DECC

SEVERN TIDAL POWER - SEA THEME PAPER

Biodiversity Effects and Interrelationships

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Prepared by
Parsons Brinckerhoff Ltd
Queen Victoria House
Redland Hill
Bristol
BS6 6US

In association with
Black and Veatch Limited
and
British Trust for Ornithology

Prepared for
DECC
3 Whitehall Place
London
SW1A 2HD

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Prepared by	**:**	**Lucy Wright and Nigel Clark**
Checked by	**:**	**Nigel Clark**
Approved by	**:**	**Tom Matthewson**

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ABBREVIATIONS

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The following abbreviations are used in this Theme Paper:

BAP	Biodiversity Action Plan
BTO	British Trust for Ornithology
CCW	Countryside Council for Wales
CHaMP	Coastal Habitat Management Plan
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EIA	Environmental Impact Assessment
EC	European Commission
EU	European Union
GIS	Geographical Information System
GW	Gigawatts
HA model	Habitat Association Model
HRA	Habitats Regulations Assessment
IBM	Individual-Based Model
LNR	Local Nature Reserve
MW	Megawatt
NERC	Natural Environment and Rural Communities Act
NNR	National Nature Reserve
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
TWh	Terrawatt hours
UKCIP	United Kingdom Climate Impacts Programme
WeBS	Wetland Bird Survey
WFD	Water Framework Directive

NON TECHNICAL SUMMARY

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Feasibility Study and Purpose of the SEA

The Government announced a two-year feasibility study on harnessing the renewable energy from the tidal range in the Severn Estuary in January 2008. This work is being carried out by a cross-Government team led from the Department for Energy and Climate Change (DECC). The aim of the Severn Tidal Power (STP) Feasibility Study is to investigate whether Government could support a tidal power scheme in the Severn and, if so, on what terms.

The Feasibility Study has been split into two phases: Phase One examined the scope of work and analysis required to make an evidence-based decision on whether to support a tidal power project in the Severn and what potentially feasible schemes exist for converting this energy. Phase One ended with the publication of the consultation document in January 2009. Phase Two (the current stage) has involved work on environmental, regional, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible.

A Strategic Environmental Assessment (SEA) is being carried out in support of the Feasibility Study, in accordance with EU Directive 2001/42/EC (the SEA Directive), implemented in England and Wales through the Environmental Assessment of Plans and Programmes Regulations (SI 2004/1633 and Welsh SI 2004/1656), to predict and analyse the environmental effects of alternative short-listed Severn tidal power options over their entire lifetime, in order to inform decision making at the end of the Feasibility Study.

The studies that inform the SEA have been conducted at a strategic level and further work would be required to provide sufficient detail that a tidal power option could be implemented.

Purpose of the Theme Papers

The SEA Directive requires that 'the likely significant effects on the environment… and the interrelationship' are described (SEA Directive Annex 1 (f)). The theme papers therefore to summarise the interrelationships between related topics and thereby ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. Each theme paper also examines the interrelationships between this theme and other themes within the STP SEA. As the biodiversity theme paper, this paper covers the Marine Ecology, Waterbirds, Migratory and Estuarine Fish, and Terrestrial and Freshwater Ecology SEA topics.

Furthermore, the theme papers also assist the Environmental Report to meet the requirements of the SEA Directive by collating the difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information (SEA Directive Annex 1 (h)).

Each theme paper therefore provides an integrated summary across the theme, drawing on information presented in its topic papers. This theme paper also addresses the interrelationships between this theme and the Habitats Regulations Assessment. Each theme paper considers the likely significant effects on the environment of the variations of alternative options referred to as combination and multiple basin options.

Throughout this report the term "receptor" is used to mean any entity that may be affected by direct or indirect changes to an environmental variable. The report considers the effects on a range of receptors, which can be habitats, species or species guilds. These receptors were identified during the Phase 1 scoping stage and are described in the SEA Scoping Report.

Biodiversity Baseline Environment and Significant Effects

The Severn is a very large estuary. Its classic funnel shape is one of the factors causing the Severn to have the second-highest tidal range in the world (Stroud *et al*. 2001). As a result, the Severn Estuary and Bristol Channel are typified by extreme physical conditions such as high water flow speeds causing high turbidity, and a dynamic environment with high variability in salinity, seawater temperature and other physical characteristics. These features mean that the ecology of the area is unlike that of any other UK estuary. Characteristic habitats in this unusual, physically stressful, environment include some of the largest areas of intertidal mudflats and sandflats in the UK, one of the largest aggregations of saltmarsh in the southern UK, as well as *Sabellaria* reefs, *Zostera* beds and *Corallina* run offs. Although the invertebrate communities are relatively species-poor they do include high densities of certain species which form an important food resource for predators, particularly waterbirds and fish.

The Severn supports internationally important populations of a range of waterbird and fish species, and nationally important populations of many others, as well as holding a range of marine, terrestrial and freshwater habitats of international and national importance. As a result, the estuary and its tributaries are protected under various international and national designations including several Special Areas of Conservation (SACs), a Special Protection Area (SPA) for waterbirds, a Ramsar Site as it is considered a wetland of international importance, and a number of Sites of Special Scientific Interest (SSSIs), National Nature Reserves (NNRs) and Local Nature Reserves (LNRs). Internationally designated fish species protected via Annex II of the European Habitats Directive and encompassed within Natura 2000 sites within the study area include five migratory fish species. In addition the European eel is internationally protected via European eel management plan. A range of species are also protected at a national level under the UK Biodiversity Action Plan. The estuary and its tributaries also form an important nursery area for marine fish.

More than 80,000 waterbirds were recorded on the Severn in 2008/09, but the five-year mean peak (used as the baseline) was 72,909. This makes the Severn one of the 20 most important waterbird sites in the UK. There is a small amount of uncertainty surrounding the numbers of waterbirds using the Severn because of variations between years in the numbers recorded, and incomplete coverage of the estuary by waterbird surveys prior to 2008/09. For other biodiversity receptors there are less precise data regarding baseline numbers, and for most migratory and estuarine fish, and some marine ecology receptors, there is a paucity of data on baseline conditions and on key life-history parameters or functional requirements. Although evidence suggests that the populations of internationally protected fish species are currently in unfavourable condition in most rivers in the study area (and they are therefore subject to conservation measures that aim to return them to favourable condition); their baseline numbers are not known and had to be predicted using novel life-cycle modelling methods. This lack of data and understanding of key ecological parameters leads to large uncertainties in the baseline conditions for these receptors and even greater uncertainties in predicting future changes either with or without a tidal power option. Although there is much better knowledge of some taxa than others, this does not equate to differences in their levels of importance.

Five alternatives for the development of tidal power using the tidal range of the Severn Estuary have been identified, and the effects of these options on biodiversity are considered in this report. The five options comprise three tidal barrages and two tidal lagoons:

- B3 - Brean Down to Lavernock Point Barrage (also known as Cardiff to Weston)
- B4 - Shoots Barrage
- B5 - Beachley Barrage
- L2 - Welsh Grounds Lagoon
- L3d - Bridgwater Bay Lagoon

Further details of each of these options are provided in Table 2.2, and throughout this report these options may be abbreviated to the codes above (B3, B4, B5, L2, L3d).

All five of the tidal power options are likely to have significant negative effects on biodiversity. These effects include large reductions in the area of intertidal mudflat, sandflat, saltmarsh and other marine ecology features. Substantial reductions in the populations of some species of fish and waterbirds are predicted for all options, and there is the potential for local extinction of some fish species, including internationally protected species, for some options. The only known UK spawning sites for twaite shad are in the Severn and its tributaries, and the River Tywi in south Wales (where the population could also be affected by the implementation of a tidal power option on the Severn). Therefore there is a risk of extinction of the entire UK spawning stock of this species under some of the tidal power options. A wide range of other changes to the ecosystem are predicted as a result of habitat change and loss, and the resultant increases in mortality rates of some species. Despite this overall picture, there are considerable differences in the nature of effects on biodiversity receptors predicted as a result of each of the tidal power options.

Effects of all options are likely to begin during the construction phase, when significant negative effects are predicted to marine ecology and terrestrial and freshwater ecology receptors within or near the footprint of options and their landfalls, largely as a result of the loss, fragmentation or degradation of habitat. Disturbance during construction could also have a significant effect on waterbirds, fish and some terrestrial and freshwater ecology receptors, and migratory and estuarine fish may be affected by a range of other construction effects.

