Point Barrage' is negative across most habitat types. This final category of valuation studies that fall within the scope of this study covers an eclectic mix of heritage assets that incorporate archaeological sites. A number of studies focus on ancient monuments, ruins or sites of archaeological interest (as shown in **Table 7.6**). In terms of the Severn Estuary none of the above studies can be taken forward for use within value transfer due to the unique nature of each of the resources valued. Furthermore, information relating to the effect of STP scheme on archaeological sites within the estuary area is not quantifiable following the conclusion of Phase 2.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Bell (1997)	The economic valuation of saltwater marsh supporting marine recreational fishing in the south eastern US		USA	\$981-\$6471 per acre of saltmarsh
Bergstrom et al (2000)	Economic value of wetlands-based recreation	Expenditure and WTP data		Pub. 1990 Values for recreational fishing, hunting crabbing etc. \$20.73 per ha per year CS \$360 per user; \$93.95 expenditure per year
Bergstrom, J.C., J.R. Stoll, J.P. Titre, and V.L. Wright. (1990)	"Economic Value of Wetlands-Based Recreation," CV	Wetlands loss and recreational value. Exp. Data and consumer surplus recreational use of coastal wetlands	USA	US\$1986-87 per user 360 T. mean exp per trip: \$93.95 s.e.2.73
Bonnieux, F., et al. (1991)	The value of sports fishing in Western France. CV	The value of sports fishing in Western France.	W. France	Data from 1990-FF/person/year (a. Salmon angling; angling without catch limitation after June 1st: 103; (b. Sea-trout angling; WTP to participate in a fund to buy 5 km, where anglers would be entitled to fish freely for three years: 578.
Bloczynski et al. (2000)	Irreversible investment in wetlands preservation	Uses an optimisation process to decide between cost and management option attributes	USA	N/a
Bultler et al. (2009)	Expenditure data for the river Spey in Scotland	Expenditure	UK	Salmon rod catch:7599 (5 yr average) Sea trout: 3772 (as above)
Carlsen, A.J. (1985)	Non-use values of freshwater fish stocks. CV	WTP to avoid ''some'' and ''considerable'' reductions in the salmon stock in River Numedalslågen	Norway	43-88NOK/household/yr
Carlson et al. (2003)	A valuation is used to identify the attributes of wetlands that increase or decrease citizens perceived wetland values	Value of individual wetland attributes that respondents perceive to increase or decrease the value of wetlands. n=480	Sweden	Mean value is not reported, but a function that can incorporate different wetland attributes is specified and thus their worth estimated. Walking facilities attribute = 601.41 SEK (467.9-764.7)

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Connelly, N.A. and T.L. Brown (1991)	Net economic value of freshwater recreational fisheries CV	Recreational value of freshwater fisheries.	USA	15.87 (data from 1988)
Cooper, J. and J.B. Loomis. (1993)	"Testing whether Waterfowl Hunting Benefits Increase with Greater Water Deliveries to Wetlands," TC	Impact on recreational waterfowl hunting benefits of an increase in refuge water supplies to levels necessary for biologically optimal refuge management	USA	US$ per acre-foot of additional water supply (1990): 0.93 - 20.40 (OLS), 0.64 - 14.05 (Poisson)
Cooper, J.C. (1988)	"Using the Travel Cost Method to Link Waterfowl Hunting to Agricultural Activities," TC	Impact of contaminated irrigation run-off on waterfowl hunting benefits.	USA	US$ per hunter day and total for Kesterson (1988): 55.41
Curtis (2002)	Estimating the demand for salmon angling in Ireland	CS per day fishing Expenditure per trip data	Ireland	Pub 1992: Salmon (mean): IR£138.6 Northern Irish visitors: IR£115.6 Rep Ireland visitors: IR£145.9 German visitors: IR£161.5 Other European visitors: IR£151.7 Mean travel cost: IR£22 Mean equipment cost: IR£14 Mean Accommodation cost: IR£32 Rep Ireland visitors: IR£203 German visitors: IR£161 Other European visitors: IR£153
Davis, J. and C. O'Neill (1992)	Discrete choice value of recreational angling in N. Ireland - CV	WTP for angling licences.	N. Ireland	Data from 1992 £40.54/annual licence cost
ECOTEC (1993)	Creation of a new trout fishery. - CV	WTP for a Trout fishery	UK	(a. economic rent: 4.4-12.2; (b. consumer surplus: £2.2-6.7/angler visit

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Gaterell et al. (1999)	Investing in the aquatic environment – comparing the use of two different populations to generate aggregate values following the application of the water resource manual.		UK	1996-97 values New Holl estuary Informal recreation: £9062/yr Non-use value: £294617/yr Orwell estuary Informal recreation: £1022550/yr Boating: £276579/yr Non-use value: £61329/yr
Goodman et al. (1998)	Study to assess non-use value of the coastal environment - CV	Environmental protection of the coast	UK	Mean WTP in £ per house hold per year: 21.84 n=766
Hanemann, W.M. (1981)	''Water Quality and the Demand for Recreation,'' TC	Beach recreation and water quality at selected beaches in the Boston area.	USA	(1974 - US cents per household):(a. Average benefit per household from a 50% reduction in TURB at Malibu Beach/Savin Hill, Boston is reported: 3; (b. Average benefit per household from a 50% reduction in TURB at Sandy Beach/Upper Mystic Lake, Winchester is reported: 0.3.
Nick Hanley* and Andrew R Black`(2005)	rental valuations by the Tay District Salmon Fisheries Board for the river Tay		UK	£2250 per/km or where recovery takes place, restoration has to occur in a place where there were no Salmon other wise the benefits are lower!
Harpman, et al. (1993)	Method for quantifying and valuing the impact of flow change on a fishery CV	Mean WTP of anglers for their average catch of brown trout, and hypothetical additions to this number of fish caught.	UK	£16 - 21.5.
Jay, J.M. (1996)	"The Net Benefits of Backcountry Canoeing in Ontario Wilderness Parks: The Application of Random Utility Methods to Travel Cost Analysis," TC	The primary purpose of this study is to estimate non-market recreational welfare measures associated with policy decisions affecting the quality and quantity of wilderness canoeing in three parks.	Canada	Canoeing season 1993-US$ per trip: Estimated mean compensating variation (CV) for the elimination of each trip and park alternative: A: 1/2/3 or > trips (in $): 119.46/62.50/ 1.67; K: 39.76/4.32/0.00; Q: 9.03/ 19.33/12.43. Per day: A: 36.45/17.55/ 0.56; K: 9.43/1.14/0.00; Q: 1.43/2.49/ 2.06. Mean estimates CV for a 50% reduction in expected encounters while paddling and portaging: A: 33.52/48.39/43.07; K: 1.97/3.58/4.48; Q: 1.508/2.23/1.47.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Johnstone & Markandya (2006)	improvement in condition inc biological criteria and fish pop data - TCM	Water quality improvement	UK	Data from 2006: Angling (improved ecol. qual.)-lowland rivers:£47.31 Angling (improved ecol. qual.) -upland rivers: £19.27 Angling (improved ecol. qual.) - chalk rivers: £5.78
Kaoru, Y., V.K. Smith, and J.L. Liu. (1995)	"Using Random Utility Models to Estimate the Recreational Value of Estuarine Resources," TC	Using a household production framework to link nonpoint source pollution to fishing quality and a random utility model to describe how that quality influences sport fishing parties' decision.	USA	(1981-82) Dollars, years, miles per hour, horsepower and nitrogen loadings. Range of mean value in the database per study*(min - max):* 11-site Model: 0.1186/appr. 9.5; 23-site Model: appr. 1.0/11.0; 35-site; Model: appr. 2.0/9.0.
Kline & Swallow (1998)	The demand for access to coastal recreation in S. England - CV	WTP for access to Gooseberry Island	UK	WTP function is reported includes variables for camping weekend visits boating, and fees Mean value and model fit not reported
Laitila et al (2006)	Study of anglers WTP - CV	WTP for one extra caught fish	Sweden	46.61SEK
Lawerence (2005)	A Study of Sea Angling in the South West of England	WTP for increased catch and fish size across different species	UK	Pub. 2005 Increase in catch from zero to 1 fish: £13.56; Increase in fish size: Cod: £4.74; Bass: £12.45; Mackerel: £9.29; other fish: £12.45; all species: £10.24 Increase of 50% of number of fish caught: Cod: £6.35; Bass: £8.46; Mackerel: £-0.61; Other fish: £5.60; All species: £6.38
Loomis, J.B. (1980)	"Monetizing Benefits Under Alternative River Recreation Use Allocation Systems," TC	An optimal capacity, when the binding use constraint is ecological damage and monetization of recreational benefits, under alternative means of rationing that capacity, were conceptually and empirically developed. Efficiency was suggested as one of the prime criteria.	USA	(1977-US$ per trip per capita) Demand curve: the optimal use is 50 trips (in stead of 211) and the price is $112.67 a trip (permit) rather than zero. In case of a price system: permits would be sold for at least: $112.67; the recreational benefits by this allocation would be appr. $6500 ($800 to the users; $5620 to the taxpayers. Lottery system: the expected value of the lottery is appr. $3690. With regard to Wastewater, using the expected value for the lottery, the equity index would be 0.57 (3690/6500). Thus 43% of the potential benefits are lost to society by adopting a more equitable allocation system.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Loomis, J.B., C.F. Sorg, and D.M. Donnelly. (1986)	"Evaluating Regional Demand Model for Estimating Recreation Use and Economic Benefit: A Case Study," CV, TC	To evaluate the US Water Resource Council recommendation that regional or multi-site recreation can be relied on instead of single site models by developing the advantages and disadvantages of different types and sizes of regional demand models relative to water resources planning issues needing to be addressed in benefit cost analyses.	USA	(1983-US$ per trip): 51 site TCM: per trip/total site: $34.37/ $2131; 3 site TCM: $56.15/$3392; 1 site TCM: $66.64/$3205; CVM: $70.11/$3365.
Loomis, J.B. (1989)	Bioeconomic approach to estimating economic effect of watershed disturbance on recreational and commercial fisheries TC	To predict the change in catchable fish populations due to watershed disturbances from road building and timber harvesting.	USA	Net present value for alternative current direction: sport salmon/sport steelhead/ commercial salmon/total (in million $): 1.132/3.667/1.274/6.073; timber benchmark: 1.083/3.594/1.259/5.936; fish benchmark: 1.535/3.968/1.683/7.186; minimum management: 1.742/4.170/2.116/8.028. The economic value of the lost fish for recreational and commercial anglers is $2 million (30-year period). GNF: the difference between PV of the benefits was: $3.5 million (50-year period).
Loomis, J.B. (1989)	To demonstrate how site specific marginal values per fish can be estimated using the TCM and to systematically relate the variation in sites marginal fish values to variables in the fishing demand function. TC		USA	Data from 1977 For rivers with the four lowest and four highest MV per fish (in $): Coos: 18; Chetco: 22; Alsea: 23; Coquille: 34; Clackamas: 176; Salmon: 178; Santiam: 185; Willamette; 333. For example: on the Hood River a decrease in fish stocks resulting in a 10% decrease in recreational steelhead catch causes the MV per fish to rise from 123 to 125.69. An increase results in a 10% increase in recreational steelhead catch results in the MV falling from 123 to 119.84. A similar sensitivity of MV to change in fish catch occurs for the other rivers as well.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Loomis, J.B. (1996)	WTP for removing dams to restore salmon fishery. - CV	Restoration of Salmon fishery	USA	(a. local households: 41; (b. households in the rest of the state: 50; (c. households in the rest of the USA: 47.
Navrud (2001)	Economic value of inland recreation fisheries: empirical studies and their policy use	Recreational fisheries for different rivers/wetlands in Norway	Norway	Values in 1994 NOK – recreational value per angling day Only additional studies reported here the rest are within this table. River Hallingdalselv (brown trout): 170 (Navrud, 1984) Lake Lauvann (brown trout): 119-151 (Navrud, 1993a), CVM – 76-103 Gjerstadskog Lakes (brown trout): TCM-85-95, CVM 44-65 (Navrud, 1993a) Saltwater (coastal, salmon and sea trout) ITCM – 27-56 (Navrud, 1993b) Around river Audna CVM – 40-65
Navrud, S. (1989)	Social benefit of decreased acid deposition CV	Non-use values of freshwater fish stocks.	Norway	Mean annual WTP for increased fish stocks as a result of 30-70% reductions in an European sulphur emissions: 405 TC: 214-243 CV: 94-274 (NOK/household)
Navrud, S. (1988)	Recreational value of Salmon and Sea trout angling in River Vikedalselv TC, CV	Effect of acid deposition on fresh water fish stocks	Norway	NOK/angler day TC: 139-190 ; CV: 131-187
Olaussen (2005)	Bioeconomic model of wild salmon recreational fishery		Norway	Land owner value approach used, no mean values reported
Paulrud & Laitila (2004)	Valuation of management policies for sport fish on Kaitum river CV	point estimate of catching an extra fish per day on a 4 day fishing trip	Sweden	(cost 3000 SEK): trout & grayling < 30 cm: 16.81SEK trout & grayling 30-40 cm: 109.39SEK trout & grayling > 40 cm: 333.36SEK trout & grayling (per killed fish): 43.50SEK

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Peirson et al. (2001)	Economic evaluation of inland fisheries in England and Wales EXP	Angling associated expenditure (data collected during 1999) Actual expenditures made by anglers in their most visited areas as well as their visits to the three case study areas of River Thames, The Afon Teifi, and urban Leeds.	UK	Estimated expenditure of anglers directly related to angling: £617 (Teifi); £611 (Leeds); Average expenditure for coarse angling (from the national anglers' survey): £875; Median expenditure for coarse angling (from the national anglers' survey): £320. Mean value of salmon fishery (at average of 27.2 average catch over 5 years), parking facility and 144, 618 population within 20 miles is £145,294. Mean value of river trout fishery (at average of 0.383lbs weight per angler day, 14.82 meters in river width, 63.6% of catch as wild brown trout and 7678 meter river length) is £88,521. Mean value of coarse river fishery (at average of 2578 meters in river length, 7.78lbs weight per angler day, 24.03 meters in river width and with parking facilities) is £63,191. Mean value of stillwater trout fishery (at average 8.34lbs in weight and 61 swims) is £168,983. Mean value of canal fishery (at average of 3323 meters in length and 135 pegs) is £1,045.
PES USA ()	Sea angling	WTP per person per trip	USA	CS: $40.25
O'Neill, C.E. and J. Davis.	The effects of three alternative definitions of demand on freshwater angling - TC	Recreational angling on estimated parameters are explored in a TC-study of aggregate demand for angling	N.Ireland	Data from 1988 Estimated user benefits (in millions of UK pounds): 1. 9.1; 2. 22.21; 3. 10.66.
Radford, D. *et al*. (1991)	Total expenditure by anglers on recreational fishing activities. EXP	Angler expenditure	UK	(a. 17.18; (b. 548.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Radford, D. et al. (1991)	Total expenditure by anglers on recreational fishing activities.	other	UK	(a. 17.18; (b. 548.
Rolfsen, J. (1991)	Recreational value of alternative Salmon and sea trout angling in Gaula TC, CV	Recreational value of freshwater angling.	Norway	TC: 440-607; CV: 321. NOK/angling day
Rollins, K.	"Wilderness Canoeing in Ontario: Using Cumulative Results to Update Dichotomous Choice Contingent Valuation Offer Amounts," CV	To demonstrate empirically how using cumulative results from returned surveys to update contingent valuation offer amounts can improve the efficiency of estimates.	Canada	(1993 $ per day and per trip): Model 1: increase in general trip costs/increase in permit fee: $63.42/24.44; model 2 (increase in total trip costs/permit fee): A: $67.37/$22.35; Q: $65.82/$28.63; K: $66.76/$21.59; model 3: this ranged from 3 days to > 20 days: $75.99-$15.42/$27.06-$15.32.
Rollins, K. and W. Wistowsky. (1997)	"Benefits of Back-Country Canoeing in Ontario Wilderness Parks," CV	This study reports on an application of non-market valuation to an activity with which it has not previously been applied: wilderness canoeing n Ontario.	Canada	1993-$per person per day and per trip: Mean WTP for "same trip": all parks/AP/QP/KP (in $): 66.40/67.37/ 65.82/66.76; trip length: ranged from 3 days to > 20 days: 75.99 to 15.42. Mean WTP for "Back-Country Permit": 26.38/22.35/ 28.63/21.59; trip length: 27.06 to 15.32.
Ragkos et al. (2006)	Value for all functions of a Greek wetland CV	WTP for food web functions of Zazari-Cheimaditida wetland	Greece	£2008 Mean WTP €40.15 CI95%: €35.50-€47.08 n = 174 individuals
Scancke (1984)	Recreational value of freshwater angling. TC		Norway	170 NOK/angling day
Singsaas, (1991)	Estimated economic value of recreational fishing TC	Recreational value of freshwater angling.	Norway	217-339 NOK/angling day
Smith, and Kavanagh (1969)	Estimation of the benefits of trout fishing at Graftham reservoir.TC	Estimation of the benefits of trout fishing at Graftham reservoir.	UK	£39,944

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Spurgeon et al. (2001)	Maintaining and/or improving water quality and angling opportunities in (a) the respondents' most frequently used water body and (b) in three case study areas and (c) River Wye (Wales - England border) for the general public. CV	Water quality	UK	(a.) WTP to increase water quality from none to poor (5% and 10% truncation): £7.64 (5.3-2.96); WTP to increase water quality from poor to reasonable: £4.79 (2.34-1.73); WTP to increase water quality from reasonable to good: £7.64 (4.59-3.46); Maintain good: £10.19 (7.75-5.50). (b.) WTP for an angling trip for coarse fishing (national survey): £2.14; WTP for an angling trip for game fishing (national survey): £2.75; WTP for River Wye scheme: £3.70 (1.79-1.35); WTP for angling experience at the Afon Teifi £7.64 per (local) angler per trip; WTP for angling experience in urban Leeds £1.83 per (local) angler per trip. Those who had previously visited River Wey had WTP of £5.00 per household per year, while those who had not visited the river had WTP of £3.66 per household per year.
Söderqvist e al. (2005)	Economic valuation for sustainable development of the Swedish coastal zone CV, TCM, RC and CE	Increased bathing water quality Increased fish catch Replacement cost of sea trout management practices MWTP for changes in water quality attributes	Sweden	Decrease of 40% Nitrogen estimated as SEK57 million/yr TCM used to understand WTP for increased fish catch: coefficients for Travel cost and catch size in Kg of different fish species given (function available, mean values not reported and function does not account for socio-economic variables Restoration of streambed: SEK327,000 total cost Weir fishway: SEK70,000 total cost Fishway Solbergsan: SEK1004000 total cost Fishway Kavlingean: SEK817000 total cost Bathing water: SEK600 Cod stock (kg): SEK1200 High biodiversity: SEK600 Low biodiversity:SEK1400

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Sorg, C.F. and J.B. Loomis. (1986)	Economic value of Idaho's sport fisheries CV, TC	The purposes of this study are to refine the conceptual framework of valuation by identifying and clarifying the values generated from fishery recreation, identifying refinements in the travel cost and contingent value methods that have been made since Gordon et al. (1973), and report results of a 1983 survey measuring cold-water and warm water fishing values and to compare them to other studies.	USA	$/trip and $/day A: (I): 1a) 22,52; 1b) 14,25; 1c) 31,87; 1d) 35,30; 2a) 16,35; 2b) 12,02; 2c) 24,26; 2d) 26,16; 3a) 31,45; 3b) 20,29; 3c) 41,36; 3d) 39,14. (II):1a) 39,71; 1b) 21,02; 1c) 51,03; 1d) 53,88; 2a) 19,36; 2b) 11,39; 2c) 22,45; 2d) 28,45; 3a) 45,71; 3b) 19,13; 3c) 57,14; 3d) 48,57. B: CWF: mean net WTP per trip/per day for current conditions (in $): 42.93/25.55. WWF: 42.18/26.36. SHF: 27.87/14.29. Mean variable cost per trip: CWF/WWF/SHF: 37.05/24.62/ 72.21.
Strand, J. (1981)	Recreational value of Salmon fishing in Gaula. - TC	Recreational value of Salmon fishing in Gaula.	Norway	335 NOK/angling day
Tapsell, S. M., et al. (1992)	''Ravensbourne River Queen's Mead Recreation Ground Survey,'' CV	WTP for recreational values.	United Kingdom	£/user/visit. £/resident/ visit. £/user/visit. £/resident/ visit. Present condition: (a. 1.88; (b. 1.45; Recovery to full river condition: (c. 3.31; (d. 3.16.
Ulleberg, M. (1988)	Recreational value of freshwater angling. TC	Recreational value of freshwater angling.	Norway	235-311 NOK/angling day
Vaughan, W.J. and C.S. Russell. (1982)	Value of a fishing day TC	The objective of this study is to estimate the value, in average WTP terms, of a day of freshwater recreational fishing differentiated by fish species sought.	USA	$/person and $/day Average surpluses: Trout: TC1: excluding resource costs (CS)/including resource costs (WTP): 10.96/15.60; TC2: 19.49/ 24.09. Catfish: TC1: 7.00/10.62; TC2: 12.48/16.03. For example, an increase of one fish per angler above the mean catch of trout (4.7 fish per person) raises average WTP above the TC1 value of $15.60 by $0.45. An increase of one catfish per angler above the mean catch (4.2 fish per person) raises average WTP from $10.62 to $10.93, an increase of $0.31 per person.

Table 7.2: Summary of valuation studies relating to fisheries, angling and other recreation

References	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Whitehead, J.C. and G.C. Blomquist. (1991)	''Measuring Contingent Values for Wetlands: Effects of Information About Related Environmental Goods,'' CV	Wetland preservation.	USA	(1989 - $/person/year) (a. Value is the mean WTP per respondent for the reclaimed wetland lake as a replacement for the Clear Creek wetland after surface coal mining (80 respondents in this subsample): 8.13; (b. value is the mean WTP per respondent for the reclaimed grassland as a replacement for the Clear Creek wetland and the undisturbed, nearby Henderson Sloughs was the related environmental good (72 respondents in this subsample): 16.61.
Whitmarsh et al. (1999)	Study to determine benefits of a seafront - CV	Future scenarios relating to sea front erosion n=600	UK	£8.63
Woodward & Wui (2000)	A meta-analytic study to value single ecosystem finctions within wetlands - MA	Value of single wetland functions only	North USA and European studies	Value of recreational fishing: $357 per acre per year
WWF (2004)	Meta-analysis		Global	Value of nursery areas $201 per ha per year Value of fishing £374 per ha per year
	This study extends the TC literature on valuing quality improvements by measuring the benefits of improved quality in a single-site recreation demand model. TC	TC		CS: annual benefits of recreation quality improvements: 10% improvement: change in CS: $14; 25%: $34; 50%: $73.
Meyerhoff & Dehnhart 92007)	The EU WFD and Economic valuation of wetlands: the restoration of Flood plains along the river Elbe - CV	Preservation of endangered species	Germany	Function derived based on attributes of conservation knowledge socio-economic variables and the site

Table 7.5a: Summary of studies relating to flood control services

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Bateman et al. (1991)	Elicitation and Truncation Effects in Contingent Valuation Studies CV	Analysis of methods of eliciting WTP in a CV study of flood protection of a UK wetland.	UK	£67.19/yr
Brouwer et al. (1999)	Wetland MA of CVM studies	Mean WTP for all wetland functions relating to freshwater wetlands	USA and other developed countries	Saltwater wetland feature: (1990 special drawing rights) mean WTP of 92.6 per hectare Broad meta-analysis that derives values for specific wetland functions and wetland types N=30 studies
Posford, D. (1990)	Estimating the flood alleviation scheme for the Thames Valley CV	WTP for reducing flood risk	UK	£ per household per year 4-6 for reduced risk level, amounting to present value at 6% and 50-year time horizon of £2.5-3.7million for approx. 40,000 households.
Donnelly (1989)	Analysis of the Effects of a Floodplain on Property Values HP	flood hazard potential reflected in land values	USA	5.53 per $ property tax liability
Driscoll et al. (1994)	Investigation of non-linear budget constraints with the example of flood risk	Methodology paper with case study example	USA	204.29 - 6,105.20 US$ per chance of flooding
Holway, J.M. and R.J. Burby	The purpose of this study is to determine the extent to which floodplain management programs are indeed reducing the value of vacant land in the floodplain. HP	Considering the effects of the National Flood Insurance Program (NFIP).	USA	US$1975-77 per thousand square feet. Arvada: mean land value/mean parcels size (acre)/mean flood hazard (fifths in floodplain): 1,009/3.1/4.4; Cape Girar-deau: 200/1.8/3.5; Fargo: 706/1.9/4.6; Omaha: 499/ 9.6/3.0; Palatine: 1,248/0.4/3.5; Savannah: 348/9.7/4.3; Toledo: 387/4.5/2.3; Tulsa: 259/3.5/3.8; Wayne: 1,131/4.5/4.4; average: 782/3.7/3.7.

Table 7.5: Summary of studies relating to flood control services

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
MacDonald et al. ()	Investigate behavioural responses to a natural hazard (flooding) by examining residential property values. HP	Change in residential property values	USA	Squared feet and US$1985 Full-sample: SP: 62,939.6; HSQFT: 1,722.1; OSQFT: 466.3; BATH: 1.81; AIR: 0.79; FIRE: 0.62; HIGH: 0.28; MEDIUM: 0.47; LOW: 0.25; FLOOD: 0.71. Sub-sample: SP: 90,839.3; HSQFT: 2,094.1; OSQFT: 606.92; BATH: 2.2; AIR: 0.82; FIRE: 0.75; FLOOD: 0.56.
Shabman, L., and K. Stephenson.	To compare residential flood risk reduction benefit estimates from the property damages avoided HP, CV	Residential property damages avoided WTP for avoiding property damage	USA	A: 1) n.v.t.; 2) property transactions sold between 1980 and 1990. B: 1) n.v.t.; 2) fall of 1987. A: The HP technique generated the largest estimates, with the gap between the estimates greatest for the most flood prone areas. Mean estimates: HP: $1,333; PDA: $597. B: CVM (lump-sum): $314. Mean CVM bids: Flood Zone (FZ): all bids/excl. uncertain bids/excl. uncertain & protest bids: FZ<.05: 115.00/143.75/230.00;.02<FZ<=.05: 203.33/305.00/381.25;.01<FZ<=.02: 980.00/980.00/1,225.00;.002<FZ<=.01: 223.08/241.67/322.22;.0001<FZ<=.002: 240.00/272.72/428.57; all FZ: 313.70/369.35/520.45. Annual payment bids: the 16 positive bidders who were not registered to vote had stated they would be WTP on average about $124 each year for 15 years. Controversially, those who actually voted stated a WTP of about $93 each year

Table 7.5a: Summary of studies relating to flood control services

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
King & Lester (1995)	Comparison of spending on sea defences and thus the value of salt marsh as an alternative, has values for agricultural land (out of date), also estimates of wildfowling value RC	Cost of sea defence spending	UK	sea defence capital saving: £30-60 per m2 per year sea defence maintenance saving: £0.60 per m2 per year
Stevens, T.H., S. Benin and J.S. Larson.	Investigation into the value of wetland preservation CV	Annual WTP for wetland protection – flood control service estimate is available	USA	US$1993 per respondent (a. Value is the high end estimate of respondents' yearly WTP to protect New England wetlands that provide flood protection, water supply and pollution control: 80.41; (b. Value is the low end estimate of respondents' yearly WTP to protect New England wetlands that provide flood protection, water supply and pollution control: 73.89.
Bateman et al. (1991)	Survey of non-users WTP to prevent saline flooding in the Norfolk Broads	Flood protection	UK	mean £WTP for flood protection per year: £21.75
Woodward & Wui (2001)		Flood protection service	Global	$393 per acre per year
WWF (2004)	Valuation of the world's wetlands (based on meta-analysis – no further detail given)		Global	Value of flood protection US$1990 per ha per year $464
Ragkos et al. (2006)	Value for all functions of a Greek wetland CV	WTP for specific functions of Zazari-Cheimaditida wetland	Greece	restoration flood water retention 42.53 Euro per year

Table 7.5: Summary of studies relating to flood control services

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Brander et al. (2008)	Study to calculate the per heactaare value of different wetland habitat types Saltmarsh Intertidal mudflats MA	Value per ha per year	European wetland types	£2008 per hectare per year Mean value of UK wetlands of £1949 Function described by Brander can be used within a function transfer for the policy site and a per ha value derived n=166 studies yielding 264 observations)
Ghermandi et al. (2008)	Study to calculate the per heactaare value of different wetland habitat types Estuarine habitat MA	Value per ha per year	Based on global studies	Mean values not reported but function is available
Huggett (2008)	Value of saltmarsh width	Uses cost of sea defence per metre at different crest levels	UK	Saltmarsh Width / crest of wall / cost of sea wall 80 m 3 m £400 per metre run 60 m 4 m £500 per metre run 30 m 5 m £800 per metre run 6 m 6 m £1,500 per metre run 0 m 12 m £5,000 per metre run
Luisetti et al. (2008b)	This study determines the value of saltmarsh characteristics for new areas of salt marsh created RC	RC for sea defences	Essex, UK	

Table 7.6: Archaeological sites

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Beltrán and Rojas (1996)	WTP per visit; 2. WTP per month for conservation CV	Valuing visits to and preservation of archaeological sites	Mexico	US $4-6 (visits), $1-4.60 (conservation) n=3500 (on- & off-site)
eftec (1999a)	WTP per person per visit, entry fee CV (DB DC and PC)	Valuing visits to the Machu Picchu citadel archaeological site,	Peru	$40-47.60 (all users), $26 (Peruvians), $47 (foreigners) n=1014 (visitors)
Kinghorn & Willis (2008)	Valuing the components of an archaeological site CE	An application of Choice Experiment to Vindolanda, Hadrian's Wall	UK	The greatest loss of utility (from the attributes included in this study), to the value of £27.18 per individual, would occur if excavation and research at the site ceased People are willing to pay £6.16 to see an increased amount of reconstructions on the site. There would be a loss of utility to the value of £18.65 if the artifacts were moved to other museums n=149 interviews
Maddison and Mourato (2002)	Valuing impacts of road improvements upon Stonehenge CV	road improvements upon Stonehenge	UK	£12.80 (tunnel scenario), £4.80 (current scenario) n = 271 (on-site UK residents), 525 (off-site UK residents)
Poor and Smith (2004)	Use value derived from visits to St. Mary's Historical City, Maryland, TC	visits to St. Mary's Historical City, Maryland,	USA	CS per visit US $6-35 n=92

Table 7.6: Archaeological sites

Reference	Study good context and methodology	Definition of the Good	Study good site	Mean WTP
Provins et al. (2008)	the scope for using results of economic valuation studies in the appraisal and assessment of heritage-related projects and programmes?' And assesses the use of value transfer in four case studies VT	to estimate the benefit generated by the restoration works proposed for Denbigh's historic buildings during Phase 2 of the THI, bring historic buildings back into use; (ii) repair the fabric and structure of historic buildings; and (iii) restore lost architectural detail on buildings	UK	mean WTP for restoration of historic buildings in Denbigh is estimated to be £6.23 per household per year on the basis of function transfer from Garrod et al. (1996). comparaison, Garrod et al. (1996) report that mean WTP for restoration of historic buildings in Grainger Town is £13.76 per household per year n=1 study
Riganti and Willis (2002)	Valuing conservation of Campi Flegrei archaeological park CV		Napoli, Italy	WTP per person per yr (donation over 5 years) US $29 n=484 visitor, 424 residents
Ruijgrok (2006)	The three economic values of cultural heritage: a case study in the Netherlands HP & CV	HP increase in property price for historic building attributes and historic landscape CV WTP for value added in terms of recreational opportunities and in terms of conservation, i.e., bequest was derived following a Cultural Heritage Conservation Plan (each ayer of heritage was described, i.e., buildings, archeology etc.)	Netherlands	Number of historical facade elements WTP for 1 extra element €3,777 Recreation EUR 1.22 Per visit SD 2.72 Bequest EUR 11.88 Per year per Household SD28.18 n=380, 591 houses
Whitehead and Finney (2003)	Valuing preservation of historic ship wrecks, CV	Valuing preservation of historic ship wrecks,	North Carolina, USA	WTP per household (one time tax) US$32.80-39 N=884 residents

8 VALUING THE ECOSYSTEM CHANGES FROM SEVERN ESTUARY TIDAL POWER OPTIONS

This section presents the process of value transfer using a value function transfer approach for the bundled ecosystem services value transfer and a unit value transfer approach for the changes in the CO_2 equivalent flux which is the only individual service for which quantitative impact data are currently available.

There are significant caveats associated with the value transfer exercise which are enough to render the analysis unsuitable for further economic analysis. These are listed in Section 8.3.

8.1 The bundled ecosystem services value transfer

8.1.1 Wetland habitats

Following on from Section 7.2, in which the Brander et al. (2008) meta-analytic value function for estimating the value of different wetland habitats while accounting for all of their main ecosystem services was chosen as the best economic evidence currently available, this section describes in detail how the function was applied within the value transfer approach to measure the 'effect' of the introduction of different STP options.

The influence of the spatial factors and substitutes are accounted for within this function with a boundary of 50 km from the centre of the saltmarsh/intertidal site of interest, as this proved to be the most accurate spatial range within the function derived for predicting the values obtained from wetland studies as part of a meta-analytic process.

The function comprises of a number of different parameters relating to ecosystem services, economic method, socio-economic characteristics, habitat and spatial characteristics as shown in Table 8.1. The first column of the table describes the variable and the second column reports the estimated coefficient.

A large number of the explanatory variables are 'dummy' variables, i.e., they can be set to either zero or one. In the case of the ecosystem service variables 1 means the presence of a particular service in the wetland and 0 means that the service is not provided. Thus the valuation model used here can only provide information relating to the presence or absence of a particular service rather than estimate values relating to ecosystem service degradation.

The function is run once with the values for each explanatory factor for the current situation (Severn Estuary without any STP options) to estimate the unit economic value in the current situation (see Table 1 below). The function is then run separately for each of the five STP options to estimate the unit economic value for each of them. As part of sensitivity analysis, lower and upper bound unit values are estimated using different values for the above factors for intertidal and saltmarsh valuation and also for the CO_2 equivalent flux.

The way in which we use the Brander et al. function relies on the definition of two contrasting scenarios one in which the assumptions made are chosen to reflect a 'conservative' economic approach (low end damage estimates) and a second in which the assumptions made are chosen to reflect the high damage estimates. These are labelled as 'low' and 'high', respectively. Thus all estimates within the results tables are presented as ranges. The following scenario definitions detail the assumptions made:

- LOW scenario (lower bound damage estimates):
  - That there are substitute wetlands available within the area, this is a conservative approach in economic terms as all the wetlands identified within the 50km radius are assumed to be substitutes of the Severn Estuary (see point (i) below).
  - The affected population considered within this estimate relates to the 'local' population only, i.e., towns along the estuary up to Minehead on the English coast and Cardiff on the Welsh coast including: the local and unitary authorities of Cardiff (305,350), Newport (137,017), Bristol (380,340) and Bath and N.E. Somerset (169,045), (see point (ii) below).
  - The use of 'average' value estimates within the calculation of value change.
  - That the habitats that remain unaffected in the 'with STP option' case provide the services they provide today, i.e., if 1 ha of a particular habitat is lost, all of its services lost or if 1 ha of that habitat remains it continues to provide all its services. We use sensitivity analysis within Section 10 to demonstrate the effect or removing each service individually.
  - Central CO_2 equivalent flux in tonnes per year are valued at the lowerbound DECC non-traded unit value in £ per tonne.

- HIGH scenario (upper bound damage estimates):
  - That there are no substitute wetlands available within the area, this is a conservative approach in ecological terms as all other wetlands within the 50km radius are assumed to be unable to substitute for the Severn Estuary (see point (i) below).
  - The affected population considered within this estimate relates to the 'regional' population only, i.e., includes the South West Region for England (4.9mn) and E. Wales (includes: Cardiff (305,350), Newport (137,017), Bridgend (128,645), Monmouthshire (84,885) and the Vale of Glamorgan (119,292), (see point (ii) below).
  - The use of 'marginal' value estimates within the calculation of value change. The Severn Estuary can be considered a scarce resource allowing for the use of the 'marginal' value as an alternative.
  - That the habitats that remain are affected in the 'with STP option' case and do not provide the services they provide today, i.e., whether 1 ha of a particular habitat is lost or remains all of its services are lost. We use sensitivity analysis within Section 10 to demonstrate the effect or removing each service individually.
  - Central CO_2 equivalent flux in tonnes per year are valued at the upperbound DECC non-traded unit value in £ per tonne.

The lower bound estimate comes from the 'low damage scenario' in which all relevant factors are defined so that the current unit value of the Severn Estuary is a lower bound estimate and the unit value of change under each STP option is also a lower bound estimate. In the 'high damage scenario', both the current unit value and the unit value of change are at their highest. In other words, the low damage scenario shows the case of losing a small value from an already low value resource, and high damage scenario shows the case of losing a high value from an already high value resource.

A final point to note about the Brander et al. function is that several of the explanatory variables relating to ecosystem service provision within the Brander et al. function have negative coefficients, i.e., decrease wetland value. These variables include: commercial fishing and hunting, recreational fishing, harvesting for natural materials, fuel and recreational hunting. Brander et al. (2008) do not provide an interpretation as to why these particular ecosystem services result in negative coefficients, however, all relate to extractive activities that take place within wetlands, which may help explain these results. As each of these activities take place they remove part of the wetland ecosystem be it fuel material or fish, leaving less behind to contribute to other services and for other user participating in extractive uses of the ecosystem and thus causing a negative effect.

The third column of the table indicates the value of the variable in the case of the Severn Estuary, while the fourth column provides notes on this value. The final column reports the source of data for the Severn Estuary.

Freshwater wetland (or inland marsh in Brander et al. (2008)) is not valued due to lack of scientific data available from the SEA in relation to the effects of STP scheme. Finally, both subtidal and rivers and stream valuation is not possible within the 'bundled' approach due to the lack of valuation literature available in relation to the ecosystem services that an area of each habitat type provides and their value. Ecosystem services relating to these specific habitat types are better served by looking at the specific ecosystem services provided by each habitat for example, fishing, and taking a 'single service' approach (see above).