For all options, the largest predicted changes for marine ecology receptors are associated with the large modification to water levels and consequent reduction in the extent of intertidal habitat. As well as the initial losses if a tidal power option is implemented, further losses of intertidal habitat are predicted as a result of long-term morphological changes, and these are predicted to be significant for options B3 (Brean Down to Lavernock Point Barrage), B4 (Shoots Barrage) and L3d (Bridgwater Bay Lagoon), but not for B5 (Beachley Barrage) and L2 (Welsh Grounds Lagoon) where the long-term morphological changes are predicted to result in a modest (less than 1 %) increase in intertidal area. The combined effects on marine ecology receptors of the initial and long-term losses to intertidal habitats are predicted to be biggest for the B3 (Brean Down to Lavernock Point Barrage) option, followed by L2 (Welsh Grounds Lagoon), B4 (Shoots Barrage) and B5 (Beachley Barrage). The smallest overall losses of intertidal habitat are predicted for the L3d (Bridgwater Bay Lagoon) option.

It is likely that there would be increases in phytoplankton productivity upstream of the B3 (Brean Down to Lavernock Point Barrage) option due to reduced turbidity and therefore increased light penetration to the water column. The increased phytoplankton productivity could be transferred up the food chain and result in increases in the density of some other taxa, including some intertidal invertebrate species, that can be supported. Although this means that the suitability of the remaining intertidal habitat for some species may increase, this effect is considered likely to be far outweighed by the scale of intertidal habitat loss, such that significant negative effects are still predicted for most marine ecology receptors. These effects would also alter the unique stressed environment that is one of the characteristics for which the Severn Estuary / Môr Hafren SAC is currently protected. Increased phytoplankton productivity may occur on a small scale upstream of the other four options, but this is not considered likely to be significant.

Other negative effects predicted for marine ecology receptors include a significant negative effect on subtidal sandbanks for all of the tidal power options, due to changes in sand transport and mud deposition. Significant negative effects on subtidal *Sabellaria alveolata* reefs as a result of reductions in flow speed are predicted to occur if any of the options except L3d (Bridgwater Bay Lagoon) were implemented.

Loss of saltmarsh is predicted to be a significant negative effect for option B3 (Brean Down to Lavernock Point Barrage) only, and the distribution and quality of the saltmarsh could change in the longer term as the estuary adjusts.

For option B3 (Brean Down to Lavernock Point Barrage), far-field changes to water levels are predicted which are considered likely to have a significant negative effect on some marine ecology receptors. Saltmarsh in particular may be affected as a result of increases in the level of high water along much of the south west and west Wales coast and the north Devon and north Cornwall coast. However the extent and magnitude of these changes is considerably less certain than that of changes within the estuary. For option L3d (Bridgwater Bay Lagoon), there is also the potential for far-field significant negative effects to saltmarsh as a result of decreases in the level of high water in the vicinity of the Kenfig SAC. No far-field effects are predicted as a result of options B4 (Shoots Barrage), B5 (Beachley Barrage) and L2 (Welsh Grounds Lagoon).

The predicted loss of and changes to intertidal habitat represents the principal effect of all of the tidal power options on waterbirds. The negative effects of both immediate and long-term habitat loss, changes to the intertidal exposure period and effects of maintenance dredging on habitat quality are predicted to far outweigh any positive effects on waterbirds caused by predicted increases in the productivity of intertidal habitat. A total of 50 waterbird receptors were considered as part of the SEA. Changes to intertidal habitat are predicted to have significant negative effects on 30 of these receptors as a result of the B3 (Brean Down to Lavernock Point Barrage) option, 17 as a result of the B4 (Shoots Barrage) option, 15 as a result of the B5 (Beachley Barrage) option, 13 as a result of the L2 (Welsh Grounds Lagoon) option and 9 as a result of the L3d (Bridgwater Bay Lagoon) option. In addition, loss of saltmarsh (in both the short- and long-term) is predicted to cause significant negative effects to 4 waterbird receptors for option B3 (Brean Down to Lavernock Point Barrage) only.

Displacement to far-field sites is predicted to have significant effects on waterbirds for two of the tidal power options, with significant negative effects predicted for 15 waterbird receptors on three sites as a result of the B3 (Brean Down to Lavernock Point Barrage) option, and 1 receptor on two sites as a result of the B4 (Shoots Barrage) option. Far-field effects of changes in water levels are predicted to cause significant negative effects to two waterbird receptors on the Dyfi Estuary as a result of the B3 (Brean Down to Lavernock Point Barrage) option only.

Other significant effects to waterbirds include disturbance (largely during construction and decommissioning), for all options except B4 (Shoots Barrage). This effect is predicted to be largest for the L2 option (Welsh Grounds Lagoon), having a significant negative effect on 11 waterbird receptors, because the lagoon structure crosses extensive areas of intertidal habitat used by waterbirds. Disturbance is also predicted to have significant negative effects for three waterbird receptors as a result of the L3d (Bridgwater Bay Lagoon) option, two as a result of the B3 (Brean Down to Lavernock Point Barrage) option, and one as a result of the B3 (Beachley Barrage) option. Significant negative effects to breeding seabirds are predicted for three and two species as a result of the B3 (Brean Down to Lavernock Point Barrage) and L3d (Bridgwater Bay Lagoon) respectively.

For all options, significant negative effects are predicted to all migratory and estuarine fish as a result of turbine passage, disruptions to routes of passage, altered migratory cues, habitat change or loss, changes to water quality and anthropogenic noise disturbance. Bearing in mind the large uncertainties surrounding effects on migratory and estuarine fish (due to limited baseline data and understanding of key ecological parameters), it is estimated that local populations of certain species could become effectively extinct.

Populations at risk of local extinction include twaite shad on the Rivers Severn and Wye under all options, and also on the River Usk under all options except B4 (Shoots Barrage). There is also the possibility for far-field effects leading to reductions in the population of twaite shad on the Tywi which, if significant, could lead to extinction of the whole UK spawning stock for all options except B4 (Shoots Barrage).

There is a risk of population collapse and effective extinction of the genetically distinct population of Atlantic salmon populations on the Severn, Wye and Usk under all options, with the risk of this

occurring on the Usk slightly higher under the B5 (Beachley Barrage) and L2 (Welsh Grounds Lagoon) options.

There is a risk of the collapse of sea and river lamprey populations on either the Wye, Usk or both under options B4 (Shoots Barrage), B5 (Beachley Barrage) and, for sea lamprey also under option L2 (Welsh Grounds Lagoon). Under all other options these significant population size reductions are predicted for these species and reductions in the UK stock of river lamprey and the European stock of sea lamprey are predicted if any of the tidal power options were implemented. Significant reductions in eel populations, which may lead to non-compliance with the EU Eel Regulations, are predicted on the Severn and Wye for all options, and on the Usk for options B3 (Brean Down to Lavernock Point Barrage) and L2 (Welsh Grounds Lagoon).

These reductions may affect the status of the European eel stock, although this is thought unlikely to occur for option L3d (Bridgwater Bay Lagoon). Eel is categorised as critically endangered by the IUCN so further reductions in the population could compound the existing threat to its survival.

For many species of fish the future baselines and effects of the options cannot be quantified but it is considered that there is potential risk of reductions in population size for all fish species that occur in the Severn. However, there are very high levels of uncertainty surrounding these predictions, so if a tidal power option were implemented the changes in fish numbers might differ considerably from the predictions. This could result in more or fewer species becoming locally extinct or higher or lower levels of population reduction than predicted.

Operational effects to terrestrial and freshwater ecology receptors are generally smaller than those for other biodiversity topics, but there are still some significant effects. Options B3 (Brean Down to Lavernock Point Barrage), B4 (Shoots Barrage) and L2 (Welsh Grounds Lagoon) are predicted to have significant negative effects through land take and increased water levels on a range of sites. The key sites most likely to be negatively affected under the B3 (Brean Down to Lavernock Point Barrage) option are the SACs on the Mendip and Limestone Grasslands and Rivers Wye and Usk, as well as a range of SSSIs, NNRs and LNRs. Under the B4 (Shoots Barrage) option the River Wye SAC and two SSSIs are predicted to be negatively affected, and under the L2 (Welsh Grounds Lagoon) option significant negative effects are predicted to the Newport Wetlands NNR and the Gwent Levels SSSI. Under all options a significant negative effect on otter populations (and some crustaceans and invertebrates that feed on fish or fish carrion) is predicted as a result of predicted declines in fish populations.

Significant positive effects to freshwater wetland habitats due to increased water levels in the floodplain are predicted as a result of three of the options (B3 (Brean Down to Lavernock Point Barrage), B5 (Beachley Barrage) and L3d (Bridgwater Bay Lagoon)). For option B5 (Beachley Barrage) these effects would be predicted to occur on the Upper Severn Estuary SSSI, while for options B3 (Brean Down to Lavernock Point Barrage) and L3d (Bridgwater Bay Lagoon) positive effects are predicted for a range of wetland sites, including the Somerset Levels Ramsar Site.

Some of the key difficulties encountered in compiling the required information for the baseline and assessment of effects on biodiversity included a lack of baseline information for some species, particularly fish and some marine ecology receptors, and a lack of understanding of some key ecological variables particularly for marine ecology and fish. Some data used in the marine ecology assessment are out of date, or site specific. In the waterbird assessment, modelling of changes to waterbird numbers as a result of tidal power options was limited by the limited information on changes to habitats, invertebrates and sediments to feed into the waterbird modelling, particularly information concerning changes additional to those which take place immediately upon impoundment. As a result of this, a number of assumptions had to be made, increasing the level of uncertainty. Some terrestrial parts of option development (such as cable routes) are unknown and hence their effects on biodiversity are uncertain.

Interrelationships

Within the biodiversity theme the biggest interrelationship relates to estimates of habitat change (and, to a lesser extent, some other variables such as changes in phytoplankton productivity and invertebrate abundance) produced by the marine ecology topic. These estimates are important in informing the assessment of effects on waterbirds and migratory and estuarine fish that feed on marine and intertidal invertebrates.

Some marine ecology receptors (marine mammals such as seals), waterbird receptors (e.g. cormorant and grey heron), and terrestrial and freshwater ecology receptors (otter) feed on fish. Thus any changes to the abundance or distributions of fish populations predicted in the migratory and estuarine fish assessment are important in determining effects on these receptors.

Predicted effects of each option on biodiversity receptors are largely dependent on the predictions of future changes to the physical environment, and as such the most important interrelationship outside of the biodiversity theme is with the Physicochemical theme.

Within the Physicochemical theme, predicted changes (particularly to water levels) from the hydraulics and geomorphology topic were critical in informing the modelling conducted by all topics within the biodiversity theme. Results from the marine water quality topic were required to inform the marine ecology and migratory and estuarine fish topic assessments. The flood risk and land drainage assessment has been important in informing the likely changes to water levels on land surrounding the options, which is an important consideration, particularly regarding effects on terrestrial and freshwater ecology receptors.

Uncertainties inherent in the Physicochemical theme results lead to uncertainties in the predicted effects on biodiversity receptors. In some cases the uncertainty from the Physicochemical theme is likely to compound with the uncertainty within the biodiversity theme. In others the uncertainty within the Physicochemical theme is expressed as a component of the uncertainty in the biodiversity topics. This needs to be borne in mind when considering the overall uncertainty of predictions within the biodiversity theme.

The main interrelationship between the biodiversity theme and the study to inform the Habitats Regulations Assessment (HRA) is that the various biodiversity topics supplied data and information from their modelling and assessment to inform the Habitats Regulations Assessment. The Habitats Regulations Assessment does not generate new data, but uses the data and assessments provided by the various biodiversity (and Physicochemical) topics. However, the SEA and HRA differ in their approaches such that the results and conclusions derived from these data may differ. The SEA presents estimates of the most likely predicted effects on the receptors while the HRA takes a precautionary approach. This means that, for example, where modelling the effects of an option on a receptor predicts a range of outcomes, the most likely estimates from these predictions would be used in the SEA but the most negative impact of possible outcomes would be taken as the precautionary value used in the HRA.

Measures to Prevent, Reduce and as Fully as Possible Offset any Significant Adverse Effects

Many of the proposed measures to prevent and reduce effects are unprecedented at the scale that would be required on the Severn, and some employ novel, untested methods. There is a need for further research to better understand the likely effectiveness of these measures.

Careful timing of construction activities and pollution prevention controls during construction could potentially reduce impacts on a wide range of biodiversity receptors during that phase. Management of dredging and piling activities to limit resuspension of sediments and noise could reduce adverse effects to marine ecology and migratory and estuarine fish. Minor adjustments to the alignment and landfall of options to avoid specific features could help to reduce adverse effects, particularly for marine ecology and terrestrial and freshwater ecology receptors, although waterbirds may also benefit

from alignment adjustments to the B3 (Brean Down to Lavernock Point Barrage) option. Minor alignment adjustments to avoid eelgrass beds for options B3 (Brean Down to Lavernock Point Barrage), B4 (Shoots Barrage) and L2 (Welsh Grounds Lagoon) may also benefit birds. This would require careful planning as there could be interactions; improving the alignment to avoid certain receptors may make the negative effects on other receptors worse.

The large-scale creation of intertidal areas through topographic modification could reduce significant adverse effects of intertidal loss on marine ecology and waterbirds, and may also reduce adverse effects to estuarine fish. However, intertidal creation on the scale proposed here has never been attempted, and this method of habitat creation is novel, therefore the success of this measure is highly uncertain. Although the majority of the topographic modification is proposed on areas of current intertidal habitat that would be inundated following option implementation, some of it would occur on areas that are currently subtidal, and this would have a negative effect on subtidal receptors. Sluicing after the generation period combined with early commencement of turbine generation may also reduce the effects of intertidal loss on marine ecology and waterbirds by reducing the effect of tidal range reduction for ebb-only options.

Maintaining mean high water spring tide levels through pumping at the end of generation on flood tides may help to conserve the remaining saltmarsh, and therefore reduce adverse effects to marine ecology and waterbird receptors. Introduction of new refuges or bird roots within the estuary area could also reduce some adverse effects on waterbirds.

A range of measures have been suggested to reduce the adverse effects on migratory and estuarine fish. These include altering the operating regime, fish passage mechanisms such as altering the number, type and size of sluices, and predator control. Additional fish passage mechanisms such as fish bypasses, lifts and locks cannot be recommended at this stage as it is uncertain whether they could be operated successfully in the Severn. It is suggested that further research is undertaken prior to the implementation of a tidal power option to investigate these possibilities to reduce effects associated with disruption to route of passage. It is uncertain whether the measures to prevent and reduce adverse effects on migratory and estuarine fish could be effective on this scale and even if effective it is likely that they would only partially reduce significant adverse effects.

The management of water levels in the floodplain through pumping, sluicing to change the low water level of the options or creating attenuation areas to store water may be effective in preventing or reducing adverse effects to terrestrial and freshwater ecology receptors, and may also have a low level effect in reducing adverse effects to waterbirds.

It is likely that measures to prevent and reduce significant adverse effects would only be partially effective for most biodiversity receptors, and therefore a significant large-scale programme of offsetting and compensation measures would most likely be required particularly for waterbirds, migratory and estuarine fish, and marine ecology receptors. Significant adverse effects on terrestrial and freshwater ecology receptors are generally smaller and it is likely that the majority of these could be resolved through measures to prevent and reduce effects. As the level of compensation likely to be required would be unprecedented, there is a significant risk that it may not be possible to offset or compensate for all of the adverse effects on a 'like-for-like' basis.

SEA Objective Compliance

The SEA Objectives were drafted and consulted upon as part of the Phase 1 SEA scoping stage. This theme paper identifies any interactions or inconsistencies between topics within this theme with regards to the assessment against SEA Objectives.

The majority of SEA Objectives for marine ecology, waterbirds and migratory and estuarine fish were not considered likely to be met for any of the alternative tidal power options due to the significant adverse residual effects that are predicted to these receptors as a result of all the proposed tidal

power options, even if foreseen measures to prevent and reduce adverse effects were successful. There were some differences between options in the numbers of receptors for which each Objective was not met.

Exceptions, i.e. SEA Objectives that were considered likely to be met for all of the alternative options, were one marine ecology objective and one migratory and estuarine fish objective as follows:

- To avoid adverse effects on other protected marine species and their habitats.
- To minimise the risk of introduction of non-native fish species.