Table 8.1: Economic Value function for intertidal and saltmarsh habitat - Severn Estuary

Variable	Coefficient value	Severn Estuary value	Value of explanatory variable	Source
Constant	-3.078	-3.078	N/A	N/A
Wetland Type A group of dummy variables relating to Inland marshes Peatbogs Saltmarshes Intertidal mudflats	 0.114 -1.356 0.143 0.110	 0 0 1/0 1/0	The two wetland categories valued within this value transfer were intertidal mudflats and saltmarshes. Both habitat types were valued separately rather than added together to give separate values for each habitat type.	Table 6.1 in Section 6 above
A group of dummy variables relating to economic methodology used Contingent valuation Choice experiment Hedonic pricing Travel cost Net factor income Replacement cost Production function Opportunity cost Market prices	 0.065 0.452 -3.286 -0.974 -0.215 -0.766 -0.443 -1.889 -0.521	 0 0 0 0 0 0 0 0 0	All set to zero because our study does not use the meta-analytic function to predict the value of an economic valuation study for the area	N/A
Marginal relates to the study characteristics, i.e., whether the study conducted was to find average (0) or marginal values (1) (dummy)	1.195	0	Low: Set to 0 to obtain a more conservative value High: Set to 1 to obtain the maximum value (see above).	N/A
Wetland size (in	-0.297	780ha -	Saltmarsh: range from	

Table 8.1: Economic Value function for intertidal and saltmarsh habitat - Severn Estuary

Variable	Coefficient value	Severn Estuary value	Value of explanatory variable	Source
hectares) (size of wetland created in terms of this case study)		1,240ha 13,950ha - 27,580ha	Intertidal mudflats: range from	See Table 6.1 in Section 6 above
Does the wetland provide a flood control service (dummy)	1.102	1	This ecosystem function was identified within the ecosystem services framework and remains part of the 'final ecosystems services table' it is therefore set to 1 – i.e., provided for the 'low' scenario and 0 for the 'high' scenario.	Table 5.1 in Section 5 above
Does the wetland provide a surface and ground water supply (dummy)	0.009	1	This ecosystem function was identified within the ecosystem services framework and remains part of the 'final ecosystems services table' it is therefore set to 1 i.e., provided for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide a water quality improvement (dummy)	0.893	1	Water quality services are provided by the Severn Estuary and thus the service is set to 1 i.e., provided for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide recreational fishing (dummy)	-0.288	1	Recreational fishing services are provided within the area and identified within the final ecosystems services table, thus the service is set to 1, i.e., provided for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide commercial fishing and hunting (dummy)	-0.040	0	The Severn estuary currently provides a commercial fishing ecosystem service and wildfowling service (although not commercial), the variable is set to 1 as provided for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide recreational hunting (dummy)	-1.289	0	The Severn Estuary area provides opportunities for wildfowling which is identified within the final ecosystems services table thus the recreational hunting service however, given that the above variable also provides for hunting this is currently set to 0 for both scenarios.	
Does the wetland provide for the harvest of natural material (dummy)	-0.554	0	The harvesting of natural material was not identified within the ecosystems services table as an ecosystem service currently provided within the Severn estuary area, thus this service is set to 0 i.e., not	

Table 8.1: Economic Value function for intertidal and saltmarsh habitat - Severn Estuary

Variable	Coefficient value	Severn Estuary value	Value of explanatory variable	Source
			provided for both scenarios.	
Does the wetland provide material for fuel (dummy)	-1.409	0	As for harvesting set to 0 for both scenarios.	Table 5.1 in Section 5 above
Does the wetland provide for non-consumptive recreation (dummy)	0.340	1	Non-consumptive recreational services are part of the final services table and include bird watching and hiking, although these activities are not identified directly this service accounts for them generally within the model, thus the service is set to 1 for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide amenity and aesthetic services (dummy)	0.752	1	Amenity and aesthetics services are part of the final ecosystems services table in terms of the Severn Landscape, thus the service is set to 1 for the 'low' scenario and 0 for the 'high' scenario.	
Does the wetland provide biodiversity (dummy)B_{PG}	0.917	1	Biodiversity services have been identified within the final ecosystem services framework and within the wider context of the area in terms of providing bird habitat for species such as the Bewick's Swan, Bittern etc. this services is therefore set to 1 for the 'low' scenario and 0 for the 'high' scenario.	
GDP per capita for the case study area (logged)	0.468	$32,102	The mean GDP per capita for the UK in 2008 converted to US$2003 is used within the meta-analysis for both scenarios.	ONS database (see section below on calculating GDP)
Population within 50 km of the policy site (logged)	0.579	LOW: 3.054 mn Converted value= 387 people per km^2 HIGH: 5.57 mn Converted value= 709 people per km^2 (logged)	The sum of the populations of Cardiff, Newport, Bristol, Bath and NE Somerset. This value is then converted to the population density within 50km radius of the centre of the Severn estuary for the 'low' scenario to provide the 'local' population estimate. The sum of the populations of the South West and East Wales This value is then converted to the population density within 50km radius of the centre of the Severn estuary for the 'high' scenario.	Office of national statistics ONS 2001 Census: Standard Area Statistics England and Wales (see notes Table 5.1, Section 5)
Wetland area within 50 km radius of the policy site (logged)	-0.023	LOW: 6659 ha HIGH:	The hectares of wetland within a 50km radius of the Severn estuary were calculated using	EEA data service[25]

[25] http://dataservice.eea.europa.eu/dataservice/

Table 8.1: Economic Value function for intertidal and saltmarsh habitat - Severn Estuary				
Variable	**Coefficient value**	**Severn Estuary value**	**Value of explanatory variable**	**Source**
		0 ha	EEA CORINE land cover data for 2000 (see Section 7) for the 'low' scenario, the value is set to 0 for the 'high' scenario	
Summary statistics reported by Brander et at. 2008: *n* = 264, R^2 = 43%				

The coefficient values in Table 8.1 are taken from the model specified by Brander et al (2008) However, Ghermandi (2008) specifies a slightly different meta-analytic function that accounts for a larger range of wetland types (using a global dataset). Brander et al. (2008) function is preferred as it show a function specifically derived for European wetland types. Ghermandi (2008) function is used within sensitivity analysis (see Section 10).

The rest of this sub-section explains the data gathering and analysis process used in applying this function to value the changes to the intertidal and saltmarsh habitats due to STP options. This process includes the following steps:

(i) Identify other wetlands within 50 km radius of the Severn Estuary;
(ii) Calculate the population within 50 km radius the Severn Estuary;
(iii) Calculating the GDP per capita (modified from Brander et al. 2008)
(iv) Calculate wetland size
(v) Calculate the economic value of the change in intertidal and saltmarsh habitat

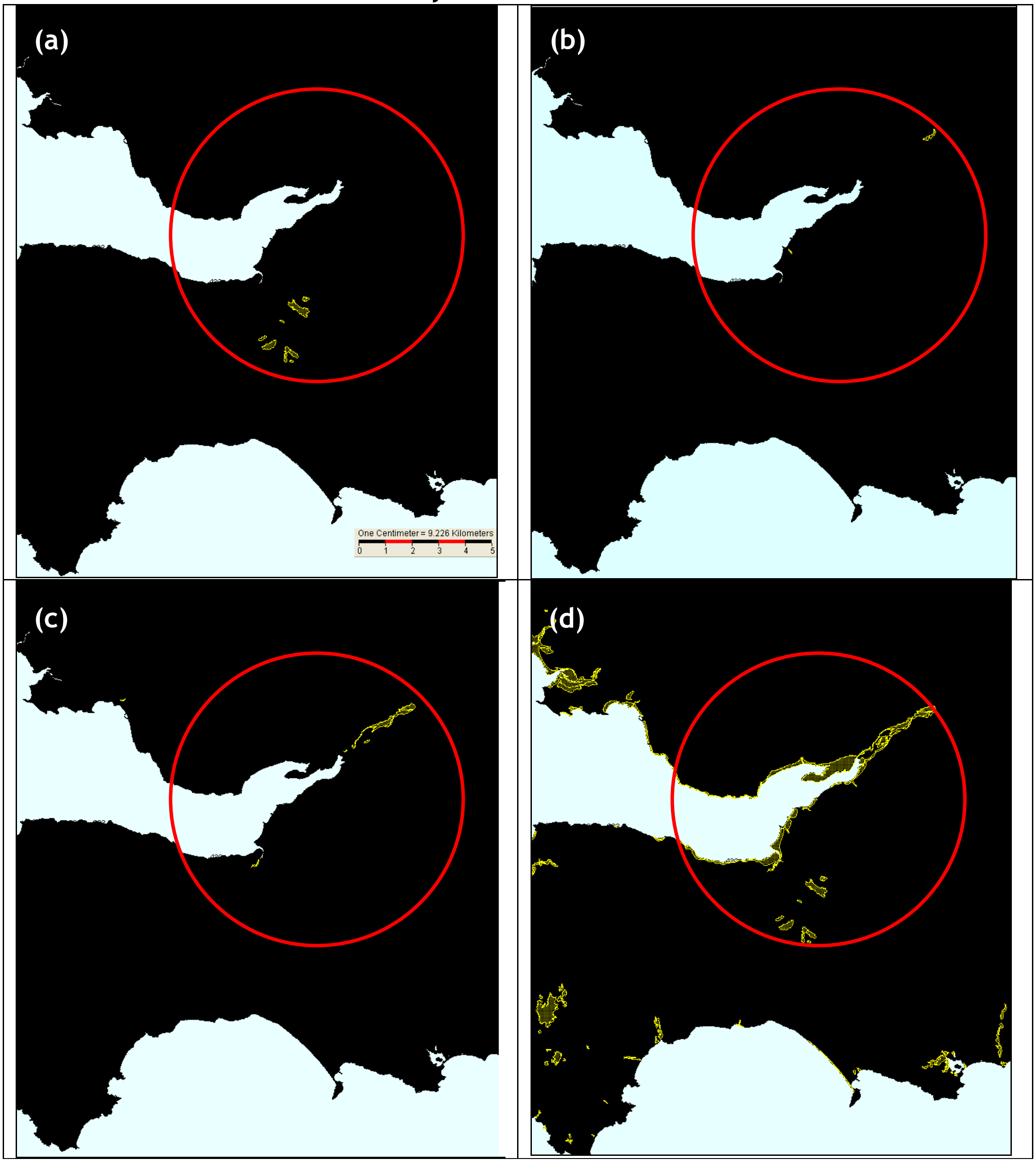
(i) Identify other wetlands within 50km radius of the Severn Estuary - value used within the 'low' scenario only

Following Brander et al. (2008) other wetlands sites within a 50 km radius of the Severn Estuary were calculated by using values from the EEA CORINE land cover data for 2000. Four grid cells were downloaded and merged to produce maps to show the extent of all wetland types, i.e., CORINE classifications codes 411, 412, 421 and 423 or Inland marshes, Peat bogs, Saltmarshes, and Intertidal flats respectively within a 50km radius of the Severn estuary but not connected to the estuary as these would be incorporated within environmental change estimates Figure 8.1 shows the wetland areas identified by type within the 50km radius. ArcExplorer was used to determine the km^2 area of each wetland type, these values were then summed and incorporated within the meta-analytic function (see Brander et al. (2008) for further details regarding the downloading of data, and merging of file information), Table 8.1 above shows the area of each individual wetland within the 50km radius considered within the meta-analytic function transfer.

- Low scenario: set to 6659ha; and
- High scenario: set to 0ha.

The affect of including substitutes has been tested within the sensitivity analysis (See Section 10).

Figure 8.1: The wetland area of (a) Inland marshes, (b) Saltmarsh, (c) Intertidal flats and the total wetland area within the study



(ii) Calculate the population within 50 km radius of the Severn Estuary - figures for the 'local' population are used within the 'low' scenario, while the 'regional' population is used for the 'high' scenario

Low scenario: Population within 50 km of the Severn Estuary is measured using an overlay to the case study area map with a 50 km circle (see **Figure 8.1 above**). The population of each Unitary Authority or county was obtained from the 2001 Census, see Table 5.1 for a definition of the 'local' population used within this study, this is however, a simplified version of the approach used by Brander et al. (2008) in which more detailed estimates of population were used. The values of the total population was then divided by the total area within a $50km^2$ radius of the Severn Estuary, i.e., the surface area of the case study = $\pi \times r^2$ i.e., 3.14159654 x 2500 = $7854km^2$

Thus the average population density over the study area *PD* is:

PD = 1,461,300/7854
PD = 387.61 population per km^2

To match the inputs needed within the meta-analytic function applied.

High scenario: Population within 50 km of the Severn Estuary is measured using an overlay to the case study area map with a 50 km circle (see **Figure 8.1 above**). The regional population of the South West and East Wales were obtained from the 2001 Census, see Table 5.1 for a definition of the 'regional' population used within this study, this is however, a simplified version of the approach used by Brander et al. (2008) in which more detailed estimates of population were used. The values of the total population was then divided by the total area within a $50km^2$ radius of the Severn Estuary, i.e., the surface area of the case study = $\pi \times r^2$ i.e., 3.14159654 x 2500 = $7854km^2$

Thus the average population density over the study area *PD* is:

PD = 5,566,750/7854
PD = 708.78 population per km^2

To match the inputs needed within the meta-analytic function applied.

These population values were varied during the sensitivity analysis phase of this process.

Limiting the population affected to the 50km radius matches the value function used; however, both scenarios described are conservative estimates as they assume that the population beyond this area do not hold values for the changes to the Severn Estuary. While the radius may be representative of the valuation studies in the literature, the scale of the Severn Estuary is likely to justify a much larger area. The implication of this assumption for the range presented in this report is that it is an under estimate of the value of the effect of the STP on wetland habitats (see list of assumptions and caveats in Section 8.3).

(iii) Calculate the GDP per capita (modified from Brander et al. 2008)

Following Brander et al. (2008) a single socio-economic variable is considered – GDP per capita of the UK was obtained from the Office of National Statistics (www.ons.gov.uk) – in the value transfer function. As stated above the Brander et al. (2008) meta-analysis use values converted to US$2003, thus figures obtained from the ONS are converted from £2008. A mean GDP per capita of 32,102 US$2003 was calculated for use within the value transfer. The GDP estimate is the same for both 'low' and 'high' scenarios. The effect of altering GDP per capita values is also tested within sensitivity analysis (see Section 10).

(iv) Calculate wetland size

The wetland size used within calculations was that defined by the SEA for each STP option (see Table 6.1), the aggregated value of this option was then subtracted from the value of the current area in order to determine the monetary loss/gain associated with the change in intertidal and saltmarsh habitats (see Table 9.1 for aggregate value of each loss/gain). These estimates are the same for both 'low' and 'high' scenarios for a particular STP option.

(v) Calculate the economic value of the change in intertidal and saltmarsh habitat

Based on the function and data reported in Table 8.1, each value is calculated by multiplying the function coefficient and the Severn Estuary value from Table 8.1 as shown for the current per hectare per year value of saltmarsh under the 'low' scenario for the Shoots Barrage option (B4) (note that only non-zero terms are shown):

$$
\begin{aligned}
EV = \; & -3.078 - \\
& (0.297 \times ln(1130)) + \\
& (0.143 \times 1) + \\
& (1.102 \times 1) + \\
& (0.009 \times 1) + \\
& (0.893 \times 1) - \\
& (0.288 \times 1) + \\
& (0.34 \times 1) + \\
& (0.752 \times 1) + \\
& (0.917 \times 1) + \\
& (0.468 \times ln(32{,}102)) + \\
& (0.579 \times ln(387)) - \\
& (0.023 \times ln(6659)) \\
= \; & ln(6.681)
\end{aligned}
$$

The value of the dependent variable ($/ha/year) is in natural log terms. This is transformed by raising the exponential to the power of 6.681:

$$e^{6.681} = \$903 \text{ per hectare per year (2003 US \$)}$$

This value can then be converted to 2003 £ using a purchasing power parity exchange rate (we use the OECD exchange rate in this example) and inflated to 2008-2009 £ using the HM Treasury inflator/deflator values (2010):

$903 x 0.64 = £579 per ha per year (2003 £)
£579 x 1.137 = £658 per ha per year (2008-2009 £)

The figure shown in Table 8.2 is averaged over three different conversion rates – this is why the values do not match exactly here.

The per hectare values for both saltmarsh and intertidal mudflats for each STP option along with the current situation and as a result of the introduction of each STP option are reported in Table 8.2 (see Section 9 for aggregate values and PV's relating to each STP option). Given that the size of the habitat is a determining factor of the unit value of that habitat, for each habitat area in each STP option, there is a different unit value estimate.

Table 8.2: Economic value of intertidal and saltmarsh habitat change (based on Brander et al., 2008) in £2008-2009 (£ per hectare per year)

Habitat - value type	Current value	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Saltmarsh						
Area (ha)	990	780	1,130	1,070	1,070	1,240
Value (£ per ha per yr) low - high	697 - 1,337	748 - 36	670 - 32	681 - 33	681 - 33	652 - 31
Intertidal mudflat						
Area (ha)	29,930	13,700	26,480	27,030	22,600	27,150
Value (£ per ha per year) low - high	245 - 466	309 - 15	254 - 12	252 - 12	266 - 13	252 - 12
Included:	Change in the area of intertidal and saltmarsh habitats. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).					
Excluded:	Saltmarsh and Intertidal habitat estimates do not include intertidal areas of sub-estuaries and changes arising from long term morphological processes. Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by each STP scheme. The following factors that are likely to have an effect on the unit economic value estimate but are excluded from the analysis due to lack of data: • Ecosystem services of archaeology and health effects of wetlands, • Population (users and non-users) outside the 50 km diameter area, and • Far field effects (beyond Bristol Channel). Ecosystem services excluded because STP scheme is likely to lead to no change or no significant change in an ecosystem service include: habitat provision for bees, subsistence cropping, subsistence shell fishing and catch, wildfowling, water for industrial cooling, air quality, other recreation, and renewable energy (i.e., fuel for biomass). Ecosystem services included within other technical reports (i.e., aggregate extraction and navigation/port services) are excluded here. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2.					
Caution	There are several other caveats that need to be taken into account which are listed in Section 8.3.					
Source:	See Tables 6.1 and 8.1					

The results in Table 8.1 show that the 'large barrage' option, i.e., B3 Brean Down to Lavernock Point Barrage, results in the greatest per hectare values for both saltmarsh and intertidal mudflats due to the large reductions in the size of both habitats. The per hectare values differ by a maximum of £ 10 and £78 per hectare for saltmarsh (high and low estimates respectively) and £3 and £57 per hectare high and low estimates respectively) for intertidal mudflats across all STP options. While the loss in intertidal mudflat is much larger than that for saltmarsh, saltmarsh is a much more productive environment leading to higher value. A comparison of the per hectare values calculated with the mean per hectare value reported in Brouwer et al. (1999) is included in Section 10. The variation in the per hectare values is much lower in the 'high' scenario as all the ecosystem services are assumed unavailable, i.e., following STP scheme all ecosystems services are lost. This assumption leads to a reduction in the variation across options, as the loss of services becomes the overriding factor in terms of determining the change in overall estuary value rather than the amount of habitat lost.

8.1.2 Calculation of the economic value (EV) of the change grassland habitat across the study area

Grassland is not included within Brander et al. (2008), thus the values report within the ELF model (Oglethrope, 2005) are used to calculate the monetary value associated with change in grassland expected with the introduction of STP options. The unit value is given as £5.74 (corrected to 2008 values) per hectare per year (see Section 9 for aggregate value).

8.2 The single ecosystem services value transfer

The only individual ecosystem service that can be monetised at the moment is the annual carbon flux. Details of the quantitative data available from the SEA currently are given within Table 8.2. Of the single services functions that maybe of most interest the changes in water quality and fishing are likely to be most affected by STP options. There are currently no additional data relating to these effects available.

The immediate effect of the introduction of any STP option is a change in CO_2 equivalent emissions due to the habitat lost the central estimate for each STP option are shown as the total change in monetary value (in net present value terms) over the project lifetime, i.e., 120 years, in Table 8.3 below. The error bands for each option depend on the change in the amount of habitat caused by each option. This means that the error margins vary according to the estimates of the loss of carbon through processes of methanogenesis, and sequestration as saltmarsh habitats are lost and loss of carbon emissions assuming that siltation occurs over the project lifetime, these error bands are shown in Section 10 along with the associated change in monetary values related to carbon emission change.