The marine ecology objective "to avoid deterioration in status class of WFD water bodies" was considered likely to be met for options B4 (Shoots Barrage), B5 (Beachley Barrage) and L2 (Welsh Grounds Lagoon). It is uncertain whether this objective would be met for options B3 (Brean Down to Lavernock Point Barrage) and L3d (Bridgwater Bay Lagoon). Although this objective was considered likely to be met for three of the options because the status class of WFD water bodies would not deteriorate, it is likely that there may be deteriorations of some components of the relevant WFD water bodies.

In contrast to the other topics, it was considered likely that all seven of the SEA objectives for terrestrial and freshwater ecology were likely to be met for options B3 (Brean Down to Lavernock Point Barrage), B5 (Beachley Barrage) and L3d (Bridgwater Bay Lagoon), while all but one (To conserve and enhance designated freshwater and terrestrial site features) were considered likely to be met for options B4 (Shoots Barrage) and L2 (Welsh Grounds Lagoon).

Implementation

It is suggested that to inform the future development of any Severn Tidal Power option, significant investment in research to establish the potential effectiveness of measures to prevent or reduce effects on migratory and estuarine fish would be necessary. The likely efficacy of proposed measures, and the potential development of additional measures to prevent or reduce effects on fish, is currently highly uncertain. Were any of the options taken forward for further investigation, it is suggested that research would be necessary to reduce this uncertainty prior to option implementation.

The levels of certainty surrounding the assessment of effects on migratory and estuarine fish could be greatly improved if research were conducted to improve understanding of key behavioural, life-history and ecological parameters for a range of species in the Severn. Although the suggested research could reduce uncertainty regarding the likely effects of tidal power options on fish and potential effectiveness of measures to prevent or reduce effects, it would not reduce the level of effect of the proposed schemes. However better understanding of the likely effects may aid the decision-making process.

To improve the estimated effects of options on waterbirds, development of the habitat association modelling to produce models at the mudflat (rather than the whole estuary) scale would be valuable. Better information on mudflat invertebrate abundance and predicted changes would improve the individual-based models for waterbirds.

To assess options prior to permitting construction it would be necessary to establish a more accurate and detailed understanding of the baseline conditions for all biodiversity receptors, but most particularly fish, and some marine ecology receptors such as cephalopods. Comprehensive monitoring would be recommended for at least five years prior to construction to allow an accurate baseline to be established. However, the scale of the work required for fish in particular is very large, subject to technological and methodological constraints, and there is therefore a risk that some of these aims could not be achieved. There is also insufficient time to implement the five-year pre-construction monitoring recommended for all biodiversity receptors if the construction begins in 2014 as currently considered.

By establishing a sound and long-term monitoring programme from the outset, a firm evaluation of the changes consequent of construction and operation of any of the alternative options would be possible. This could also be important in informing any future proposals for other tidal power options. It would be useful to establish a framework for the feedback of monitoring results during the construction and operation of an option, in order that findings can be acted on where possible.

To monitor effects during construction and operation, a detailed intensive long-term monitoring programme for all biodiversity receptors, including changes to habitat extent and quality, and population-level responses of key receptors would be recommended. Comprehensive monitoring of a variety of biodiversity receptors would be recommended throughout the construction period and for a minimum of 10 years afterwards, or until the environment and the population sizes of receptor species have stabilised if this takes longer than 10 years. It would be recommended that the same methods as recommended prior to construction (above) be continued throughout this period.

If a tidal power option was taken forward, it would be recommended that a strategic long-term monitoring programme for all biodiversity receptors be implemented throughout the life of any of the alternative options.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Background

1.1.1 The Government announced a two-year feasibility study on harnessing the renewable energy from the tidal range in the Severn Estuary in January 2008. This work is being carried out by a cross-Government team led from the Department for Energy and Climate Change (DECC), including representatives of the Welsh Assembly Government (WAG) and the South West Regional Development Agency (SWRDA), taking external advice as necessary and engaging stakeholders and the wider public. The aim of the Severn Tidal Power (STP) Feasibility Study is to investigate whether Government could support a tidal power scheme in the Severn and, if so, on what terms.

1.1.2 Any project to generate power from the tidal range of the Severn Estuary would need to meet the following objectives:

- To generate electricity from the renewable tidal range resource of the Severn Estuary in ways that would have an acceptable overall impact on our environment and economy both locally and nationally, would meet our statutory obligations and provide benefit to the UK; and
- To deliver a strategically significant supply of renewable electricity, which is affordable and represents value for money compared to other sources of supply in the context of the UK's commitments under the forthcoming EU Renewable Energy Directive and Climate Change Act and our goal to deliver a secure supply of low-carbon electricity.

1.1.3 The Feasibility Study has been split into two phases:

- Phase One: Examining the scope of work and analysis required to make an evidence-based decision on whether to support a tidal power project in the Severn and what potentially feasible schemes exist for converting this energy. Phase one ended with the publication of the consultation document in January 2009.
- Phase Two: Work on environmental, regional, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible. This is the current stage.

1.2 Purpose of the SEA

1.2.1 A Strategic Environmental Assessment (SEA) is being carried out in support of the Feasibility Study, in accordance with EU Directive 2001/42/EC (the SEA Directive), implemented in England and Wales through the Environmental Assessment of Plans and Programmes Regulations (SI 2004/1633 and Welsh SI 2004/1656), to predict and analyse the environmental effects of alternative short-listed Severn tidal power options over their entire lifetime, in order to inform decision making at the end of the Feasibility Study.

1.3 Purpose of the Theme Papers

1.3.1 The SEA Directive requires that 'the likely significant effects on the environment, including on issues such as biodiversity, population, human health, fauna, flora, soil, water, air, climatic factors, material assets, cultural heritage including architectural and archaeological heritage, landscape and the interrelationship between the above factors' are described (SEA Directive Annex 1 (f)).

1.3.2 The theme papers therefore summarise the interrelationships between related topics – see Table 1.1 below – and thereby ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. This approach emerged from the SEA scoping phase to allow related topics to interact and interface more effectively. Each theme paper also examines the interrelationships between this theme and other themes within the STP SEA.

Table 1.1 SEA themes and topics

SEA Theme	SEA Topics
Physicochemical	Hydraulics & Geomorphology Marine Water Quality Freshwater Environment & Associated Interfaces Flood Risk & Land Drainage
Biodiversity	Marine Ecology Waterbirds Migratory & Estuarine Fish Terrestrial & Freshwater Ecology
Landscape & Seascape and Historic Environment	Landscape & Seascape Historic Environment
Air & Climatic Factors and Resources & Waste	Air & Climatic Factors (including Carbon Footprint) Resources & Waste
Society & Economy	Communities Navigation Other Sea Uses Noise & Vibration

1.3.3 Furthermore, the theme papers will also assist the Environmental Report to meet the requirements of the SEA Directive by collating the difficulties (such as technical deficiencies or lack of know-how) encountered in compiling the required information (SEA Directive Annex 1 (h)).

1.3.4 Each theme paper therefore provides an integrated summary across the theme, drawing on information presented in its topic papers. Each theme paper presents a review of the environmental baseline and considers the environmental effects for the topics within this theme, taking into account the interrelationships between them and identifying difficulties in compiling the information and uncertainties in the assessment. However, no substantive analysis is provided within each theme paper, that is not already contained within its topics. This theme paper also addresses the interrelationships between this theme and the Habitats Regulations Assessment.

1.3.5 Each theme paper also considers the likely significant effects on the environment of the variations of alternative options referred to as combination and multiple basin options. These are however considered outside the main SEA assessment.

SECTION 2

APPROACH

2 APPROACH

2.1 Overall approach adopted in the SEA

2.1.1 The assessment process involved the collection of information and the development of SEA objectives, definition of alternatives and identification of significant environmental effects. Measures to prevent, reduce and as fully as possible offset significant adverse effects on the environment were developed, and proposals reviewed in the light of identified significant environmental effects. A more detailed description of the purpose of each SEA task and the STP SEA approach is given in the Environmental Report (Severn Tidal Power 2010a).

2.2 SEA Objectives

2.2.1 SEA Objectives are a recognised tool for comparing alternative options. SEA Objectives, and associated assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage. The Government response to the consultation for the most part confirmed the SEA Objectives and in some cases made some minor modifications (DECC, 2009b).

2.2.2 The SEA Objectives for this theme, as amended in response to the Scoping consultation, are set out in Table 2.1.

Table 2.1 SEA Objectives for Biodiversity

SEA Topic	SEA Objective
Marine Ecology	To avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance.
	To avoid adverse effects on valuable marine ecosystems.
	To avoid adverse effects on other protected marine species and their habitats.
	To avoid adverse effects on national and local biodiversity target features that include marine habitats and species.
	To avoid deterioration in status class of WFD water bodies.
	To minimise the risk of introduction of non-native invasive marine species.
	To conserve and enhance designated marine site features.
	To restore and enhance marine BAP species populations and/or BAP habitat.
Waterbirds	To avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance.
	To avoid adverse effects on other protected bird habitats and species.
	To avoid adverse effects on national and local biodiversity target features that include bird habitats and species.

SEA Topic	SEA Objective
Migratory and Estuarine Fish	To avoid adverse effects on designated wildlife sites for fish of international and national importance.
	To avoid adverse effects on the populations of other protected fish species and habitats.
	To avoid adverse effects on national and local biodiversity target features that include fish habitats and species.
	To avoid adverse effects on recreational and heritage fishing.
	To avoid adverse effects on commercial fish resources.
	To minimise the risk of introduction of non-native fish species.
Terrestrial and Freshwater Ecology	To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.
	To avoid adverse effects on valuable terrestrial and freshwater ecological networks.
	To avoid adverse effects on other protected terrestrial and freshwater habitats and species.
	To avoid adverse effects to national and local biodiversity target features including terrestrial and freshwater habitats and species.
	To minimise the risk of introduction of non-native invasive terrestrial and freshwater species.
	To conserve and enhance designated freshwater and terrestrial site features.
	To restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat.

2.3 Alternative Options for Tidal Power

2.3.1 At the beginning of Phase 2, five alternatives for the development of tidal power using the tidal range of the Severn Estuary were identified as the preferred candidates for more detailed study. The five options comprise three tidal barrages and two tidal lagoons (Severn Tidal Power 2010b). These alternative options and key parameters associated with alternative options are set out in Table 2.2.

Table 2.2 Alternative options

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B3: Brean Down to Lavernock Point Barrage (also known as Cardiff to Weston)	Lavernock Point to Brean Down	16km	Ebb only	Bulb-Kapeller	216 (40MW)	15.1 to 17.0 TWh/year	129	2
B4: Shoots Barrage	West Pill to Severn Beach	7km	Ebb only	Bulb-Kapeller	30 (35MW)	2.7 to 2.9 TWh/year	46	1

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B5: Beachley Barrage	Beachley to land directly to the east on the English side	2km	Ebb only	Straflo	50 (12.5MW)	1.4 to 1.6 TWh/year	31	1
L2: Welsh Grounds Lagoon	River Usk to Second Severn Crossing	28km	Ebb only	Bulb	40 (25MW)	2.6 to 2.8 TWh/year	32	1
L3d: Bridgwater Bay Lagoon	Brean Down to Hinckley Point	16km	Ebb & Flood	Bulb-Kaplan	144 (25MW)	5.6 to 6.6 TWh/year	42	1

2.3.2 Variations in the alternative options have also been considered. Whilst at this stage none of these constitute alternative options under the feasibility study, initial consideration has nonetheless been given to their potential effects. The variations considered included multiple basins and combinations of the five short-listed alternative options. Multiple basin variants are configured with the aim of providing continuous power to better align energy yield with peak demand.

2.3.3 The effects of the combinations and multiple basin options have not been considered in the topic papers, thus only a high level review of potential effects is included here. If one of the combinations or multiple basin options were taken forward it would be necessary to conduct the same detailed modelling that has already been done for the five main short-listed options.

2.3.4 Following an evaluation process (considering energy yield, costs, programme and opportunities for optimisation) one multiple basin and two combinations of options were identified for further high level review. This does not constitute the same level of detail as assessment of the short-listed alternatives, but if any of the variations are found to have advantages over the alternatives, then further work would be required.

2.3.5 The multiple basin option variant identified for high level consideration of environmental effects is a double basin version of the L3d Bridgwater Bay lagoon (with pumping). The double basin concept splits the L3d lagoon into a high basin and a low basin using a rockfill dividing wall with its landfall at Berrow. The variant is then configured to provide a continuous cycle of water from the sea to the high basin, from the high basin to the low basin and then from the low basin to the sea. This variant employs two powerhouses, one between the high and low basins and a second between the low basin and the sea. Each basin would experience a tidal range, but the high basin water levels would always be kept above the low basin. Pumping is used to raise water levels in the high basin and lower them in the low basin to increase power output. The option variant would utilise single direction turbines (in contrast to the ebb/flood generation of the standard L3d alternative option).

2.3.6 Both of the potential combinations of options include the standard single basin L3d option, with the assumption that it would generating with an ebb/flood configuration. A combination of L3d (ebb/flood) with B3 Brean Down to Lavernock Point barrage (ebb

only) has been shown to be worthy of further consideration; as has a combination of L3d (ebb/flood) with B4 Shoots barrage (ebb only).

2.3.7 L3d and B3 would be constructed sequentially due to the large amount of resources required to build either of these alternative options. Either option could be constructed first. L3d and B4 could be constructed either sequentially or concurrently. The operating rules and forms of construction for the combined options are assumed for the purpose of this high level review to be the same as those for the individual alternative option.

2.4 Technical studies within the theme

2.4.1 The SEA Directive specifies the criteria that should be taken into account when determining the likely significant effects of the plan and thus these criteria have been adopted throughout the assessment process of this SEA. Each topic paper therefore considers the characteristics of the effects and of the area likely to be affected.

2.4.2 Under the biodiversity theme, studies were carried out under four topics, marine ecology, waterbirds, migratory and estuarine fish and terrestrial and freshwater ecology. These assessments used a combination of quantitative modelling and qualitative assessments using information available in the literature and expert judgement.

2.4.3 For all topics within the biodiversity theme, general assumptions have been made regarding climate change (the UKCP09 central estimate projections for medium emissions scenario (UKCP09, 2009) are assumed to apply) and the application of Government policy (it has been assumed that existing policies, for example relating to climate change response and biodiversity, would continue to apply in the future).

2.4.4 At this strategic level of assessment, no new data have been collected, except for waterbirds, and the extent of existing available data is limited for many of the receptors. This lack of new data means that there are inevitably uncertainties in the results of the assessment, and more detailed work would be required to reduce these uncertainties were any of the tidal power options taken forward for further consideration.

2.4.5 The spatial extent of the study area has largely been determined by the maximum scale of the predicted effects to the physical environment following option implementation.

Receptors

2.4.6 Each topic paper considers the effects on a range of "receptors", which can be habitats, species or species guilds. These receptors were identified during the Phase 1 scoping stage and described in the SEA Scoping Report.

2.4.7 The marine ecology topic assessment considers effects on the following receptors:

- Plankton
- Macroalgae
- Benthic habitats and species
- Intertidal mudflats and species
- Saltmarshes
- Shingle and rocky shore
- Subtidal sandbanks
- *Sabellaria* reefs
- Eelgrass (*Zostera*)
- Other subtidal habitats
- Epibenthos
- Cephalopods
- Marine mammals and turtles

2.4.8 Receptors considered for the waterbirds topic assessment include 45 waterbird species or subspecies, as well as the waterbird assemblage on the Severn estuary, and four waterbird breeding assemblages associated with specific SSSI habitats outside the estuary but within the study area floodplain.

2.4.9 The migratory and estuarine fish topic assessment suggested that over 100 fish species had been recorded in the estuary. However for the purposes of the assessment only seven internationally or nationally designated fish species were considered in detail as individual receptors (Atlantic salmon, twaite shad, allis shad, sea lamprey, river lamprey, European eel, sea trout and sturgeon), while other species were grouped into ecological guilds (marine migrants, marine stragglers, estuarine species, freshwater species and freshwater stragglers), with each guild being considered as a receptor.

2.4.10 A large number of individual receptors were considered in the terrestrial and freshwater ecology assessment. In summary, these can be grouped into the following categories:

- SACs and Annex 1 habitats
- Ramsar Sites
- SSSIs and NNRs
- LNRs
- Habitats and landscape corridors
- Lichen and fungi
- Plants
- Crustaceans and molluscs
- Invertebrates
- Herpetiles
- Birds
- Mammals

Sources of Information

2.4.11 The technical studies within the biodiversity theme included collection and collation of the information available within each topic covered by the theme.