Table 8.3: Valuing the change in carbon equivalency emissions NPV's (£millions), values shown to the nearest £100,000

Emission units (t/yr) and value (£2009 per tonne)	Current baseline	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
CO_2 equivalent emissions t/yr	n/a	**-1,706**	**-4,139**	**-1,981**	**-3,360**	**-376**
Low value of non-traded Carbon (2020-2140)	25-67	2.5	6.2	3.0	5.0	0.6
Central value of non-traded Carbon (2020-2140)	50-268	6.1	14.8	7.1	12.0	1.3
High value of non-traded Carbon (2020-2140)	75-469	10.6	23.5	11.2	19.0	2.1

Included:	Change in the area of intertidal and saltmarsh habitats. The estimates of CO_2 equivalent flux include: • The effect of the loss of potential carbon sequestration, i.e., the change in the amount of habitat (ha) is assumed to lead to a year on year loss of the ability to sequester carbon, • Siltation (averaged over the project lifetime to obtain an annual value), and • Methanogenesis
Excluded:	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme, these are not represented in this table but considered in Section 7.3 which addresses single ecosystem service valuation. The total flux in annual CO_2 equivalent emissions exclude: • Any changes as a result of the Nitrogen cycle, • The loss of sequestered Carbon as a result of a change in the following habitat types, intertidal, saltmarsh and grassland, and • Ecological changes that are likely to take place where an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.
Caution	• Caution should be used if comparing values between STP options as these represent estimates for the comparison of different optimisation strategies within STP options. As such these values maybe subject to different levels of reliability; in addition different design factors may have been taken into account for different options and current optimal solutions may change. The effects on sequestration and methanogenesis are extremely sensitive to ecological factors which could be altered by different design options/optimisation for each option. • Values relating to the total flux in annual CO_2 equivalent emissions should be used with caution as they are subject to high levels of uncertainty (see Section 10). Negative values relating to total flux in annual CO_2 equivalent emission relate to decreases in emissions.
Data sources and other notes:	Data provided are based on environmental metrics in the Marine Ecology paper and carbon emission calculations (Black and Veatch email 23rd March 2010). Intertidal area has been rounded to the nearest 100 ha. Saltmarsh area has been rounded to the nearest 10Ha. Grassland area has been rounded to the nearest 10Ha.

In addition to the data presented in Table 8.3 Section 10 shows the impact in monetary terms associated with the scientific error bands estimated for the CO_2 equivalent flux estimates.

8.3 Assumptions and caveats

The economic value function applied in this example entails a number of assumptions to simplify the approach, with the intention of focusing on the key principles of the function transfer methodology. And there are also some caveats associated with the function and these assumptions.

The value function used is based on a European wide dataset but not specifically for wetlands in the UK or within the Severn Estuary area. The implication is that the good valued in the study (Brander et al., 2008) is not the same (or even sufficiently similar to) the policy good (the Severn Estuary). Therefore, it is highly possible that the results do not represent the change in the Severn Estuary. Given the absence of primary value data fitting the context of the Severn Estuary and the STP options, it is not even possible to know what the error band is.

Despite this overarching and crucial caveat we have undertaken the analysis described above and the following list is the individual assumptions and caveats related to the implementation of the value function.

Types of habitats and services covered

All estimates relating to the immediate effect of STP scheme on habitat have been obtained from the SEA team the following assumptions relate to these estimates:

- Total intertidal represents area between the Highest Astronomical Tide (HAT) and the Lowest.
- Astronomical Tide (LAT) and includes saltmarsh, and mudflat which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle.
- Estimates do not include intertidal areas of sub-estuaries.
- Estimates do not include changes arising from long term morphological processes.
- The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post scheme.
- Only intertidal, saltmarsh and grassland are included in the ‘bundled’ approach – other potential (positive or negative) effects are excluded due to lack of scientific or economic data. The quantitative assessments of change used for the habitats based on the latest version of SEA data these have not been finalised or ratified by the steering group – the implication is that the results are likely to be underestimates;
- The future baseline is assumed to remain unchanged and there is no scientific data relating to the value of potential ecosystem services that maybe provided (without STP) in the future – the implication is that the results are likely to be underestimates;
- There are no specific variables that account for human health values of wetlands archaeological or agricultural values within this function. In the case of the former two services however, both have been identified as less likely to change significantly following the STP scheme, while scientific or other economic data are also lacking for human health values – the implication is that the impact on results is likely to be insignificant;
- Commercial hunting is not present within the Severn Estuary, given that there is only a single coefficient for commercial fishing and hunting –the implication is that the contribution of fishing maybe overestimated but this overestimation is likely to be insignificant;

- The WTP estimate remains constant over the lifetime of the project. Sensitivity analysis tests this assumption by assuming GDP growth from 2020 to 2140 which therefore increases the per-hectare per year value of both intertidal and saltmarsh habitat over time. The implication for the results reported above is that they are underestimates. The per-hectare per year value of grassland is not changed overtime.

Affected population and its characteristics

- The approximate population within 50 km of the wetland site are accounted for by estimating a 'local' and a 'regional' population associated with the main unitary authorities and counties – in reality there is likely to be a higher number of people affected due to the potential for a 'national' value of the resource – the implication is that the results are underestimates;
- The study area is a 50km circle centred in the Severn Estuary (see Figure 8.1 above for the exact area). This area was chosen in order to meet the criteria of the Brander et al. (2008) function. However, this is smaller than the SEA team's study area of downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and River Usk – the implication is that the results are underestimates (excluding other likely affected population – potentially national population);
- This limitation of the population also means that the non-use values are underestimated in the results. Given the uniqueness of the Severn Estuary, exclusion of even a part of non-use values means that the results are underestimates; and
- GDP per capita of the UK in 2020 is used within the calculation (see calculating GDP section), based on an assumed growth in GDP from 2009 to 2020. Although, the starting value is slightly lower than that for the South West (however, the latest data available for this is 2006 on the Eurostat website) and thus a slight underestimate, the 2.5% (EIU, 2009) annual growth rate maybe optimistic leading to a slight overestimate.

Estimates of CO_2-e flux

- The estimates have error bands that vary according to the level of habitat change seen across different habitat types, see Section 10 for further details, the implications of the uncertainty associated with these estimates is that for the highest potential estimates, CO_2 flux dominate those of the habitat values.
- In addition, the estimates do not include any changes as a result of the Nitrogen cycle and neither do they include the effects of the loss of sequestered carbon as a result of a change in the following habitat types, intertidal habitat, saltmarsh and grassland. The results also exclude any ecological changes that are likely to take place when an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration. The implication for the results is that they are likely to be significant underestimate of the carbon emission to the atmosphere.

9 AGGREGATION

This section presents the aggregation process (over habitat or service types and over time) for both the bundled and single ecosystem services value transfer, in Sections 9.1 and 9.2, respectively.

The assumptions and caveats that are listed in Section 8.3 for the unit value estimates apply here too. In addition, the assumptions and caveats that are related to the aggregation process are listed in Section 9.3.

9.1 The bundled ecosystem services value transfer

Aggregation over wetland habitat types

Table 9.1 shows the value change associated with each STP option in terms of changes in intertidal mudflat and saltmarsh habitat. All values are shown in £2008-2009 per year. Unit economic values per hectare values are aggregated over the amount of habitat available following the introduction of STP options. Value change represents the change from the current total value per year (without the STP option) to the annual value following the STP scheme (with the STP option).

The value of grassland habitat change is shown in **Table 9.1**, here the per hectare value available from (Oglethrope, 2005) is multiplied by the gain (in hectares) of grassland following the introduction of each STP option.

Table 9.1 shows that the change in grassland within the estuary area is 1-2% of the change associated with those seen in intertidal mudflats and saltmarsh following the introduction of any of the shortlisted STP options. This is driven firstly by the relative magnitude of the change, i.e., tens/hundreds of hectares as opposed to thousands/tens of thousands hectare change in the other categories of habitat.

Aggregation over time

Data available currently show the level of habitat change expected to occur in 2020 during initial STP option introduction. The values in Tables 9.1 & 9.2 show the monetary value associated with one year's worth of change. However, the life-time of any STP option maybe in the range of 120 years and as such this habitat change needs to be calculated across this time period. Figure 9.1 shows a graphical representation of this loss. The shaded area shows the habitat loss valued over 120 years assuming that the estimates of habitat do not change after the effect of implementing STP in 2020, i.e., no recovery. The purple arrow represents the SEA estimate of habitat change immediately following the introduction of STP.

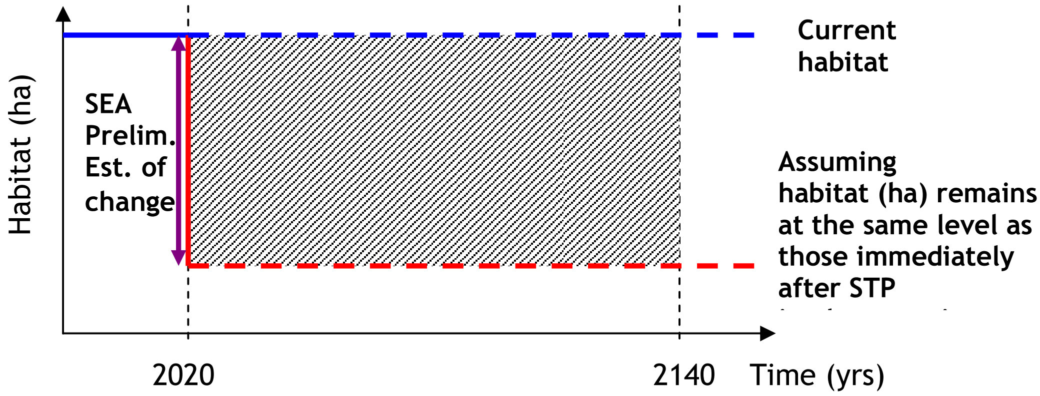
Table 9.1: Total annual value of the intertidal and saltmarsh habitat change (based on Brander et al., 2008) and grassland change based on Oglethorpe (2005); (£2008-2009)

Habitat - value type	Current value	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Saltmarsh						
Ha remaining	990	780	1,130	1,070	1,070	1,240
£/ ha / year low-high	697 - 1,337	748 - 36	670 - 32	681 - 33	681 - 33	652 - 31
£ Total Value / yr (thousands) low-high	690 - 1,323	583 - 28	757 - 36	728 - 35	728 - 35	808 - 39
£ value change / yr (thousands) low-high	0	(-106) - (-1,295)	+67 - (-1,287)	+39 - (-1,288)	+39 - (-1,288)	+118 - (-1,284)
Intertidal mudflat						
Ha remaining	29,930	13,700	26,480	27,030	22,600	27,150
£ / ha / yr low-high	+244 - +464	+309 - +15	+254 - +12	+252 - +12	+266 - +13	+252 - +12
£ Total Value / yr (thousands) low-high	+7,329 - +13,959	+4,231 - +204	+6,725 - +324	+6,822 - +329	+6,016 - +290	+6,844 - +330
£ value change /yr (thousands) low-high	0	(-3,098)-(-13,755)	(-605) - (-13,635)	(-507) - (-13,631)	(-1,313)-(-13,670)	(-485) - (-13,630)
Grassland						
Ha remaining	60	590	110	120	110	140
£ / ha / yr	5.74	5.74	5.74	5.74	5.74	5.74
£ Total Value / yr	344.40	3,386.60	631.40	688.80	631.40	803.60
£ value change /yr low-high	0.00	3,042.20	287.00	344.40	287.00	459.20
Total value change £ per yr nearest 10,000 (thousands) low-high	0.00	(-3,201) - (-15,050)	(-537) - (-14,920)	(-468) - (-14,920)	(-1,274)-(-14,960)	(-367) - (-14,910)
Included:	Change in the area of intertidal, saltmarsh and grassland habitats. See section 6 for quantitative assessment and section 8.1 for valuation calculations. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).					
Excluded:	See Table 8.2. The unit values presented here relate to information obtained from the SEA on the 16th March 2010. These values were updated after the original project cut-off date for inputs, the impact of this update was to change the annual value of the change associated with intertidal habitats by +1% - -1% across STP Options, this in turn changed the total annual value of habitat change by +0.3 - -1.8% across all STP Options. Changes in the flux of CO_2 equivalent emissions are covered in Sections 8.2.					
Caution:	All assumptions and caveats that are related to unit economic values (Section 8.3) apply					

	here too. Note that there are no error bands available for estimates of the changes in each habitat type measure quantitatively.
Sources:	Tables 6.1 and 8.2

Note: negative sign means loss of habitat and hence an economic cost.

Figure 9.1: Aggregating values over time



Although the assumption that the habitat area will remain at levels seen following STP scheme does not account for any potential recovery within the Severn Estuary, the estimates shown below are still likely to be an underestimate given that the environmental change as a result of STP will be irreversible and continue into perpetuity.

Currently, there are only rudimentary estimates relating to the 'final' equilibrium values of habitat change in terms of the total percentage change across all intertidal habitats (intertidal mudflats, saltmarsh and grassland) across each option. However, due to the uncertainty associated with these values and lack of detail in how different habitat types are affected these measurements are not used within our analysis.

The present value of the habitat change across the estimated life-time of the STP project (assumed to be from 120 years) is calculated following the Green Book guidance (HM Treasury, 2003). Given that the assumed project life-time is greater than 30 years a discount rate of 3.5% is used for the initial 30 years (2009 is year 1).

From 2020 onwards the monetary loss used to represent the total change in economic value as a result of STP scheme is calculated as:

$$\sum \Delta IM + \Delta SM + \Delta GL + \Delta CO_{2_{ze}}$$

Where ΔIM – the value of the change in intertidal habitat (mudflat, sandflat, rock and shingle) over either the next 120 years, ΔSM – the value of the change in saltmarsh habitat over either the next 120 years, ΔGL – the value of the change in grassland habitat over the next 120 years, and ΔCO_2ze – the change in the total flux of CO_2 equivalent emissions over the next 120 years.

Following HM Treasury (2003), after 30 years or 2040 the discount rate drops to 3% per annum until 2085 (or 75 years from 2010) when the discount rate drops to 2.5% until (2135) or 125 years later, the rate then drops to 2% until 200 years from the starting point. The discount rate decreases through time during long timescales to reflect uncertainty about the future which can be shown to cause declining discount rates over time (HM Treasury, 2003). The Green Book amendment on the topic recommends even lower discount rates for the intergenerational

change are used within the sensitivity analysis to demonstrate the effect of changing the discount rate on net present values (see Section 10)[26].
The resulting present value estimates are presented in Table 9.2.

Table 9.2: Present value of the habitat change over 120 years (£ 2008-2009)

Habitat - value type	Immediate Effect (~2020)				
	Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Saltmarsh					
gain/loss (ha)	-210	+140	+80	+80	+250
£ million value change per year (From Table 9.1) low - high	0.58 - 0.03	0.76 - 0.04	0.73 - 0.04	0.73 - 0.04	0.81 - 0.04
PV over the project lifetime £ million (120 years) low - high	-2.4 - -19.2	1.5 - -19.0	0.9 - -19.1	0.9 - -19.1	2.7 - -19.0
Intertidal mudflat					
gain/loss (ha)	-16,230	-3,450	-2,900	-7,330	-2,780
£ million value change per year From Table 9.1 low - high	+7.3 - +14.0	+4,.2 - +0.2	+6.7 - + 0.3	+6.8 - + 0.3	+6.0 - + 0.3
PV over the project lifetime £ million (120 years) low - high	(-69.73) - (-203.63)	(-13.61) - (-201.85)	(-11.41) - (-201.78)	(-29.52) - (-202.36)	(-10.93) - (-201.77)
Grassland					
gain/loss (ha)	+530	+50	+60	+50	+80
£ value change per year From Table 9.1	+3,042	+287	+344	+287	+459
PV over the project lifetime £ million (120 years)	+0.07	+0.01	+0.01	+0.01	+0.01
TOTAL NET EFFECT = Σ PV of SM + PV ITM + PV GL low - high	(-72.06) - (-222.73)	(-12.09) - (-220.89)	(-10.53) - (-220.84)	(-28.68) - (-221.42)	(-8.26) - (-220.77)
Included:	Change in the area of intertidal, saltmarsh and grassland habitats, assuming that the amount of each habitat remains unchanged following STP scheme. See section 6 for quantitative assessment and assumptions, and section 8.1 for valuation calculations. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).				
Excluded:	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the introduction of any STP option. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2.				

[26] http://www.hm-treasury.gov.uk/data_greenbook_supguidance.htm

Caution:	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measure quantitatively. Standard discount rates are applied within the present value calculations however, this does not address issues of the loss of inter-general equity or irreversibility both of which are likely as a result of STP scheme. The main estimate values presented here relate to information obtained from the SEA on the 16th March 2010. These values were updated after the original project cut-off date for inputs, the impact of this update was to change the total value of the change associated with intertidal habitats by +0.2% - -1.6% across STP Options.
Sources:	Tables 6.1 and 8.2

Note: negative sign means loss of habitat and hence an economic cost.

The economic loss/gain of different habitats associated with the introduction of each STP options show that the large barrage option, i.e., from Brean Down to Lavernock Point Barrage, results in the highest value loss with the introduction of the small barrage and lagoon options resulting in around a half to approximately seven times less when considering the results relating to the ‘low’ scenario. The variation between options when considering the ‘high’ option is less clear. While option B3 Brean Down to Lavernock Point Barrage results in a higher value loss the difference between options is approximately 1%. This lack of variability can be explained by the assumption that all options results in the loss of all ecosystems services in the area. This drives the main value change, which as expected is much greater than that seen in the ‘low’ option. However, this masks the changes between options as the change in habitat has a lower effect within the model.

9.2 The single ecosystem service value transfer

Comparing these results with those calculated for the value of the change in CO_2 equivalent flux in Table 8.3 (see above) shows that the change in CO_2 equivalent flux is at least 0.3-51% of the values calculated for habitat change in the ’low’ scenario but only 1-9% of values calculated for habitat change in the ’high’ scenario.

9.3 Assumptions and caveats

All the assumptions and caveats listed in Section 8.3 apply here. In addition the following assumptions and caveats have been made during the aggregation process:

- As Figure 9.1 shows the assumption that the habitat area will remain at levels seen following STP scheme does not account for any potential recovery within the Severn Estuary. Despite this, the aggregated results are still likely to be underestimates given that the environmental change as a result of STP will be irreversible and continue into perpetuity.
- The aggregation over time assumes that the change in habitats and annual CO_2 flux starts 2020 at the end of the construction period. Thus, until then the value (cost or benefit) of change is assumed to be zero. This is a conservative assumption since the damage in particular will start as soon as the construction starts. The implication for the aggregate results is that they are underestimates.
- The lower discount rate recommended by the Green Book for intergenerational effects is used in sensitivity analysis (see Section 10). The implication for the above results is that they are underestimates.

10 SENSITIVITY ANALYSIS

This section tests the use of different assumptions within the 'bundled' valuation of ecosystem effects relating to the introduction of the five shortlisted STP options. There is only scope to test the ecosystem effects relating to intertidal habitats and saltmarsh and to limited extent grassland due to the lack of suitable economic valuation evidence, scientific evidence, and the technical limitations of the Brander et al. (2008) function applied within the value transfer.

The most significant assumption that is made and needs sensitivity testing is to assume that the habitats within the Severn Estuary that are affected by the STP are comparable to the average wetlands across Europe that are covered in the Brander et al. (2008) study used here. The only alternative to this is not to do any value transfer but undertake a primary valuation exercise (see Section 13). Here we show what will happen to the results if we test key parameters within the value transfer implemented. The data used within sensitivity analysis is based on that provided by the SEA as of the 1st March 2010, except in the case of CO_2 emission data which are provided as of 23rd March 2010.

Thus, the following assumptions made during the value transfer are the starting points for sensitivity testing and include:

1. Either the Brander et al. (2008) function or the Oglethrope (2005) unit values were used to estimate the change in value associated with the change in intertidal, saltmarsh and grassland habitats;
2. GDP is set to UK GDP per capita in 2020, assuming a 2.5% growth rate;
3. That the population within 50km of the Severn Estuary habitat under investigation is either 3,053,974 'local' or 5,566,750 'regional';
4. That there are potentially 6659 ha of substitute wetlands of including: inland marsh, saltmarsh and intertidal mudflats within 50km of the Severn Estuary habitat;
5. The gain/loss of ecosystem services following the STP scheme;
6. The use of different values, i.e., 'average' and 'marginal', within the Brander et al. (2008) function;

Therefore the following sensitivity tests can be applied to the resulting data:

8. The application of an alternative value transfer function for intertidal and saltmarsh habitats;
9. Setting alternative values for: GDP and the population within 50km of the Severn Estuary habitat;
10. Determining the affect of substitute inclusion on values;
11. Comparing the effect of the removal of different ecosystem services following the introduction of an STP option within the Brander et al. (2008) function;
12. Determining the affect of using either the 'marginal' or 'average' values for habitat change within the Brander et al. (2008) function;
13. Comparing the combined value change estimated for intertidal and saltmarsh habitats to that generated by applying the mean per hectare per annum estimate reported by Brouwer et al. (1999) and Ghermandi et al. (2008); and
14. Varying economic value over time by increasing GDP at 2.5% per year from 2009;

In addition two further sensitivity tests relating to all three habitats included within the 'bundled' valuation approach, i.e., intertidal mudflats, saltmarsh and grassland, are:

15. The application of an alternative discount rate,

16. Estimating the predicted effects of STP scheme on intertidal, saltmarsh and grassland habitats if damage estimates were increased / decreased by 10%, and
17. Finally, error bars relating to CO2 emission estimates were calculated.

10.1 The bundled ecosystem services value transfer

Key sensitivities that address each of the assumptions relating to the calculation of the effects of STP scheme on intertidal and saltmarsh are:

1. The application of an alternative value transfer function, i.e., changing the model applied and thus the value of function coefficients. Here we apply two different models:

    - The model generated by Ghermandi et al (2008). In order to use this function our wetlands need to be reclassified to match those of Ghermandi et al. (2008), the category of estuarine was deemed most appropriate, additionally, the wetland was defined as occurring in a 'rural' area (dummy variable set to zero);
    - The model generated by Luisetti et al. (2008b). This study however, can only be applied to effects relating to saltmarsh habitats, as the study does not address other habitat types;
    - Comparing a mean value estimate from Brouwer et al. (1999) with that generate by the Brander et al. (2008) function. The mean per hectare value per year reported in Brouwer et al. (1999) is £327 per hectare per year for wetlands;

2. Changing the GDP per capita value. Here we increased and then decrease the mean GDP in 2020 by 10% in the Brander et al. (2008) function, as requested by the steering group (see SG Meeting minutes 13th August 2009) to determine the effect on per hectare values of both saltmarsh and intertidal habitats;

3. Changing the GDP per capita value over time. Here we use predicted growth of 2.5% per annum to determine GDP over project lifetime following predictions of growth estimated by (EIU, 2006) until 2020.

4. Assuming that there are no substitute wetlands available for the Severn Estuary within the 50km defined within the function, i.e., setting this attribute to zero for the 'low' scenario, to demonstrate its affect separately, this cannot be completed for the 'high' scenario as it is already part of the group of assumptions used to generate the upper bound damage estimates.

5. The assumed population size within 50 km of the policy site. This is not tested here as increases in population are included within the 'low' and 'high' scenario definitions;

6. Comparison of loss of specific ecosystems services as a result of STP scheme for the 'low' scenario only, i.e., demonstrating the removal of each service separately, this can only be completed for the 'low' scenario as the 'high' scenario assumes that all services have been removed.

7. Comparison of average and marginal values for the 'low' scenario only to demonstrate its affect separately, his cannot be completed for the 'high' scenario as it is already part of the group of assumptions used to generate the upper bound damage estimates.

Key sensitivities that address each of the assumptions relating to the calculation of the effects of STP scheme on intertidal and saltmarsh are:

8. Comparison of long term discount rate to account for intergenerational equity issues. Here we applied the Green Book amendment on applying lower discount rates where an intergenerational change is anticipated (2003), i.e., starting at 3%, then after 30 years or 2040 the discount rate drops to 2.57% per annum until 2085 (or 75 years from 2010) and then 2.14% until (2135) or 125 years later, the rate then drops to 1.17% until 200 years from the starting point. The discount rate decreases through time during long timescales to reflect uncertainty about the future which can be shown to cause declining discount rates over time (HM Treasury, 2003); the lower discount rate applied here attempts to address issues of severe intergenerational change.

9. Comparison of a 10% increase/decrease in measures of habitat change as requested by the steering group (see SG Meeting minutes 13th August 2009).

1. The application of an alternative value transfer functions and mean values

Table 10.1: Results of value transfer using Ghermandi et al. (2008-2009) and Brouwer et al. (1999), to determine the combined value of per hectare value of intertidal and saltmarsh habitat (millions).

Habitat value type	Current Value	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Estuarine habitat (saltmarsh+intertidal estimate) (ha)	31360	14,730	27,980	28,530	23,990	28,820
Ghermandi et al. (2008) £ per hectare value £2008 low-high	337 - 3,924	405 - 155	347 - 133	345 - 132	360 - 138	344 - 132
Ghermandi et al (2008) £ total value change per year low-high	0	-4.62 - -120.78	-0.88 - -119.35	-0.73 - -119.29	-1.95 - -119.76	-0.66 - -119.26
Brouwer et al. (1999) £ per hectare value change per year	0	-5.44	-1.11	-0.93	-2.41	-0.83
Brander et al. (2008) £ total value change per year £2008-2009 low-high	0	-3.23 - -15.19	-0.55 - -15.06	-0.47 - -15.06	-1.29 - -15.10	-0.37 - -15.05
Included	Change in the area of intertidal, and saltmarsh habitats. See section 6 for quantitative assessment and section 8.2 for valuation calculations. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1).					

	High damage scenario: regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.
Source	Tables 6.1 and 8.2

Table 10.1 shows that the Brander et al. (2008) model generates the most conservative estimate of the change in value associated with the change in amount of both intertidal and saltmarsh habitats predicted following the STP scheme. The values generated by Ghermandi et al. (2008) and Brouwer et al. (1999) are 30-44% and 51-66% greater for the 'low' scenario respectively. These values generated for Ghermandi et al. (2008) occur within the expected ranges of the errors associated with the application of value transfer, i.e., approximately 30-60% Brander et al. (2008). Estimates are up to ten times greater within the 'high' scenario for Ghermandi et al. (2008) due to the assumption that no ecosystem services will be provided following the STP scheme.

Table 10.2: Results of value transfer using Luisetti et al. (2008b), to determine the value of per hectare value saltmarsh habitat

Habitat value type	Current Value	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
Saltmarsh habitat (ha)	990	780	1,130	1,070	1,070	1,240
Luisetti et al. (2008b) £ per household £2008 low-high	14.72	14.44 - 10.67	14.87 - 11.10	14.81 - 11.04	14.81 - 11.04	14.98 - 11.21
Luisetti et al (2008b) £ total value change per year low-high	0	-304 - -9,555	169 - -8,527	99 - -8,678	99 - -8,678	287 - -8,269
Brander et al. (2008) low-high	0	-106 - -1,295	67 - -1,287	39 - -1,288	39 - -1,288	118 - -1,284
Included	The estimates shown here relate to saltmarsh habitat only. The estimates See section 6 for quantitative assessment and section 9.1 for valuation calculations. L ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).					
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.					
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the					

	changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.
Source	Tables 6.1, 8.2 and 9.1

As for the combined values of intertidal mudflats and saltmarsh Table 10.2 shows that the Brander et al. (2008) model also generates the most conservative estimate of value change in relating to the predicted change of saltmarsh habitat following the introduction of STP options for either scenario. However, as with the above values the restriction relating to the provision of ecosystem services following STP scheme leads to a much larger estimate of value change in both functions. As with the Brander function the range of values across options is much lower when all remaining habitat is assumed not to provide any ecosystem services. However, the values generated by Luisetti et al. (2008) are up to nine times greater for the 'high' scenario than those generated by the Brander function. In all cases differences in value can be attributed to i) different study sample, ii) models that account for differing variable for example, Luisetti et al. (2008b) account for biodiversity and distance from the saltmarsh area being considered but not potential substitutes.

2. Changing the GDP per capita value

Increasing the GDP per capita estimates by 10% increases per hectare values by approximately 4.5% across all options, similarly decreasing the GDP by 10% decreases per hectare value by a slightly a greater amount of 4.8-6.6%.

3. Changing the GDP per capita value over time

Increasing GDP over the life time of the project, i.e., from 2010 until 2140, results in an increase of 1.3% in per hectare value per year each year for saltmarsh and intertidal habitats, summing this over the project lifetime would equate to a total increase in per hectare per year value of 156% by 2140.

4. Assuming that there are no substitute wetlands

Removing the substitutes from the Brander et al. (2008) function increases per hectare values by approximately 22% across both saltmarshes and intertidal mudflats (see Table 10.3).

5. Changing the population size within 50km radius of the policy site

Not tested as 'low' and 'high' scenarios include the test.

6. Comparison of loss of specific ecosystems services as a result of STP scheme

Tables 10.4a and b show that the per hectare and consequently the total value of the remaining saltmarsh and intertidal habitats decrease by 60%, 67%, 59%, 29%, and 53%, respectively when biodiversity, flood protection, water quality, non-consumptive and aesthetic services respectively, are lost from the remaining habitat. The removal of more than one service results in a cumulative effect on the per hectare value e.g. if both the biodiversity and flood protection services are removed from the remaining saltmarsh habitat in the 'low' scenario following the introduction of the Brean Down to Lavernock barrage the original per hectare value decreases by 87% to £99 per hectare.

Table 10.3: Results of value transfer using Brander et al (2008), with and without substitutes (£ per hectare, £ 2008-2009) 'low' scenario only

Habitat - value type £2008 per hectare	**Immediate Effect (~2020)**				
	Brean Down to Lavernock (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
Saltmarsh per hectare value, with substitutes (see Table 8.1 low)	748	670	681	681	652
Saltmarsh per hectare value, without substitutes	916	820	833	833	798
Intertidal habitat (mudflat, sandflat, rock and shingle) per hectare value with substitutes	307	253	251	265	251
Intertidal habitat (mudflat, sandflat, rock and shingle) per hectare value with substitutes (see Table 8.1)	376	310	308	325	307
Included	Change in the area of intertidal, and saltmarsh habitats. See section 6 for quantitative assessment and section 8.2 for valuation calculations. Only the low scenario is used here to allow us to view the affect of removing substitutes from the function. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 8.2				

Table 10.4a: Results of excluding services in remaining intertidal mudflats following STP scheme (£ per hectare, £2008-2009)					
Habitat - value type	**Immediate Effect (~2020)**				
	Brean Down to Lavernock (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
All services included	748	670	681	681	652
Ecosystems Services excluded from habitat following STP scheme					
Biodiversity	299	268	272	272	260
Flood Protection	248	222	226	226	216
Water Quality	306	274	279	279	267
Non-consumptive	532	477	485	485	464
Aesthetic	352	316	321	321	307
Included	The estimates shown here only relate to saltmarsh. Section 6 for quantitative assessment and section 8.2 for valuation calculations. Only the low scenario is used here to allow us to view the affect of removing individual services from the function. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in saltmarsh. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 8.2				

Table 10.4b: Results of excluding services in remaining saltmarsh following STP scheme (£ per ha, £2008-2009)					
Habitat - value type £2008 per hectare	**Immediate Effect (~2020)**				
	Brean Down to Lavernock (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
All services included	307	253	251	265	251
Ecosystems Services excluded from habitat following STP scheme					
Biodiversity	123	101	100	106	100
Flood Protection	102	84	83	88	83
Water Quality	126	104	103	109	103
Non-consumptive	219	180	179	189	179
Aesthetic	145	119	118	125	118
Included	The estimates shown here only relate to intertidal mudflats. Section 6 for quantitative assessment and section 8.2 for valuation calculations. Only the low scenario is used here to allow us to view the affect of removing individual services from the function. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in intertidal habitat. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 8.2				

7. Comparison of average and marginal values

Classing the habitat change as marginal instead of average increases the per hectare values by approximately 330% across all options (see Table 10.5). As stated within the caveats in Section 8.3, the use of an 'average' value over a 'marginal' value are likely to result in significant underestimates in the value change associated with the introduction of any STP option however, given that the 'marginal' value is calculated on a much reduced dataset within the Brander et al. (2008).

Table 10.5: Results of value transfer using Brander et al (2008) comparing average with marginal values (£ per hectare, £2008-2009) 'low' scenario only					
Habitat - value type	**Immediate Effect (~2020)**				
	Brean Down to Lavernock (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
Saltmarsh per hectare value, 'average' (see Table 8.1)	748	670	681	681	652
Saltmarsh per hectare value, 'marginal'	2470	2213	2249	2249	2152
Intertidal habitat (mudflat, sandflat, rock and shingle) per hectare value 'average' (see Table 8.1)	307	253	251	265	251
Intertidal habitat (mudflat, sandflat, rock and shingle) per hectare value 'marginal'	1015	835	830	876	829
Included	Change in the area of intertidal, and saltmarsh habitats. See section 6 for quantitative assessment and section 8.2 for valuation calculations. Only the low scenario is used here to allow us to view the affect of using different 'values' within the function. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 8.2				

8. Applying the inter-generational discount rate

The PV estimates increase by approximately 18% across all options and habitat types when the lower discount rates are applied (see Table 10.6) for the 'low' scenario and approximately 184% for the 'high' scenario as a result of the increased value change.

Table 10.6: Results of value transfer using Brander et al (2008) and Oglethorpe (2005), the application of standard HMT discount rates in comparison to appended rates accounting for intergenerational equity issues (2008-2009 £ millions), values shown to the nearest £100,000.

PV over the project lifetime (120 years)	Immediate Effect (~2020)				
	Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Standard discount rate low-high	-72.5 - -224.9	-12.3 - -223.0	-10.5 - -222.9	-29.0 - -223.6	-8.2 - -222.9
Inter-generational discount rate low-high	-85.6 - -414.0	-14.5 - -410.6	-12.4 - -410.5	-34.3 - -411.6	-9.7 - -410.3
Included	Change in the area of intertidal, and saltmarsh habitats. See section 6 for quantitative assessment and section 9.2 for valuation calculations. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 9.2				

9. Comparing the effect of a 10% increase/decrease in measures of habitat change

Increasing the effect of the introduction of STP options on saltmarsh habitat results by 10%, i.e., less habitat following STP scheme (-10%), results in an increase per hectare value for the predicted remaining habitat. The per-hectare increase in values increases the sums by 1.6% for all STP options. Increasing, the effect of the introduction of STP options on intertidal habitat, i.e., less habitat following STP scheme, also increases per hectare values for the remaining habitat by 1.6% across all STP options. The effect of this change on total value is not straight forward as although the per-hectare value has increased the habitat remaining has decreased by 10%. Increasing/decreasing the amount of grassland gained as a result of the introduction of STP options results in an increase/decrease in a 10% increase of the total value for grassland as the per hectare value remains unchanged.

Table 10.7: Results of value transfer using Brander et al (2008), with a ±10% change in each habitat type, unit values for both 'low' and 'high' scenarios are shown as ranges (£ per hectare, £2008-2009)

Habitat - estimate of change	Immediate Effect (~2020)				
	Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
Saltmarsh - original area -	780	1,130	1,070	1,070	1,240
+10%	858	1243	1177	1177	1364
-10%	702	1017	963	963	1116
Saltmarsh - original value low-high	748-36	670-32	681-33	681-33	652-31
+10% low-high	727-34	651-31	662-31	662-31	633-30
-10% low-high	760-45	681-41	692-41	692-41	692-39
Intertidal – original area	13950	26850	27460	22920	27580
+10%	15,345	29535	30206	25212	30338
-10%	12555	24165	24714	20628	24822
Intertidal – original value low-high	307-15	253-12	251-12	265-13	251-12
+10% low-high	299-14	246-12	244-12	258-12	244-12
-10% low-high	312-19	257-15	255-15	269-16	255-15
Grassland – original area	298	102	31	181	137
+ 10%	328	112	34	199	151
- 10%	268	92	28	163	123
Grassland – original values	5.74	5.74	5.74	5.74	5.74
+10%	No change				
-10%	No change				
Included	Change in the area of intertidal, saltmarsh and grassland habitats. See section 6 for quantitative assessment and section 8.2 for valuation calculations. Substitutes are also assumed to be available. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services continue being provided by the habitat areas remaining following the STP scheme. (see Section 8.1). ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. (see Section 8.1).				
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the STP scheme. Changes in the flux of CO_2 equivalent emissions are covered in Section 8.2, 9.2.				
Caution	All assumptions and caveats that are related to unit economic values (Section 8.3) apply here too. Note that there are no error bands available for estimates of the changes in each habitat type measured quantitatively. Data from SEA as of 1st March 2010.				
Source	Tables 6.1 and 8.2				

10.2 The single ecosystem service value transfer

Currently only a valuation of the central change in CO_2 equivalent flux has been conducted (see Section 8.2). Here we calculate ranges based on the scientific error bands have been calculated. As in Table 8.2 price is assumed to stay constant beyond 2100 as requested by DECC (email 26th February 2010), results are shown for all three carbon values, i.e., low, central and high.

Scientific error bands

The scientific error bands for the CO_2 equivalent flux are calculated by varying the measurements for methanogenesis, siltation and carbon sequestration used for generating each annual estimate. Table 10.8 below shows how the values of these different processes are varied (data provided by the SEA). The following calculation shows how each of these components contribute to the annual estimate of CO_2 equivalent flux

Annual CO_2e flux = $M \times (MF_O - MF_{BL}) + SeqC \times (SM_O - SM_{BL}) + (Si \times ITM)/120$

- M – methanogenisis factor (carbon released as habitat is lost - negative);
- MF_O - mudflat area following introduction of an STP option;
- MF_{BL} - mudflat area baseline;
- $SeqC$ – sequestration factor (carbon sequestration lost as habitat is lost - negative);
- SM_O - saltmarsh area following introduction of an STP option;
- SM_{BL} - saltmarsh area baseline;
- Si – siltation factor calculated over the project lifetime
- ITM – change in area of mudflat, sandflat, rock and shingle combined following the introduction of an STP option this value is divided over 120 to give an annual value as the values generated by the SEA were for the lifetime of the project.

The low values are used to generate the lower estimate (Table 10.8), while the high the higher estimate (Table 10.8). The central estimates are reported in the main results. The carbon values used within the sensitivity analysis are the central estimates.