2.4.12 The marine ecology topic sourced information from Severn Tidal Power Group study reports from the 1980's, data and information collected as part of the recent Severn CHaMP, information on climate change from the MarClim project and Sir Alister Hardy Foundation for Ocean Science (SAHFOS), information on the distribution of habitats and species within the Severn Estuary and Bristol Channel from a wide range of sources and utilised wider scientific literature on the physical and chemical tolerances of marine ecological receptors. These are outlined in detail in the marine ecology topic paper (Severn Tidal Power 2010c).

2.4.13 The principal source of data used to inform the baseline and modelling for waterbirds is the Wetland Bird Survey (WeBS). WeBS "Core Counts" are undertaken at high tide on a monthly basis by volunteers on sites throughout the UK, including the Severn, and provide information on waterbird numbers and population trends. Low-tide counts record the feeding distributions of waterbirds. In 2008/09 a programme of waterbird surveys using professional fieldworkers was undertaken across the estuary to ensure the baseline was up-to-date and complete. This work included gap-filling of areas not surveyed by volunteers to ensure complete coverage during the WeBS Core (high tide) and Low-tide counts, as well as through-the-tide and nocturnal counts (see Annex 1 of the waterbirds topic paper). Data on the numbers of waterbird features of designated sites were received from the Countryside Council for Wales (CCW) and Natural England (NE). Additional information has been drawn from information submitted to the SEA during scoping, from local experts and a detailed review of the literature (Severn Tidal Power 2010d).

2.4.14 Data and information used within the migratory and estuarine fish topic assessment have been obtained from various sources including data and reports produced by the statutory bodies (EA, CCW and NE), local, national and international government bodies and consultancies. Input was sought from experts on several of the fish species and information gathered as part of this exercise was included and taken into consideration. Individual sources of data and information are detailed in the migratory and estuarine fish topic paper (Severn Tidal Power 2010e).

2.4.15 The terrestrial and freshwater ecology topic assessment (Severn Tidal Power 2010f) used data from the following sources:

- Multi-Agency Geographic Information for the Countryside (MAgiC)
- Data held by CCW, NE and JNCC, including; GIS data sets, published reports, data bases, designated sites information
- National Biodiversity Network (NBN)
- UK Biodiversity Action Plan (UKBAP)
- Local Biodiversity Action Plans (LBAP)
- Local Authority ecology and biodiversity information
- British Trust for Ornithology (BTO) terrestrial bird data
- UK Climate Projections 2009 (UKCP09)
- Various previously published reports on feasibility of energy generation from the Severn Estuary

Quantitative models used in the assessments

2.4.16 For some effects on some receptors it was possible to develop numerical models to determine baseline conditions and assess the effects of the alternative options.

Detailed information on the calibration and reliability of these models, and associated uncertainties, are given in the appropriate topic papers and annexes referred to below. The quantitative models used are as follows:

- A habitat model developed for the Severn Estuary CHaMP (ABPmer 2007) was used to model changes to distribution of habitats in response to the alternative options in the short-term (see Annex 3 of the marine ecology topic paper).
- A HabMAP model was used to predict changes to distribution of biotopes in response to the alternative options in the short-term (see Annex 4 of the marine ecology topic paper).
- Morphological modelling was used to model changes to the extent of habitats in the long-term. This was done using a combination of intertidal profile modelling (HR Wallingford 2009a) and ASMITA modelling (HR Wallingford 2009b). The implications of these predictions for the future evolution of intertidal areas is assessed in marine ecology Annex 3 .
- The morphological modelling methods described above were extended to include saltmarsh (HR Wallingford, 2009c). These predictions were used to evaluate the long-term sustainability of saltmarsh areas (see Annex 3 of the marine ecology topic paper).
- Changes to the numbers of waterbirds that might be expected to be supported on the Severn Estuary following option implementation were assessed using Habitat association models (HA models) and individual-based models (IBMs) (see waterbirds Technical Annexes 2 and 3).
- IBMs were also used to quantitatively evaluate the effects of further long-term changes predicted in the extent of intertidal habitats under each alternative option (see waterbirds Technical Annex 3).
- Stochastic numerical models were used to determine potential effects on fish arising from turbine passage inclusive of blade strike, pressure and shear stress injury rates (see Annexes 1 & 5 of the migratory and estuarine fish topic paper).
- Numerical modelling was used to determine potential compound mortality rates to fish resulting from turbine passage (see Annexes 1 & 5 of the migratory and estuarine fish topic paper).
- HR Wallingford fish movement model (salmon adults and smolts) (see Hydraulics and Geomorphology STP report EX 6148).
- Extrapolation and adjustment of HR Wallingford fish movement model to provide an indication of potential for multiple passes through turbine of all fish species or groupings (see Annexes 1 & 5 of the migratory and estuarine fish topic paper).

Qualitative assessments

2.4.17 All the results of the modelling described above were interpreted using expert judgement with reference to reviews of the available literature.

2.4.18 In the marine ecology assessment, quantitative modelling was not possible for all receptors, therefore qualitative assessments comprising conceptual reviews using the available literature were used for the following receptors:

- Plankton
- Marine macroalgae
- Epibenthos
- Cephalopods
- Marine mammals and turtles

2.4.19 Furthermore, for some marine ecology receptors, quantitative modelling was only possible for short-term effects following option implementation, therefore long-term

effects were assessed qualitatively for the following receptors (in addition to those listed above):

- Shingle and rocky shore
- Subtidal sandbanks
- Other subtidal habitats
- *Zostera*
- *Sabellaria*

2.4.20 The methods used to assess the potential significance of effects on waterbirds vary by effect (see Appendix E of the waterbirds topic paper (Severn Tidal Power 2010d) for details).

2.4.21 The principal effect for waterbird receptors (changes to or loss of intertidal habitat) has been modelled numerically using the two modelling approaches described above. However the purpose of using these two, complementary modelling approaches was to provide a better understanding of the range of uncertainty in model predictions. A conservative approach is used in determining which prediction should be followed in assessing the magnitude of effect, tempered by an assessment of model fit and further qualifications as outlined in Appendix E of the waterbirds topic paper (Severn Tidal Power 2010d).

2.4.22 A qualitative approach is generally used in the assessment of the potential significance of other effects on waterbirds (see Appendix E of the waterbirds topic paper (Severn Tidal Power 2010d) for details).

2.4.23 The migratory and estuarine fish topic assessment used desk-based research and literature review to assess possible effects resulting from alterations to migratory cues, anthropogenic noise disturbance and indirect effects to marine/estuarine and freshwater fish communities. A qualitative assessment of effects of changes to water quality and habitat on the fish receptors was carried out utilising the water quality and habitat change models produced by other STP SEA topic studies. Evaluation of potential effects to fisheries was informed by their valuation, and qualitative expert judgement was used to assess the remaining potential effects on migratory and estuarine fish.

2.4.24 Although the effects on fish of turbine passage were modelled quantitatively, qualitative expert judgement was then used to assess remaining potential effects from disruption to route of passage (e.g. indirect mortality through increased predation through disorientation and delay, and non-fatal effects such as decreasing spawning success) where possible, based on alternative option specific information provided by the STP SEA engineers.

2.4.25 The terrestrial and freshwater ecology topic assessment has been developed entirely through desk based study using a range of published sources including GIS mapping, databases and scientific reports. The assessment focussed on identifying effects at two key stages, construction and operation.

2.4.26 The construction phase is considered to be broadly comparable (for terrestrial and freshwater ecology receptors) to that of other types of large developments such as bridges and roads. Potential effects considered are; permanent and temporary habitat loss, habitat fragmentation, habitat degradation, species mortality, disturbance (including noise and vibration, visual) and pollution (air, ground and water).

2.4.27 The operation of an option in the Severn Estuary is expected to result in changes to the natural tidal cycle which in turn could result in changes to the wider hydrological

regime. A number of the terrestrial and freshwater ecology receptors have interest that is dependent on surface or groundwater. During operation of an option the issues considered are associated with; changes to the natural fluctuations of water levels, changes to water quality and changes to all habitats, flora and fauna associated with such habitats, including habitat degradation and/or habitat loss.

2.4.28 Both stages of the terrestrial and freshwater ecology assessment utilised GIS and the operational assessment also used outputs from the flood risk and land drainage topic which utilised hydrodynamic 1-D models.