Table 10.8: error bands associated with the carbon processes accounted for with the annual CO_2 equivalent flux estimates

Process		low	central	high	
Siltation		-400	-15	-15	tCO_2/10,000m3
Methanogenesis		-0.168	-0.84	-1.512	tCO_2/ha/year
Sequestration		-9	-5	-1	tCO2/ha/year

Results

Table 10.9 shows the change in value of CO_2 equivalent flux per annum for the lowest and highest values of each of the contributing processes accounted for within this study, in almost all cases values are positive meaning that all options result in a decrease of carbon (subject to the caveats within Sections 8 and 9). The highest possible estimates would result in domination over the original results for habitat change.

Table 10.9: Valuing the change in carbon equivalency emissions varying CO_2 equivalent flux with (low/high) estimates for methanogenesis, siltation and carbon sequestration NPV's (2008-2009 £ millions), values shown to the nearest £100,000.

Emission units (t/yr) and value (£2009 per tonne)	Current baseline	Immediate Effect (~2020)				
		Brean Down to Lavernock (B3)	Shoots Barrage (B4)	Beachley Barrage (B5)	Welsh Grounds Lagoon (L2)	Bridgwater Lagoon (L3d)
LOW CO_2 equivalent emissions t/yr	n/a	**-164078**	**-101198**	**-50661**	**-100562**	**-16963**
Central value of non-traded Carbon (2020-2140)	n/a	587.6	362.4	171.4	360.1	61.7
HIGH CO_2 equivalent emissions t/yr	n/a	**+250**	**-3331**	**-1426**	**-2409**	**+1773**
Central value of non-traded Carbon (2020-2140)	n/a	-0.9	11.9	5.1	8.6	-6.3

Included	Change in the area of intertidal and saltmarsh habitats. The estimates of CO_2 equivalent flux include: • The effect of the loss of potential carbon sequestration, i.e., the change in the amount of habitat (ha) is assumed to lead to a year on year loss of the ability to sequester carbon, • Siltation (averaged over the project lifetime to obtain an annual value), and • Methanogenesis
Excluded	Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by the introduction of any STP option, these are not represented in this table but considered in Section 7.3 which addresses single ecosystem service valuation. The total flux in annual CO_2 equivalent emissions exclude: • Any changes as a result of the Nitrogen cycle, • The loss of sequestered Carbon as a result of a change in the following habitat types, intertidal, saltmarsh and grassland, and • Ecological changes that are likely to take place where an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.
Caution	• Caution should be used if comparing values between STP options as these represent estimates for the comparison of different optimisation strategies within STP options. As such these values maybe subject to different levels of reliability; in addition different design factors may have been taken into account for different options and current optimal solutions may change. The effects on sequestration and methanogenesis are extremely sensitive to ecological factors which could be altered by different design options/optimisation for each option. • Values relating to the total flux in annual CO_2 equivalent emissions should be used with caution as they are subject to high levels of uncertainty (see Section 10). Negative values relating to total flux in annual CO_2 equivalent emission relate to decreases in emissions. Data from SEA as of 23rd March 2010.

Data sources and other notes:	Data provided are based on environmental metrics in the Marine Ecology paper and carbon emission calculations (26th February 2010 and Black and Veatch email dated 5th March 2010). Intertidal area has been rounded to the nearest 100 ha. Saltmarsh area has been rounded to the nearest 10Ha. Grassland area has been rounded to the nearest 10Ha.

11 INTRODUCTION TO THE VALUATION OF OFFSETTING AND COMPENSATORY APPROACHES

The impacts valued within this study are residual after likely mitigation measures are factored into the STP option design as part of the SEA. The SEA process requires consideration of measures to prevent, reduce or offset negative environmental effects. Separate work is undertaken on considering possible offsetting and compensatory measures. A sub-set of work on offsetting is a consideration of how the requirements of the Habitats Directive for compensation might be met should a scheme be developed. Subject to other tests being met, the Directive requires compensatory measures to be taken to protect the coherence of the network of Natura 2000 sites. Commission guidance says that compensation should refer to the site's conservation objectives and to the habitats and species negatively affected in comparable proportions in terms of number and status. This approach uses ecological criteria for establishing equivalency between compensatory measures and environmental damage caused. Location of compensatory measures is also required to be as close as possible to the damaged site. This work, within the feasibility study, is at the strategic level at present, and therefore, details such as the location and exact nature of any offsetting and compensatory measures is unknown. The requirements of the Habitats Directive mean that economic values cannot be used for the design of compensatory options, however, such values can inform decision making at the strategic level.

The requirements of the Habitat and Wild Birds Directive to provide compensatory measures that are in place to compensate the potential environmental changes necessitate a discussion of compensatory measures. Even at a strategic level a discussion of compensatory measures is necessary when considering the effect of the introduction of different STP options, to help anticipate potential future issues if the STP scheme were to be accepted and taken forward. Here, we summarise the different approaches for offsetting and compensation and the main factors that can influence compensatory measure design.

Concept of Equivalence

Deciding whether offsetting and/or compensatory measures are of equal value requires consideration of what is meant by equivalence. To establish equivalence, damage from the STP and benefits from compensatory measures need to be estimated using common units of measurement. There are three different approaches to analysing equivalence.

- Resource equivalency;
- Habitats equivalency; or
- Value equivalency.

Each approach uses the same principle steps of (i) estimating damage, (ii) estimating the benefit from a unit of each compensatory measure (e.g. benefits from a hectare of habitat created, enhanced or protected) and (iii) scaling – dividing the total damage by unit benefit to estimate the total amount of compensation required (e.g. total ha). The approaches differ in terms of the unit of measurement used.

- Resource equivalency – measures steps (i) and (ii), in terms of ecological units, for example, is the number of birds that an area of compensatory habitat supports equivalent to the number of birds displaced by an STP option (in terms of specie and population)?

- Habitats equivalency - uses both resource and ecosystem service concepts to measure the change in all ecosystem services expected in areas affected by, for example, the potential introduction of STP options, i.e., step (i) above. The benefits of any compensatory measures would therefore be measured by considering the habitat area proposed and the ecological functions it provides, i.e., step (ii) above. Alternatively, compensatory measures may be defined in terms of requirements such as the delivery of equivalence in terms of habitat area and ecological function.

- Value equivalency - may use the value of ecosystem services damaged as the budget for compensatory options (value to cost approach), within this report the potential 'damages' associated with the introduction of STP options have been measured in this way. Repeating the damage valuation steps in full to estimate the benefits from habitats and services of potential compensatory options and requiring them to deliver equivalent value of ecosystem services (value to value approach) can be used.

Requirements of the Habitats Directive

The European Commission guidance on Habitats Directive compensation follows the resource equivalency approach described above as it is concerned with ensuring that the coherent network of Natura 2000 sites is protected. The network of sites has been selected for the extent and characteristics of the ecological resource and not for the ecosystem services provided by that resource, hence when considering the Habitats Directive equivalence must be considered in terms of ecological units. In the case of STP however, this approach would not prevent the use of the value of ecosystem services provided by possible compensation areas as an additional search criterion when choosing/considering offsetting and/or compensatory measures. For example, the Government might wish to see the promotion of compensation measures that offer the widest possible benefits, such as, carbon storage, flood protection etc. However, including such an approach may further constrain the areas available for compensation with possible effects on cost and delivery. This report identifies which ecosystem services are affected by STP options and can be expressed in value (monetary) terms. If the same ecosystem services can be provided by compensatory measures and if these can be expressed in monetary terms, a value equivalency approach can be implemented. Thus, the ecosystem services expressed in monetary terms within this report can act as indicators as to the kinds of (additional) compensatory measures that may be considered. For example, in the case of 'potential future' legislative commitments such as the Environmental Liability Directive (ELD), where compensatory requirements are less strict in terms of the type of 'equivalency' measures that should be applied in a given case.

Additional information with regard to the application of compensatory measures is included within the Sustainable Development Commission (SDC) report, which considers measures outside of the requirements of the Habitats Directive that may be of equal value.

Factors influencing equivalence

This report does not include an ecosystem valuation of possible compensatory measures under the Habitats Directive as the necessary data on the specific definition and location of compensatory options are unavailable, and would only be defined as part of detailed study rather than a strategic one. However, the following five bullet points are the factors that influence the assessment of the economic cost of net damage and have been summarised as an aid when considering the ***'principle'*** factors when deciding on compensatory measure approaches within the context of the Habitats Directive and wider compensatory legislation.

- Location of compensation in relation to affected population – this will depend largely on the requirements of any compensatory measure to either provide compensation to a specific population, or whether the compensation offered is less restricted, e.g., will the option need to be within a close distance to the affected population, or can the compensation be provided in an alternative area?

- Similarity in the resource or service offered – are compensatory options restricted to provide like for like in terms of the resource or ecosystem services offered, i.e., should/can exactly the same level of fishing be offered within the compensatory option as that lost from the introduction of a particular project?

- The marginal nature of a proposed compensatory option – if a large area of habitat is to be lost, are compensatory options restricted to provide a single area of habitat of the same quality in one place or can this obligation be split across several sites potentially providing a lower level of service, e.g., a single area of 1000ha or ten areas of 100ha that will not provide the same quality of ecosystems services.

- The availability of substitutes – in areas where compensatory options are proposed, are there already a number of similar sites available? If so the value of each additional hectare added will be lower than if the site/option were located in area without substitute sites.

- The requirements of alternative legislation – as stated above there are different requirements for different types of legislation. There is no uniform list of criteria that is available to be applied within each circumstance, thus there is a need to consider compensatory options on a case by case basis, however, metrics that seek to combine quality and quantity will aid in this process.

The above five points should be the starting questions to consider when beginning the definition of compensatory options for any project that may require the compensation of an affected population or of society in general.

12 CONSTRUCTION EFFECTS

The construction of any of the STP options will result in a change in noise from construction and air pollution from construction traffic. The following final effects as a result of construction activities and increased transport (bringing materials & removing waste) have been identified for use within the EVP:

- Increased emissions to air;
- Increased congestion;
- Increased risk of accidents, and
- Increased noise.

The SEA team have also stated that there would be some construction land take and also possible land gain from water levels falling. The SEA is structured slightly differently from the EVP in that all effects covered by the SEA may start during the construction phase are listed as 'construction' including those that are permanent. However, within the EVP it is helpful to consider that effects of a temporary nature to be considered separately within this construction effects section, while other effects of a permanent nature are considered operational effects and described as 'immediate' following STP scheme. Thus, construction in terms of the EVP timeline should occur before 2020.

1. Valuing emissions to air from construction:

Levels of NO_2 (a weak greenhouse gas that can be converted to CO_2 equivalent emissions and priced using pricing for non-traded carbon, DECC, 2009), and PM_{10} emissions by construction activities, primarily transport, should be taken into consideration (emission factors according to road and vehicle type are available for combustion engine and road/tyre wear emissions www.naei.org.uk) when valuing the construction 'effect' of each STP option. Consideration should also be given to local population density and the proximity of any Air Quality Management Areas (AQMAs) and whether the meeting of objectives of the relevant Air Quality standards are threatened by the construction phase of STP scheme. In addition, the duration of construction effects relating to changes in emission levels should also be accounted for (see Table 12.1 for a list of valuation studies relating to emissions).

Table 12.1: Valuation evidence relating to air pollution and emissions

Reference	Environmental Aspect	Stressor	Context of Change	Methodology/Technique	Economic Value
Tol and Downing (2002)	External costs of climate forcing pollutants: CH4 and N2O	Emissions of air pollutants	Review of GHG assessment methodologies	Mix of market and non-market approaches	CH_4: £326/tonne; N_2O: £1337-£7998/tonne
Holland et al (1999)	External costs of NH4	Emissions of air pollutants	Impacts on human health	CV for VOSL	£87-£270 per tonne
AEA Technology (2004)	External costs of emissions from the electricity generation sector	Emissions of air pollutants	Impacts from pollution (see economic values for what is included)	CV for reductions in mortality (using VOSL approach) and morbidity plus market values.	NOx: £190-£737 per tonne (includes health from secondary pollution (nitrates) but no ozone included)
					VOC: £265-£670 per tonne (includes ozone damage to health and crops (but not buildings))
					SO_2: £744-£2296 per tonne (includes gaseous SO_2 (health) and secondary (sulphates) on health and building damage)
	External costs of emissions from the transport sector	Emissions of air pollutants	Impacts from pollution (see economic values for what is included)	CV for reductions in mortality (using VOSL approach) and morbidity plus market values.	NOx: £215-£827 per tonne (includes health from secondary pollution (nitrates) but no ozone included)
					VOC: £265-£670 per tonne (includes ozone damage to health and crops (but not buildings))
					CO: £1.4/tonne (health only)
Eyre et al, 1999.	External costs of methane and nitrogen oxide emissions.	Emissions of air pollutants	Impacts from pollution (includes health, crops, building materials, forests, and ecosystems).	Variety of market values and non-market values.	CH_4: £158 - 630 per tonne; N_2O: £2794 - £11,176 per tonne

2. Valuing increased congestion:

The impact upon existing users of the road network resulting from additional vehicle kms during the construction of an STP option must also be considered. The marginal cost estimates shown below are provided by: (i) road vehicle type; and (ii) vehicle type and time period; and iii) road type (motorway, trunk road or principal road, and other), allowing us to estimate an economic value for any increases in congestion during the construction phase (providing the necessary data estimates are available).

Table 12.2: Value estimates by vehicle class (pence/vehicle km, £ 1998)

Vehicle type	Low	High
Car	8.98	10.44
LDV	9.26	10.61
HGV-rigid	16.78	18.45
HGV-artic	24.15	24.89
PSV	5.23	18.19

LDV = light duty vehicle, PSV = Public service vehicle
Source: Table 7.4, Table 7.5 (Sansom et al., 2001)

Table 12.3: Value estimates by vehicle class and time period (pence/vehicle km, £ 1998)

Vehicle and Time	Low	(no high estimates provided)
HGV rigid, off-peak	26.00	
HGV rigid, peak	12.75	
HGV artic, off-peak	33.45	
HGV artic, peak	19.81	

Peak = week day peak (7am – 10am, 4pm – 7pm)
Source: Table 7.12 (Sansom et al., 2001)

Table 12.4: In terms of road type (pence/vehicle km, £ 1998)

Road type	Low	High
Motorway	12.80	12.80
Trunk road/principal	11.61	12.38
Other	5.86	1.08

Source: Table 7.8, 7.9 (Sansom et al., 2001)

3. Valuing increased risk of accidents

The evaluation of the increased risk in terms of traffic accidents is used by calculating the monetary values relating to increases in road use and its subsequent affect on the likelihood of potential fatalities and/or injuries during the construction phase of STP scheme. A recent meta-analysis provides an overview of estimates contained in the literature on the economic valuation of statistical life in road safety (de Blaeij et al., 2009), and thus a means of determining any potential economic effect with regard to the construction phase of any STP scheme where data is available.

4. Valuing Noise

If approximate data on the number of households or people affected by specific noise changes either as a result of construction activities or as a result of increased congestion are available then a monetary valuation can be undertaken for each STP option to determine the 'effect' of noise during the construction phase (this should include increases in traffic noise), Table 12.5 below shows current government values per household per decibel change.

Table 12.5: Monetary valuation of changes in noise level (per household, 2002 prices), DfT WebTAG (accessed September, 2009)

$L_{Aeq,\ 18hr}$ dB(A)		£ per household per dB change
High	Low	
	<45	0.0
45	46	8.4
46	47	11.1
47	48	13.7
48	49	16.3
49	50	19.0
50	51	21.6
51	52	24.2
52	53	26.9
53	54	29.5
54	55	32.1
55	56	34.8
56	57	37.4
57	58	40.0
58	59	42.7
59	60	45.3
60	61	48.0
61	62	50.6
62	63	53.2
63	64	55.9
64	65	58.5
65	66	61.1
66	67	63.8
67	68	66.4
68	69	69.0
69	70	71.7
70	71	74.3
71	72	76.9
72	73	79.6
73	74	82.2
74	75	84.9
75	76	87.5
76	77	90.1
77	78	92.8
78	79	95.4

Data Availability

The data relating to construction effects available within the SEA analysis includes:

- The estimated air pollutant emissions in tonnes (NOx, PM10 and SO_2) during the construction phase for each alternative option (Air & Climatic Factors Topic Paper, 2010).

- The likely number of construction vehicles per day during the length of the construction period, and uses this to assess the disruption in access to services and facilities (depending on the route of the traffic), (Communities Topic Paper, 2010).

- There is no assessment of any change to risk of traffic accidents across options.

- Assessment of effects on noise sensitive receptors during the construction phase for each alternative option. This assessment is based on the construction activity / associated plant and the distance of the receptor from the source of the noise (Noise & Vibration Topic Paper, 2010).

Construction impacts are excluded from the estimates. Similar economic valuation analysis for large scale water infrastructure projects has shown that construction impacts are a small fraction of the overall environmental and financial costs of a those projects. However, it is not clear how comparable those infrastructure projects are to the STP options and hence it is not possible to make a comment on the size of this gap in the analysis.

13 CONCLUSIONS AND RECOMMENDATIONS

13.1 Summary findings

Table 13.1 summarises the present value of the habitat area and carbon emission changes due to the five shortlisted STP options investigated. A negative number indicates a loss of habitat and/or an increase in carbon emissions and hence a cost, and a positive number indicates increase in habitat and/or a decrease in carbon emissions and hence a benefit. In addition to the main results **Table 13.1** includes a summary of the main findings of the sensitivity analysis expressed in PV terms. The 'MAIN' estimates summarised in Table 13.1 only relate to intertidal mudflats, saltmarsh and grassland and CO_2 equivalent flux. The application of an alternative function, i.e., Ghermandi et al. (2008); in addition to the effect of removing specific ecosystem services from remaining habitat and the affect of applying lower discount rates are included within the 'SENSITIVITY ANALYSIS' section (see Table 13.1).

In addition the current CO_2 equivalent emissions estimates are subject to extremely variable margins of error at (see Section 10), the use of the highest possible values relating to changes in CO_2 flux would dominate all values associated with habitat change. Therefore, it is currently not possible to advise with certainty as to the 'true' change in economic value as a result of the introduction of each STP option and thus the evidence presented here should not be used within the decision making process in its current form.

Result Summary:

- All five STP options lead to net environmental costs.
- The economic valuation shows that the lowest cost is associated with the Shoots Barrage for the 'low damage' scenario. The cost increases for Beachley Barrage, Bridgwater Lagoon, Welsh Grounds Lagoon and Brean Down to Lavernock Point Barrage options, respectively. Looking at habitat only related changes this order remains similar for the 'high damage' scenario with Shoots Barrage, Beachley Barrage and Bridgwater Lagoon producing very similar estimates. However, accounting for the 'high' cost estimate of CO_2 emissions changes Bridgwater Lagoon to the highest cost option. This change is driven by the fact that the change in CO_2 emissions associated with this option is estimated to be at least 80% lower than for all other options.
- The estimates range from PV cost of £5.9 million for the low damage scenario for Shoots Barrage to PV cost of £218.6 million for the high damage scenario for Bridge Water Lagoon. PV combines the change in the area of habitat (in both low and high damage scenarios) and change in the amount of ecosystem services provided by remaining habitat (same as current situation in low-damage scenario, no provision in high damage scenario).
- The inclusion of CO_2 equivalent emissions values affects the total value of change by up to approximately 50% (option B4, Shoots Barrage).
- Using a lower discount rate over time increases the present value of the cost of STP options, as expected.
- Using the Ghermandi et al. (2008) function instead of the Brander et al. (2008) (see technical report) increases the estimate of the cost of STP options.

- The table shows that there are large differences between low and high scenarios including for some habitats, low scenario shows a net benefit, while high scenario shows a net cost (a negative sign in the table). This increase in the 'damage' value is driven by the assumption that no ecosystems services are provided by the remaining habitat following STP introduction in the 'high' scenario. All other sensitivity analyses affected estimates by less than 10%. A full list of the caveats relating to the value transfer is listed below **Table 13.1**.

- Assuming that remaining habitat after the introduction of STP options will not provide any ecosystem services increases the cost of each option, as expected.

Table 3: Summary of present values of selected environmental impacts of STP options in the Bristol Channel (applying standard discount rates, HMT, 2003 in £ millions, rounded to the nearest £10,000)

Habitat - value type	**Immediate Effect (~2020)**				
	Brean Down to Lavernock Point Barrage (B3)	**Shoots Barrage (B4)**	**Beachley Barrage (B5)**	**Welsh Grounds Lagoon (L2)**	**Bridgwater Lagoon (L3d)**
MAIN ESTIMATE	PV over the project lifetime £ million (120 years)				
Saltmarsh: low-high	(-2.40) - (-19.17)	+1.51 - (-19.05)	+0.87 - (-19.07)	+0.87 - (-19.07)	+2.66 - (-19.01)
Intertidal mudflat: low-high	(-69.73) - (-203.63)	(-13.61) - (-201.85)	(-11.41) - (-201.78)	(-29.52) - (-202.36)	(-10.93) - (-201.77)
Grassland	+0.07	+0.01	+0.01	+0.01	+0.01
Total change in habitats: low-high	(-72.06) - (-222.73)	(-12.09) - (-220.89)	(-10.53) - (-220.84)	(-28.68) - (-221.42)	(-8.26) - (-220.77)
Carbon costs: low-high	+2.55 - +10.60	+6.18 - +23.46	+2.96 - +11.23	+5.02 - +19.05	+0.56 - +2.13
TOTAL – MAIN ESTIMATE RANGE: low-high	**(-69.51) - (-212.13)**	**(-5.91) - (-197.43)**	**(-7.57) - (-209.61)**	**(-23.66) - (-202.37)**	**(-7.70) - (-218.64)**
SENSITIVITY ANALYSIS – total value is shown with percentage change from the original estimate underneath (+ showing an increase in value lost, - showing a decrease) - **Sensitivity analyses are not updated with new values for intertidal marsh.**					
Total change in habitats using Ghermandi et al. (2008) function (ITM, SM): low-high	(-104.0) - (-1,788.0)	(-19.7) - (-1,766.8)	(-16.5) - (-1,766.0)	(-43.8) - (-15.2)	(-14.8) - (-1,765.5)
Applying a lower discount rate (ITM, SM, GL): low – high	-85.6 (+18%) - -414.0 (+184%)	-14.5 (+18%) -410.6 (+184)	-12.4 (+18%) - -410.5 (+184)	-34.3 (+18%) - -411.6 (+184%)	-9.7 (+18%) - -410.3 (+184%)
Testing the effect of losing a single ecosystem service on unit values (£ per hectare): 'Low damage scenario' assumes that ALL ecosystem services of habitats remaining after STP options will continue to be provided. In this test, the effect of a single service being lost while others continue is shown. For example, the 'flood protection' row shows that if this service alone is lost, the cost estimate for Brean Down to Lavernock Point under the low damage scenario will increase by 67%.					
Flood protection	67%	67%	+67%	+67%	+67%
Biodiversity	60%	60%	+60%	+60%	+60%
Water Quality	59%	59%	+59%	+59%	+59%
Non-consumptive	29%	29%	+29%	+29%	+29%
Aesthetics	53%	53%	+53%	+53%	+53%
Included:	Change in the area of saltmarsh, intertidal and grassland habitats and CO_2 equivalent flux. Saltmarsh and intertidal habitats (which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle) represents area between the Highest Astronomical Tide (HAT) and the Lowest Astronomical Tide (LAT) . The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post STP scheme. ***Low damage scenario:*** local population, wetland substitutes, average wetland values, and assumes that all services				

Table 3: Summary of present values of selected environmental impacts of STP options in the Bristol Channel (applying standard discount rates, HMT, 2003 in £ millions, rounded to the nearest £10,000)	
	continue being provided by the habitat areas remaining following the STP scheme. ***High damage scenario:*** regional population, no substitutes, marginal wetland values, and assumes that all services are lost (even those of the remaining habitats) following the STP scheme. The estimates of CO_2 equivalent flux include: The effect of the loss of potential carbon sequestration, i.e., the change in the amount of habitat (ha) is assumed to lead to a year on year loss of the ability to sequester carbon, Siltation (averaged over the project lifetime to obtain an annual value), and Methanogenesis
Excluded:	Saltmarsh and Intertidal habitat estimates do not include intertidal areas of sub-estuaries and changes arising from long term morphological processes. Change in the area of freshwater wetlands, changes to Rivers and Streams and the Water column, i.e., subtidal are likely to be affected by each STP scheme. The following factors that are likely to have an effect on the unit economic value estimate but are excluded from the analysis due to lack of data: • Ecosystem services of archaeology and health effects of wetlands, • Population (users and non-users) outside the 50 km diameter area, and • Far field effects (beyond Bristol Channel). Ecosystem services excluded because STP scheme is likely to lead to no change or no significant change in an ecosystem service include: habitat provision for bees, subsistence cropping, subsistence shell fishing and catch, wildfowling, water for industrial cooling, air quality, other recreation, and renewable energy (i.e., fuel for biomass). Ecosystem services included within other technical reports (i.e., aggregate extraction and navigation/port services) are excluded here. The total flux in annual CO_2 equivalent emissions exclude: • Any changes as a result of the Nitrogen cycle, • The loss of sequestered Carbon as a result of a change in intertidal, saltmarsh and grassland, and Ecological changes that are likely to take place where an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration.
Caution:	Caution should be used if comparing values between STP options as these represent estimates for the comparison of different optimisation strategies within STP options. As such these values maybe subject to different levels of reliability. In addition different design factors may have been taken into account for different options and current optimal solutions may change. The effects on sequestration and methanogenesis are extremely sensitive to ecological factors which could be altered by different design options/optimisation for each option. Values relating to the total flux in annual CO_2 equivalent emissions should be used with caution as they are subject to high levels of uncertainty. Negative values relating to total flux in annual CO_2 equivalent emission relate to decreases in emissions. The main estimate values presented here relate to information obtained from the SEA on the 16^{th} March 2010. These values were updated after the original project cut-off date for inputs, the impact of this update was to change the total

Table 3: Summary of present values of selected environmental impacts of STP options in the Bristol Channel (applying standard discount rates, HMT, 2003 in £ millions, rounded to the nearest £10,000)	
	value of the change associated with intertidal habitats by +0.2% - -1.6% across STP Options. The affect of these changes has been documented here and within the technical report as the accompanying sensitivity analyses relating habitat estimates have not been updated within the technical report due to the magnitude of the associated change (Steering group meeting 23rd March, 2010).
Sources:	Tables 9.1 and 8.2

13.2 Assumptions and caveats

Estimates of intertidal habitat (Black and Veatch, 2010)

All estimates relating to the immediate effect of STP scheme on habitat have been obtained from the SEA team the following assumptions relate to these estimates:

- Total intertidal represents area between the Highest Astronomical Tide (HAT) and the Lowest.
- Astronomical Tide (LAT) and includes saltmarsh, and mudflat which includes: intertidal mudflat, intertidal sandflat, intertidal rock and intertidal shingle.
- Estimates do not include intertidal areas of sub-estuaries.
- Estimates do not include changes arising from long term morphological processes.
- The predictions of initial habitat extent take account of short-term changes in water levels, bathymetry (water depth), sediment type, tidal curve and fetch. In this context the initial changes are in relation to the outputs of a spring neap cycle immediately post scheme.

Economic values

The key economic value evidence used (Brander et al. 2008) is based on a European wide dataset but not specifically for wetlands in the UK or within the Severn Estuary area. Therefore, the key assumption that had to be made for this value transfer is that the Severn Estuary is a typical European wetland. This is clearly incorrect with the implication that given the unique characteristics of the Severn, the results reported here are significant underestimates. Primary value data fitting the context of the Severn Estuary and the STP options are needed to compare the value transfer results in order to estimate the error bands. In the absence of such data, it is not even possible to know what the appropriate error bands are.

Despite this overarching and crucial caveat, we have undertaken the analysis described above and the following list is the individual assumptions and caveats related to the implementation of the value function. As part of sensitivity analysis, lower and upper bound unit values are estimated using different values for the above factors for intertidal and saltmarsh valuation and also for the CO_2 equivalent flux.

The lower bound estimate comes from the 'low damage scenario' in which all relevant factors are defined so that the current unit value of the Severn Estuary is a lower bound estimate and the unit value of change under each STP option is also a lower bound estimate. In the 'high damage scenario', both the current unit value and the unit value of change are at their highest. In other words, the low damage scenario shows the case of losing a small value from an already low value resource, and high damage scenario shows the case of losing a high value from an already high value resource.

The two scenarios used for unit economic value estimates are defined as follows:
The LOW damage scenario (lower bound damage estimates):

- There are wetlands available within the 50km diameter of the Estuary that could function as substitutes to the Severn Estuary.
- The affected population considered within this estimate relates to the 'local' population only, i.e., towns along the estuary up to Minehead on the English coast and Cardiff on the

Welsh coast including: the local and unitary authorities of Cardiff, Newport, Bristol and Bath, and N.E. Somerset.
- The 'average' value estimates are used within the calculation of value change.
- The habitats that remain unaffected in the 'with STP option' case provide all the services they provide today, i.e., each 1 ha of a given habitat that remains continues to provide all its services.
- Central CO_2 equivalent flux in tonnes per year are valued at the lowerbound DECC non-traded unit value in £ per tonne.

The HIGH damage scenario (upper bound damage estimate):

- There are no substitute wetlands available within the 50km diameter area.
- The affected population considered within this estimate relates to the 'regional' population, i.e., the South West Region for England and E. Wales.
- The 'marginal' value estimates are used within the calculation of value change.
- The habitats that remain unaffected in the 'with STP option' case do not provide any of the services they provide today, i.e., due to the changes to the complex nature of the Severn Estuary that exist today, remaining habitats also lose their ecosystem services.
- Central CO_2 equivalent flux in tonnes per year are valued at the upperbound DECC non-traded unit value in £ per tonne.

For the unit values in the current situation, 'low damage' scenario has the same definition as it has for STP options. This is evident in similar unit values for current situation and the individual options, which only differ because of the change in the area of each habitat under the current situation and each STP option. As for the 'high damage' scenario, ecosystem services continue to be provided in the current situation (without the STP option) but are entirely lost in all STP Options. All other parameters of high damage scenario apply in the same way for the current situation as listed above for the STP options. Both damage scenarios use the same unit economic value for grassland. Other sensitivity analyses were also implemented during the study.

Types of habitats and services covered

- Only intertidal (includes: mudflat, sandflat, rock and shingle), saltmarsh and grassland are included in the 'bundled' approach – other potential (positive or negative) effects are excluded due to lack of scientific or economic data. The quantitative assessments of change used for the habitats covered have not been finalised or ratified by the steering group – the implication is that the results are likely to be underestimates;
- The future baseline is assumed to remain unchanged as there is currently only a qualitative description within Black and Veatch (2010) and there is no scientific data relating to the value of potential ecosystem services that maybe provided (without STP) in the future – the implication is that the results are likely to be underestimates;
- There are no specific variables that account for human health values of wetlands archaeological or agricultural values within this function. In the case of the former two services however, both have been identified as less likely to change significantly following the STP scheme, while scientific or other economic data are also lacking for human health values – the implication is that the impact on results is likely to be insignificant;
- Commercial hunting is not present within the Severn Estuary, given that there is only a single coefficient for commercial fishing and hunting –the implication is that the contribution of fishing maybe overestimated but this overestimation is likely to be insignificant;
- The most conservative (lowest) economic value estimates are selected for the Severn Estuary to feed into the function used to estimate of the monetary value of the change in

both intertidal and saltmarsh habitat within the Severn Estuary as a result of STP scheme within the 'low' scenario. The (highest) values 'ecologically' are inputted into the function used to estimate of the monetary value of the change in both intertidal and saltmarsh habitat within the Severn Estuary as a result of STP scheme within the 'high' scenario. – Despite the provision of a range it likely that both results sets will be underestimates; and

- The WTP estimate remains constant over the lifetime of the project. Sensitivity analysis tests this assumption by assuming GDP growth from 2020 to 2140 which therefore increases the per-hectare per year value of both intertidal and saltmarsh habitat over time. The implication for the results reported above is that they are underestimates. The per-hectare per year value of grassland is not changed overtime.

Affected population and its characteristics

- The approximate population within 50 km of the wetland site are accounted for by looking up the populations associated with the main unitary authorities and counties for both the 'local' and 'regional' estimates – in reality there are likely to be further population in the area – the implication is that the results are underestimates;
- The study area is a 50km circle centred in the Severn Estuary. This area was chosen in order to meet the criteria of the Brander et al. (2008) function. However, this is smaller than the SEA team's study area as defined within the initial SEA Scoping report as downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and River Usk. This definition has since been extended in Black and Veatch (2010), however, the exact study area will vary by topic (see pg. 20 Black and Veatch, 2010, for study area definitions for each SEA topic) – the implication is that the results are underestimates (excluding other likely affected population – potentially national population);
- This limitation of the population in both sensitivity analysis scenarios also means that the non-use values are underestimated in the results. Given the uniqueness of the Severn Estuary, exclusion of even a part of non-use values means that the results are underestimates; and
- GDP per capita of the UK in 2020 is used within the calculation (see calculating GDP section), based on an assumed growth in GDP from 2009 to 2020 and constant after that. Although, the starting value is slightly lower than that for the South West (however, the latest data available for this is 2006 on the Eurostat website) and thus a slight underestimate, the 2.5% (EIU, 2009) annual growth rate maybe optimistic leading to a slight overestimate.

Estimates of CO_2-e flux

- The estimate has an error band of that depends on the amount of habitat lost (see Section 10 for additional information relating calculations) the implications of which are that estimations with the highest emission predictions dominate the habitat values calculated within this study.
- In addition, the estimates do not include any changes as a result of the Nitrogen cycle and neither do they include the loss of currently sequestered carbon as a result of a change in the following habitat types, intertidal habitat, saltmarsh and grassland. The results also exclude any ecological changes that are likely to take place when an STP option is installed, for example, an increase in algal growth which may lead to an increase in sequestration. The implication for the results is that they are likely to be significant underestimate of the carbon emission to the atmosphere.

Construction Impacts

- Construction impacts are excluded from the estimates. Similar economic valuation analysis for large scale water infrastructure projects has shown that construction impacts are a small fraction of the overall environmental and financial costs of a those projects. However, it is not clear how comparable those infrastructure projects are to the STP options and hence it is not possible to make a comment on the size of this gap in the analysis.

Aggregation

- Assuming that the habitat area will remain at the levels seen immediately following the introduction of an STP scheme and that they will remain constant over time means that potential recovery within the Severn Estuary is unaccounted for within the valuation. Despite this, the aggregated results are still likely to be underestimates given that the environmental change as a result of STP will be irreversible and continue into perpetuity. Rudimentary estimates of recovery are available however, as they cannot be separated into different habitat types, i.e., intertidal, saltmarsh and grassland, these values are not used within our calculations.
- The aggregation over time assumes that the change in habitats and annual CO_2 equivalent flux starts 2020 at the end of the construction period. Thus, until then the value (cost or benefit) of change is assumed to be zero. This is a conservative assumption since the damage in particular will start as soon as the construction starts. The implication for the aggregate results is are underestimates.
- The lower discount rate recommended by the Green Book for intergenerational effects is used in sensitivity analysis (see Section 10). The implication for the above results is that they are underestimates.

13.3 Conclusions and recommendations for decision-making

The two main conclusions from the analysis above are that:

- All five shortlisted STP options results in net environmental costs. However, because of all the caveats listed above, what can be estimated here given the currently available quantitative impact and economic value data is very likely to be a significant underestimate, and
- Most importantly, the value transfer and sensitivity analyses are based on the initial assumption that the Severn Estuary is like a typical wetland which is clearly not the right assumption.

This project is possibly the most extensive value transfer applied in the UK. There are, however, several significant caveats that make the results insufficient (on their own) as input to final decision making. The appropriate input for any further analysis should come from a primary valuation study. The recommended approach would be the stated preference method.

Here we assess the scope for a stated preference study; however, these recommendations do not represent a commitment by the steering group to undertake any such work in the future or currently. In assessing the scope for a stated preference study, a number of key considerations are relevant.

1. The sufficiency of scientific evidence to qualitatively and quantitatively define the 'good to be valued'. Much uncertainty is associated with effects to all ecosystem services and this is a significant limitation for economic valuation. However, if the major effects of interest or if potential effects can be broadly defined within an expected range relevant to STP

options, and an appropriate baseline can be defined, then definition of valuation scenarios will be feasible.

2. A 'holistic' approach with regard to any primary valuation study would be most suitable to the decision making context covered by this project, with a single study undertaken to value net changes across all (or most significant) ecosystem services affected by STP options. Such an approach is beneficial when compared with alternatives that look at specific ecosystem services only as

    a. The focus on single changes alone permits scope to address the key gaps in valuation evidence; however, there is the potential for an inflated valuation as a single change will be taken out of context of all changes. In contrast a holistic approach would likely limit the scope to address all changes given the need to balance coverage across all major areas of interest.

    b. In addition the holistic approach allows different emphasis for the valuation scenario, for example: (i) valuing effects of STP options compared to a 'no STP' baseline; or (ii) valuing changes to the overall Severn Estuary regime, in which tidal power development is one possible scenario; alternative scenarios could include large-scale (re-)establishment of natural habitats, which in effect represent the opportunity cost of STP options.

    c. A holistic approach in which a method such as choice modelling is applied need not define the direction of ecosystem service effects with certainty as several possibilities can be tested through the different values each environmental attribute could take, e.g. both an increase and decrease in provision could be tested.

    d. Finally, a holistic approach can also be used to either input into the definition of compensatory measures or alternatively to value specific options for measures designed by DECC.

3. An alternative to this would be the commissioning of separate studies relating to specific single services e.g., fishing, however, one would need to be careful not to double count estimates generated in this way, the 'holistic' option is preferred over this option.

4. Appropriate effort for appraisal: the decision-making context, legal requirements, the uniqueness of the good (the Severn Estuary), scheme characteristics, location, habitats affected, uses of the environment, scale of environmental effects and so on determine the 'accuracy' that is needed from economic valuation evidence. This, in turn, determines the effort that is appropriate. Value transfer, even at the in-depth scale we endeavoured to conduct here, seems below the level of effort justified on these grounds.

5. Sensitivity analysis: limitations of data and uncertainty over environmental effects and monetary values can be compensated by appropriate sensitivity analysis. Analysis should be proportionate to the decision in-hand.

There are two main research options for a potential stated preference study. The options differ in the way they can generate evidence for compensation measures. Given the current level of development of compensation measures, we believe Option 1 is the more feasible option.

1. Objectives

A primary valuation study using the stated preference method will:

(A) Assess preferences (attitudes and opinions) in relation to STP options;
(B) Estimate the economic value – in terms of willingness to pay (WTP) or willingness to accept compensation (WTA) - of the environmental effects of STP options; and
(C1) Elicit preferences (or priorities) for the key features (e.g. ecosystem services, species of importance, location) of compensation measures; and/or
(C2) Estimate the economic value (WTP or WTA) of compensation measures.

2. Stated preference study options

A typical stated preference questionnaire consists of four sections: (i) respondent attitudes and opinions; (ii) valuation scenario(s) – STP option effects and compensation measures; (iii) follow-up questions; and (iv) socio-economic characteristics.