Difficulties encountered - Marine Ecology

2.4.29 Limited baseline information was available on the distribution and abundance of some marine ecology receptors, particularly cephalopods, and some receptors such as *Sabellaria* have highly variable distributions making it difficult to predict future changes.

2.4.30 There is generally a poor understanding of some key ecological variables within the marine ecology topic, such as seasonal variation in the subtidal and pelagic environment. The sensitivity and vulnerability of many receptors is not well understood. There is a lack of knowledge and understanding about the functional requirements and linkages within marine ecosystems, and how human pressures, for example a tidal power option, might affect them.

2.4.31 Many of the data used to inform the study are old (derived from studies in the 1970s or 1980s) or limited to certain receptors. Furthermore, many studies used to define the baseline and predictions are site specific. Extrapolation to other locations is based on known gradients from the open sea to the freshwaters of the upper Severn. However, these generalisations introduce a degree of uncertainty, particularly since the species assemblages on the Severn are different from other estuaries in the area, so predictions may not be as accurate on the Severn as for other estuaries.

2.4.32 For the most part, it has not been possible to incorporate changes to sub-estuaries into the modelling of changes in habitat extent due to changes in water levels, so only the main estuary is modelled. It is therefore likely that the predicted changes in habitat extent are underestimates of the total losses of some habitat types under some options.

Difficulties encountered - Waterbirds

2.4.33 The WeBS Core Count data used to represent the baseline for the non-breeding numbers of the waterbirds using the Severn Estuary in this assessment incorporates counts from 2004/05-2008/09. As coverage in years prior to 2008/09 was less complete, the five-year mean peak values for some species may provide underestimates of the overall numbers using the estuary. Furthermore, some species are difficult to detect during surveys, e.g. bittern, water rail, snipe, and thus counts of these species are always likely to be underestimates of the actual population.

2.4.34 Waterbird modelling is based on the WeBS dataset, which has a relatively long time series (late 1960s - present). However, there will be a large level of uncertainty in predictions made for much greater periods into the future. It was therefore not appropriate to develop quantitative predictions of bird numbers to the end of the operation phase.

2.4.35 There is a degree of uncertainty in relation to the assessment of each of the potential significant effects on waterbirds. The assessment of the principal effect of changes to or loss of intertidal habitat is primarily limited by the accuracy of hydraulics and geomorphology and marine ecology predictions and secondarily by the limitations of the modelling approaches used. Nevertheless, subject to qualification, the predictions provided by the IBM default scenario and the HA models do indicate the most likely outcome and so together provide a reasonable basis for assessing the likely significance of effects.

Difficulties encountered - Migratory and Estuarine Fish

2.4.36 Limited baseline information was available on the distribution and abundance of many migratory and estuarine fish receptors.

2.4.37 There is little information available regarding the behaviour of fish within the estuary, the effect of turbine passage on fish populations, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species. There is also a paucity of data describing important life stages in many species' life-history, so that either species were excluded from models or parameters from non-UK rivers were used to predict population changes.

2.4.38 The modelling methods used to predict effects on migratory and estuarine fish are novel, and thus subject to a high level of uncertainty. Furthermore a wide range of assumptions had to be made in the assessment of effects due to the limited information available to inform the assessment. Some of these assumptions may be inaccurate and thus there is a high level of uncertainty surrounding predicted effects. Further research to develop and test the methods used to assess effects on fish would be useful to improve predictions if any option were taken forward.

2.4.39 The majority of the potential measures to prevent and reduce effects on fish are untested on the scale that would be required were a tidal power option implemented. There is therefore a very high level of uncertainty in terms of whether measures to prevent, reduce and offset effects on fish could be effective, and the scale of the compensation need.

2.4.40 This lack of information means that there is a very high level of uncertainty surrounding the baseline, future baseline, and predictions of the effects of the alternative options on migratory and estuarine fish.

Difficulties encountered - Terrestrial and Freshwater Ecology

2.4.41 Some of the terrestrial parts of option development (such as cable routes) are unknown, therefore it has been assumed that efforts would be made to avoid siting these in areas that would affect sensitive terrestrial and freshwater ecology receptors.

2.4.42 There are uncertainties surrounding the quantitative predictions of changes to water levels, and therefore the effect of these changes on terrestrial and freshwater ecology receptors.

2.4.43 The baseline for the terrestrial and freshwater ecology topic has been developed entirely through desk based study, in line with the strategic nature of the study. As such it is unrealistic to assume that all the individual habitats and species within the baseline study areas have been identified. Some precautionary assumptions regarding the presence of flora and fauna have been made. It is considered that the

information sourced provides a robust baseline scenario with an accurate representation of the receptors present in order for the assessment to be undertaken.

2.4.44 It was identified that local wildlife sites could not be incorporated consistently across the study areas as a result of inconsistencies in the availability of information about them. Therefore specific local sites have not been referenced in the terrestrial and freshwater ecology assessment, however the value of local sites and undesignated habitat features are acknowledged.

2.4.45 Although extensive information has been published in recent years regarding the impacts of climate change to biodiversity, no publications extend to the periods considered in this assessment. Therefore it is extremely difficult to predict the future baseline conditions, and a judgement has been made with the information available.

2.5 Consultation

2.5.1 Both the Feasibility Study and the SEA within it have included a programme of formal consultation and opportunities for informal input. These consultations have allowed technical specialists to input into the methods, information and conclusions presented in the SEA, but they have not considered the acceptability of the options. These include the public consultation exercise in early 2009, technical workshops during both Phase 1 and 2, and informal meetings and other communications. These are detailed in the topic papers and summarised in the Environmental Report (Severn Tidal Power 2010a).

SECTION 3

BIODIVERSITY BASELINE ENVIRONMENT AND SIGNIFICANT EFFECTS OF THE ALTERNATIVE TIDAL POWER OPTIONS

3 BIODIVERSITY BASELINE ENVIRONMENT AND SIGNIFICANT EFFECTS OF THE ALTERNATIVE TIDAL POWER OPTIONS

3.1 Introduction

3.1.1 This section summarises the current state, characteristics and evolution of the environment for the topics within this theme.

3.1.2 This section also considers, within this theme, the likely significant effects on the environment for each alternative option and the interrelationships between these effects (SEA Directive Annex 1 (f)). These effects may arise from direct, indirect, far-field, cumulative and consequential development effects during construction, operation and decommissioning phases and may include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects (SEA Directive Annex 1 (f)).

3.1.3 This section also considers the difficulties encountered in compiling the required information (SEA Directive Annex 1 (h)) and the level of certainty in the assessment of effects.

3.2 Current state, characteristics and evolution of environment

3.2.1 Baseline information provides the basis for predicting and monitoring environmental effects. Alternative options considered within this Feasibility Study would only be developed several years into the future and would have a long life. It is therefore necessary to project a 'future baseline' against which to compare effects, rather than using the present day baseline.

Baseline environment (up to 2009)

3.2.2 The Severn Estuary is a very large estuary with extensive intertidal mudflats and sandflats, as well as rocky platforms and islands. Saltmarsh fringes the coast, backed by grazing marsh with freshwater ditches and occasional brackish ditches. The seabed is rock and gravel with subtidal mud and sandbanks. The estuary's classic funnel shape, unique in the UK, is one of the factors causing the Severn to have the second-highest tidal range in the world (Stroud *et al*. 2001). As a result, the Severn Estuary and Bristol Channel are typified by extreme physical conditions such as high flow speeds causing high turbidity, and a very dynamic environment with high variability in salinity, seawater temperature and other physical characteristics. These features mean that the ecology of the area is unlike that of any other UK estuary with plant and animal communities typical of liquid mud and tide-swept sand and rock; the turbidity leads to a lack of light penetration into the water column, and hence low primary productivity and the benthic community has relatively low species diversity because of the dynamic nature of the environment. Although the invertebrate community is relatively species-poor it does include high densities of certain species which form an important food resource for predators, particularly waterbirds and fish. The large tidal range also leads to a large intertidal area. Characteristic habitats in this unique, physically stressful, environment include some of the largest areas of intertidal mudflats and sandflats in the UK, one of the largest aggregations of saltmarsh in the southern UK, as well as *Sabellaria* reefs, *Zostera* beds and *Corallina* run offs. There are only two other known sites with subtidal *Sabellaria alveolata* reefs in the entire north-east Atlantic and those in the Severn are the only designated

subtidal occurrence of this species in Europe, as it is usually restricted to intertidal habitats.