We propose two options for a stated preference study, both of which will contain all four sections and differ only in the way they treat the information about compensation measures in the following way:

- ***Option 1 (meeting objectives A, B and C1 above)***: a valuation scenario on the STP options and an additional opinion section (non-economic valuation) on the compensation measures.

- ***Option 2 (meeting objectives A, B and C2 above)***: a valuation scenario on the STP options and an additional valuation scenario on the compensation measures.

The valuation scenario(s) could use a contingent valuation or a choice modelling approach. The decision as to which approach to use will be made in the initial design stages. The feasibility of Option 2 (estimating the economic value of different compensation measures) depends on how much information is available about the compensation measures within the timescale of the primary valuation study. Currently, it seems Option 1 is feasible but the measures are not developed to a sufficient level of detail to enable Option 2. If a STP scheme were chosen compensation measures would need to be determined in terms of extent and location. For this strategic study it is neither feasible or desirable to specify location of compensation however, at the more detailed project level, these issues would need to be addressed. It is also worth noting that compensatory measures could be scattered across several different parts of the UK if for example, one of the larger schemes were taken. Thus there are potentially considerable resource implications that may impact any primary valuation study.

3. Scientific data needs

The design and testing of the valuation scenario(s) will be based on the evidence collated and synthesised for the value transfer analysis to date. This has identified the key habitat types impacted by STP options, the potential change in provision of ecosystem services, the timescale for effects and affected population(s). This provides much of the 'groundwork' for the initial stated preference questionnaire design.

The current gaps in the scientific evidence for the environmental effects of STP options and compensation measures limit the suitability of value transfer but do not necessarily preclude a stated preference study.

With value transfer detailed impact information is required to *match* the existing valuation evidence to effects of STP options. Specific criteria guide this matching process[27] to ensure that aspects such as the current level of provision (the baseline) and change in the provision of the good to be valued, as well as the availability of substitutes and the characteristics of the affected population are consistent between the existing valuation evidence and effects of STP options (or can be controlled for by the analysis).

With a primary study the scientific information requirements have a different emphasis. Information is needed to *communicate* the environmental effects to respondents. This communication will likely involve visual materials (e.g. maps and photos) of the baseline and change conditions accompanied with concise and accessible descriptions. There is currently sufficient information about the STP options and compensation measures to provide such materials and descriptions. Testing through focus groups and cognitive interviews will help fine tune the existing information for the stated preference questionnaire.

4. Workplan, tasks and outputs

The proposed workplan for both Option 1 and Option 2 is identical which is based on the three principle phases of work required for a stated preference study[28]: (i) design and testing; (ii) implementation (main survey); and (iii) analysis and reporting. Tasks within each phase of work are set out in Table 13.2.

Table 13.2: Stated preference study methodology (Option 1 and Option 2)

Tasks	Milestones
Design and testing	
1. Inception meeting	• Agree STP options and compensation measures
2. Qualitative testing	• Prepare initial questionnaire and visual material • Focus groups • Cognitive interviews
3. Pilot questionnaire and experimental design	• Revise questionnaire and decide on the stated preference method • Prepare 'experimental design' (if using CM) • Devise sampling strategy
4. Pilot survey	• Pilot survey • Pilot survey data analysis • Final stated preference questionnaire
Implementation	
5. Main survey	• Main survey fieldwork
Analysis and reporting	
6. Analysis of survey data	• Descriptive analysis (all questions) • Econometric analysis (determinants of WTP/WTA) • Estimate WTP/WTA for STP impact (both Options) and compensation measures (Option 2 only) • Analyse preferences for compensation measures (Option 1 only)

[27] For example, see eftec (2009) *Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal* Draft Guidelines submitted to Defra, August 2009.
[28] See Bateman et al. (2002) *Economic Valuation with Stated Preference Techniques: A Manual*, Edward Elgar.

	• Validity testing • Aggregation
7. Reporting	• Draft final report • Presentation of results • Final report

Individual tasks listed in Table 13.2 are further detailed below.

Design and testing

Inception meeting: will confirm the STP options and compensation measures that will be included in the testing of the stated preference questionnaire since this will determine the sampling strategy, visual material requirements and, to a certain extent, the stated preference approach adopted.

Qualitative testing: will consist of a series of focus groups and cognitive interviews. Six focus groups are proposed: 4 in the STP 'local area' covering both England and Wales, and 2 non-local groups intended to provide a wider national perspective. A similar split is possible for the cognitive interviews. These are in-person interviews during which respondents are taken through the main questionnaire and also answer detailed debriefing questions about their understanding of questionnaire material and reasons behind their responses. The proposed budget (Section 6) includes provision for 25 cognitive interviews.

Visual materials will be developed in parallel to testing of the questionnaire. Option 2 entails a greater requirement for visual material and design input to accompany two different sets of valuation scenarios (STP option effects and compensation measures).

After each round of testing the questionnaire is further developed and revised until a version is ready and agreed with the steering group for pilot testing in the field.

Pilot survey, experimental design and sampling: A pilot survey is the application of the questionnaire to a relatively small sample to test both the revised questionnaire design and material and also the proposed survey method for the main survey. Here a mix of 200 in-person and online interviews is proposed given the timescale available for the study.

The experimental design task is relevant to the choice modelling approach only, where a statistical design is required to specify the levels of attributes about the STP options and compensation measures (e.g. sizes of different types of habitat or access to different types of recreation) that will be presented on choice cards to respondents.

The sampling strategy will be based on the affected population assessment undertaken for value transfer but will also be informed by the qualitative testing; i.e. determining the limits to the 'local user population'.

Implementation

Main survey: Two decisions are required for the main survey: (i) the sample size; and (ii) the survey method.

The sample size is determined by a number of considerations including the requirements to:

- Cover different populations – here 'local' population (England and Wales) who will be directly affected by the effects of the STP options on the environment and 'national' population (England and Wales) who will not be directly affected but may hold non-use values;
- Provide for split samples, if necessary, for different STP options depending on the number of these options;
- Provide sufficient observations for data analysis depending on the elicitation format (the way the WTP or WTA question is asked) and
- Account for likely protest responses[29], the necessary exclusion of which from analysis reduces the number of useable observations.

Larger sample sizes generally result in more efficient economic value results (i.e. smaller confidence intervals).

On the basis of all these considerations, we recommend a sample of 2000, split equally between the local and national populations. We also recommend in-person interviews for the local population and a mainly online survey for the national population. The proposed budget is prepared on this basis including 250 of the 1000 national population for in-person interviews as a control group.

Analysis and reporting

Analysis of survey data: The analysis task will follow the standard procedure for stated preference studies, covering descriptive statistical analysis of all questions, econometric analysis to identify the determinants of WTP (or WTA), estimation of unit values (mean and median WTP or WTA) on the basis of the sampling strategy (e.g. local, national estimates, estimates for different STP options if relevant), validity testing and aggregation. Option 2 will provide economic valuation evidence for both the impact of STP options and compensation measures. Option 1 will provide economic valuation evidence for the impact of STP options only and descriptive statistics for the preferences and priorities for the key features of the compensation measures.

Reporting: Initial results will be reported in the draft final report and a presentation. Following comment from DECC and the steering group the final report will be submitted. There will also be progress reports after each milestone listed in Table 1.

5. Peer Review

The significance of the overall STP decision-making context implies and best practice stated preference guidance requires that independent peer review is a fundamental input in a study like this. Such review is integral to the study with reviewers involved throughout the study from the initial design stage and not only reviewing the results.

An allowance for peer review is included in the proposed budget in the next Section. Appointment of reviewers is at the discretion of DECC and the steering group but two potential candidates are Prof. Ken Willis (University of Newcastle-upon-Tyne) and Dr. Mike Christie (Aberystwyth University). Both are currently leading separate stated preference studies for Defra and are external to the eftec team working on the *Ecosystem Valuation of Habitat*

[29] A protest response refers to instances when a respondent rejects the proposed valuation scenario for reasons that do not reflect a genuine zero WTP; i.e. it is not that the changes in provision presented do not affect their welfare, rather it is that they object to some aspect of the institutional set-up of the valuation scenario, such as the payment vehicle or a lack of faith in local and central Government.

Change for Severn Estuary Tidal Power Feasibility Study. Neither individual has been approached in preparing this note.

6. The proposed budget for Options 1 and 2

The budget for Options 1 and 2 comprise of four main elements: (i) staff costs for design and analysis; (ii) development of visual materials; (iii) market research cost for fieldwork implementation; and (iv) expert review. A proposed budget was provided to DECC at the end of 2009, showing the breakdown between these elements.

As described in Section 2 the key distinction between Option 1 and Option 2 is the treatment of compensation measures. Option 2 entails separate valuation scenarios for STP options and compensation measures, with associated design and analysis input and visual material. Additional time allowance is made for peer review under Option 2 as well.

The ballpark fieldwork costs for Option 1 and Option 2 are identical. As detailed in Section 6 proposed fieldwork tasks permit for a certain degree of flexibility, being able to accommodate both contingent valuation and choice modelling approaches and a selection of split sample designs that may be required (e.g. local versus national). However, the cost estimates provided were ballpark figures and likely to be more appropriate for Option 1 and probably underestimates for Option 2.

We proposed to use the current project team to conduct this work but bring in expertise as necessary to ensure that deliverables were met within the timescales available. Since this initial costing was completed the steering group decided that it would not be possible to conduct a primary valuation as part of the Severn Tidal Power feasibility study (steering group meeting 12th November 2009).

7. Potential risks associated with a potential stated preference study

In setting out options for the stated preference study it is also necessary to outline the key risks:

Timescale: The time available for the study represents a key limiting factor. This was one of the main reasons for not completing a stated preference study as part of the Severn Tidal Power feasibility study.

- **Empirical exercise**: Primary valuation work is an empirical exercise and hence the magnitude of the valuation results cannot be predicted in advance. What can be done in advance is to ensure that the work follows the best practise to ensure robust and valid results and this is what the proposed methodology, budget and work plan presented in this note aim to achieve.

14 REFERENCES

Bateman, I., Willis, K. G., Garrod, G. D., Doktor, P., Langford, I. H., & Turner, K. 1992. *Recreation and environmental preservation value of the Norfolk Broads: a contingent valuation study*, CSERGE.

Bateman, I. et al. 2002. *Economic Valuation with Stated Preference Surveys*. Cheltenham, Edward Elgar.

Black and Veatch 2010. Severn Tidal Power – Environmental Report.

Black & Veatch 2009. Severn Tidal Power – Phase 2 SEA Climate Change Scenarios

Black and Veatch in association with ABPmer, IPA Consulting Ltd., Econnect Consulting Ltd., Baker, C. and Sinden, G. 2007. *Tidal Power in the UK: Research Report 3 - Severn Barrage Proposals*, report to the Sustainable Development Commission, October 2007. See: http://www.sd-commission.org.uk/pages/tidal-power.html

Birol, E. & Cox, V. 2007. Using choice experiments to design wetland management programmes: The case of Severn Estuary wetland, UK. *Journal of Environmental Planning and Management*, 50, (3) 363-380 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-34248164020&partnerID=40

Brander L.M., Florax R.J.G.M., & Vermaat, 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

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.

Brouwer, R., Langford, I. H., Bateman, I. J., Crowards, T. C., & Turner, K. 1999. *A Meta-Analysis of Wetland Contingent Valuation Studies*, CSERGE, GEC97-20.

Butler, J.R.A., Radford, A., Riddington, G., & Laughton, R. 2009. Evaluating an ecosystem service provided by Atlantic salmon, sea trout and other fish species in the River Spey, Scotland: The economic impact of recreational rod fisheries. *Fisheries Research*, 96, 259-266

Carlsson, F., Frykblom, P., & Liljenstolpe, C. 2003. Valuing wetland attributes: An application of choice experiments. *Ecological Economics*, 47, (1) 95-103 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0345446702&partnerID=40

Cooper, J. & Loomis, J. 1993. Testing whether waterfowl hunting benefits increase with greater water deliveries to wetlands. *Environmental and Resource Economics*, 3, (6) 545-561 available from: http://dx.doi.org/10.1007/BF00364059

Dalecki, M., Whitehead, J.C., & Blomquist, G.C. 1993. Sample Non-Response Bias and Aggregate Benefits in Contingent Valuation: an Examination of Early, Late, and Non-respondents. *Journal of Environmental Management*, 38, 133-143 de Blaeij, A.T., Florax, R.J.G.M., Rietveld, P., Verhoef, E. 2009. The Value of Statistical Life in Road Safety: A Meta-analysis. Working Paper, Tinbergen Institute, The Netherlands.

Department of Energy and Climate Change (DECC) 2009. *Carbon Valuation in UK Policy Appraisal: A Revised Approach*.

Department for Transport (DfT) Web Transport Analysis and Guidance (WebTAG), (accessed, September 2009): http://www.dft.gov.uk

Defra 2007. *An introductory guide to valuing ecosystem services*, Department for Environment, Food and Rural Affairs.

Donnelly, W.A. 1989. Hedonic price *analysis of the effect of a floodplain on property values. Water Resources Bulletin*, 25, (3) 581-586

Drew Associates 2009. *Research into the economic contribution of sea angling*, Department for Environment, Food and Rural Affairs.

Driscoll P.J., Dietz B.C., & Alwang J.A. 1994. Welfare analysis when budget constraints are nonlinear: The case of flood hazard reduction. *Journal of Environmental Economics and Management*, 26, (2) 181-191

Dymond, J.R., Ausseil, A.E., & Overton, J.M. 2008. A landscape approach for estimating the conservation value of sites and site-based projects, with examples from New Zealand. *Ecological Economics*, 66, 275-281

eftec 2009. *Review of the Economic Value Associated with the Severn Estuary's Fisheries*, Environment Agency for England and Wales.

Economics Intelligence Unit (EIU). 2006. 2020, Economic, industry and corporate trends. A report from the Economist Intelligence Unit sponsored by Cisco Systems

Environment Agency. Wye Catchment Salmon Action Plan. Consultation Document. 1997.

Environment Agency. Severn Estuary Salmon Action Plan. Consultation Document. 2001.

Environment Agency 2009. *Salmonid and Freshwater Fisheries Statistics for England and Wales*.

Ghermandi, A., van den Bergh, J.C.J.M., Brander, L.M., de Groot, H.L.F. and Nunes, P.A.L.D. 2008. 'Exploring diversity: A meta-analysis of wetland conservation and creation', Working paper, Free University of Amsterdam.

González, M. & Léon, C.J. 2003. Consumption process and multiple valuation of landscape attributes. *Ecological Economics*, 45, (2) 159-169 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0037933178&partnerID=40

HM Treasury 2003. *The Green Book: Appraisal and Evaluation in Central Government*. Available online at: http://www.hm-treasury.gov.uk/d/green_book_complete.pdf.

Jacobs 2004. *An Economic Assessment of the Costs and Benefits of Natura 2000 Sites in Scotland*, The Scottish Government.

Kuriyama, K. 2000. Measuring the ecological value of the forests around the Kushiro marsh: An empirical study of choice experiments. *Journal of Forest Research*, 5, (1) 7-11

Lawrence, K.S. 2005. Assessing the value of recreational sea angling in South West England. *Fisheries Management and Ecology*, 12, (6) 369-375 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-33745201580&partnerID=40

Loomis, J.B. 1989. A Bioeconomic Approach to Estimating the Economic Effects of Watershed Disturbance on Recreational and Commercial Fisheries. *Journal of Soil and Water Conservation*, January-February, 83-87

Luisetti, T., Bateman, I., & Turner, K. 2008a. Testing the fundamental assumption of choice experiments: Are values absolute or relative? Working paper, CSERGE, 2008.

Luisetti, T., Turner, K. and Bateman, I. 2008b. An ecosystem services approach to assess managed realignment coastal policy in England, CSERGE working paper, available at http://www.uea.ac.uk/env/cserge/pub/wp/ecm/ecm_2008_04.htm

Milon, J.W. & Scrogin, D. 2006. Latent preferences and valuation of wetland ecosystem restoration. *Ecological Economics*, 56, (2) 162-175 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-32144444204&partnerID=40

Navrud, S., Ready, R.C., Magnussen, K., & Bergland, O. 2008. Valuing the social benefits of avoiding landscape degradation from overhead power transmission lines: Do underground cables pass the benefit-cost test? *Landscape Research*, 33, (3) 281-296 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-46649093964&partnerID=40

Oglethorpe, D.R. & Miliadou, D. 2000. Economic valuation of the non-use attributes of a wetland: A case-study for Lake Kerkini. *Journal of Environmental Planning and Management*, 43, (6) 755-767 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0033665411&partnerID=40

Oglethorpe 2005. *Environmental Landscape Features (ELF) Model Update*, report to Department for Environment, Food and Rural Affairs.

PACEC 2006. *The Economic and Environmental Impact of Sporting Shooting*, BASC.

Parsons Brinckerhoff and Black Veatch 2008. *Analysis of options for tidal power development in the Severn Estuary – Interim Options Analysis Report*, report to DECC, December 2008.

Parsons Brinckerhoff and Black Veatch 2009. Strategic Environmental Assessment of proposals for tidal power development in the Severn Estuary – Options Definition Report (ODR), report to DECC.

Pate, J. & Loomis, J. 1997. The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. *Ecological Economics*, 20, (3) 199-207 available from: http://www.sciencedirect.com/science/article/B6VDY-3SVYSRC-2/2/b6c53f65c7ce91491900a8c600c2f2c2

Poor, J. 1997. *The Value of Additional Central Flyway Wetlands in Nebraska's Rainwater Basin Wetland Region*, Western Agricultural Economics Association.

Radford, A. & Hatcher, A. 1991. *An economic evaluation of the recreational salmon fisheries in Great Britain: principles of economic evaluation and discussion of results for Wales*, Centre for the Economics and Management of Aquatic Resources.

Ragkos, A., Psychoudakis, A., Christofi, A., & Theodoridis, A. 2006. Using a functional approach to wetland valuation: the case of Zazari–Cheimaditida . *Regional Environmental Change*, 6, (4) 193-200

Sansom T., Nash C., Mackie P., Shires J. & Watkiss P. 2001. Surface Transport Costs and Charges: Great Britain 1998, University of Leeds.

Simpson, D. & Willis, K. 2003. *Study to develop and test a method for assessing the heritage value of net fisheries*, Environment Agency.

Söderqvist, T., Eggert, H., Olsson, B., & Soutukorva, Å. 2005. Economic valuation for sustainable development in the Swedish coastal zone. *Ambio*, 34, (2) 169-175

Ward, F. & Beal, D. 2000. *Valuing nature with travel cost models: a manual*. Cheltenham, Edward Elgar.

White, P.C.L., Gregory, K.W., Lindley, P.J., & Richards, G. 1999. Economic values of threatened mammals in Britain: A case study of the otter Lutra lutra and the water vole Arvicola terrestris. *Biological Conservation*, 82, (3) 345-354 available from: http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-0030985381&partnerID=40

Whitehead, J.C. 1991. Environmental Interest Group Behaviour and Self-Selection Bias in Contingent Valuation Mail Surveys. *Growth and Change*, 22, (1) 10-21

Whitehead, J.C. 1991. Measuring Willingness to Pay for Wetlands Preservation with the Contingent Valuation Method. *Wetlands*, 10, (2) 187-201

Woodward, R.T. & Wui, Y.S. 2001. The economic value of wetland services: a meta-analysis. *Ecological Economics*, 37, (2) 257-270 available from: http://www.sciencedirect.com/science/article/B6VDY-42Y7F3H-7/2/4dd9732304e12ca637479bf5a29c1f6f