3.2.3 The habitats of the Severn Estuary support large numbers of waterbirds (for which the intertidal mudflats and sandflats are the most important habitat), fish and other organisms. As a result, the estuary and its tributaries are protected by international legislation. Under the EC Habitats Directive (92/43/EC), Special Areas of Conservation (SACs) are designated on the rivers Usk and Wye and the Severn Estuary / Môr Hafren, while the Severn Estuary Special Protection Area (SPA) is designated under the EC Birds Directive (79/409/EC). The estuary is also designated as a wetland of international importance under the Ramsar Convention 1971. At a national level, several sites in the study area are protected as SSSIs under the Wildlife and Countryside Act, and many habitats and species that are the subjects of the UK Biodiversity Action Plan (UKBAP) occur.

3.2.4 The Water Framework Directive (WFD) sets objectives for the achievement of 'good ecological status' in surface waters, including an assessment against a number of relevant biological quality elements for marine ecology receptors including plankton, macroalgae, benthic invertebrates and angiosperms. The areas likely to be affected by a tidal power development on the Severn are divided into 10 waterbodies under the WFD. Eight of the waterbodies are heavily modified waterbodies so their objective is 'good ecological potential". The Bristol Avon is classified as of good ecological potential. Only one of the 10 waterbodies in the study area (Bristol Channel Inner North) is assessed as being of good ecological status.

3.2.5 The Severn Estuary and its tributaries form an internationally important area for six diadromous fish species (Atlantic salmon, twaite shad, allis shad, sea lamprey, river lamprey and European eel) which are protected either by the SACs on the rivers Usk and Wye and the Severn Estuary / Môr Hafren, or the European eel management plan. The Severn Estuary and its tributaries, along with the nearby River Tywi in south Wales, are the only known spawning sites for twaite shad in the UK. The Rivers Wye and Usk are two of the most important sites in the southern UK for salmon. At least six waterbird species occur in internationally important numbers (ringed plover, curlew, dunlin, pintail, redshank and shelduck), and are protected under the SPA and Ramsar site. Sea trout, Atlantic salmon and European eel are also listed as features of the Ramsar site. A further 10 estuarine and migratory fish species (cod, herring, plaice, sole, whiting, blue whiting, hake, horse mackerel, ling and saithe) and 11 waterbird species (gadwall, Bewick's swan, wigeon, lapwing, teal, mallard, shoveler, pochard, tufted duck, grey plover and white-fronted goose) occur in nationally important numbers. The waterbird assemblage as a whole is protected under both the SPA and the Ramsar site, and comprises more than 70,000 individuals, which makes the Severn one of the top 20 sites in the UK in terms of the total numbers of waterbirds supported (Holt *et al*. 2009). Other internationally protected features include the intertidal mudflats and sandflats, saltmarshes, reefs, sandbanks and otters (as features of the SACs on the Severn Estuary / Môr Hafren and/or the Rivers Usk and Wye), and many other habitats and species also occur in the study area.

3.2.6 In addition to the biodiversity interests of the estuary itself, the floodplain of the Severn and its tributaries supports a broad mix of terrestrial and freshwater ecology conservation features. This includes SACs and Annex 1 habitats, Ramsar Sites, SSSIs & NNRs, LNRs, habitats & landscape corridors, lichens and fungi, plants, crustaceans and molluscs, invertebrates, herpetiles, birds and mammals. At the period up to 2009 it was identified that amongst these terrestrial and freshwater receptors there were many features subject to a range of pressures including climate change, development pressures and habitat management changes. Government and

Regional strategies and targets set out measures to ensure that a number of these receptors are enhanced and conserved.

3.2.7 Some of the protected species and habitats in the study area currently have unfavourable conservation status, or their populations have declined, as a result of existing man-made pressures on the environment. Shad and salmon are currently classified as having unfavourable conservation status in both the River Usk and River Wye SACs. River lamprey has unfavourable conservation status in all sites except the River Usk while all sites but the River Wye have unfavourable conservation status for sea lamprey. These two rivers support larger populations of the two lamprey species than any other British SACs. A number of issues have been identified as contributing towards the unfavourable conservation status of the Usk and Wye SACs and because of policy regarding SACs, it is assumed throughout this assessment that management actions will return these SACs to favourable conservation status in the future baseline. However there is a significant risk that this might not occur and hence the predicted effects of the tidal power options may have a greater impact. Eel recruitment has also declined since the 1970s, which could be due to habitat loss, oceanic influences, parasites, contaminants, predation, exploitation or a combination of these factors. Catches of sea trout have declined since 2000, although this species only occurs in small numbers.

3.2.8 Bird species whose populations have declined since the designation of the SPA and Ramsar site include European white-fronted goose, pochard, tufted duck, grey plover and dunlin. The decline in the dunlin population involves the largest number of birds as this is the most numerous waterbird species on the estuary. Some of these declines can be explained by birds “short-stopping” on their migration (they do not migrate as far as the UK because the winter temperatures at sites closer to their breeding grounds are warmer than in the past) or birds shifting from the west to the east because warmer winter temperatures mean that food-rich sites in the east are now more climatically suitable for winter species (Austin & Rehfisch 2005; Maclean *et al*. 2008).

3.2.9 Conversely, some species’ populations have increased in recent years. Water quality improvements have had beneficial effects on certain marine migrant fish species such as bass, sole, herring, sprat, grey mullet, whiting and cod. Sprat is the most abundant of these marine migrants. Bird species whose numbers have increased notably since designation include shelduck, wigeon, ringed plover and lapwing (Holt *et al*. 2009).

3.2.10 For some migratory and estuarine fish, and some marine ecology receptors, there is a paucity of data on baseline conditions or on key life-history parameters or functional requirements. This lack of data leads to large uncertainties in the baseline conditions, particularly for marine straggler fish (blue whiting, hake, horse mackerel, ling and saithe), estuarine fish (black goby and common goby) and freshwater straggler fish. There are some uncertainties regarding the baseline status of other fish species. In marine ecology, the current status of cephalopods is unknown, while the precise distribution of some receptors such as *Sabellaria* reefs varies over time. Not all parts of the estuary have been sampled for all receptors so predictions of the baseline and future environments are based on well-documented gradients from the upper estuary to the open sea, but these will not provide precise answers. Much of the existing data regarding these broad-scale patterns is from the 1970s/1980s so it is assumed that similar patterns still apply today. Furthermore, seasonal variations in the subtidal and pelagic parts of the study area are poorly understood, although there is a better understanding of these variations in the intertidal parts of the estuary.

3.2.11 For waterbirds, there is generally a better knowledge of baseline conditions than for other taxa, however there are still some uncertainties. One of the biggest uncertainties occurs because the baseline numbers are taken as the mean of peak counts over the latest five years, but there was incomplete coverage of the estuary by Wetland Bird Surveys (WeBS) in four of these years, with almost complete coverage achieved in the latest year. As a result, the highest numbers were recorded in 2008/09, and the five-year mean peak values for some species may provide underestimates of the overall numbers using the estuary. Furthermore, some species are difficult to detect during surveys and thus their numbers are likely to be under-estimated.

3.2.12 For all studies, when predicting the future baseline it is assumed that climate change will occur in line with the UK Climate Projections (UKCP09) central estimate projections for the medium emissions scenario and that existing Government policies relating, for example, to climate change response and biodiversity, will continue to apply into the future. This means that average temperatures and other environmental variables are assumed to change due to climate change. It is assumed that government policies to compensate for any effects of climate change on biodiversity, such as using managed realignment to compensate for the effect of sea level rise on intertidal habitats, will occur. If some of these assumptions were not met then the predictions of the future baseline could alter, although this is considered unlikely. It is important to note that although the future baseline may predict declines (relative to the present baseline) of some species as a result of climate change, current legislation requires that conservation action is undertaken to ensure that the population levels of protected species are maintained.

Baseline during construction (2014 – 2020)

3.2.13 Climate change represents a significant pressure on marine ecology receptors both in the short and long-term. Key relevant changes associated with climate change include sea level rise (causing coastal squeeze of intertidal habitats), increased average and maximum water temperatures and ocean acidification. Such changes, for example, are predicted to alter the geographical distribution of primary and secondary plankton production. Macroalgal species could also show changes in both range and distribution in the UK in response to changing sea temperatures. Projected changes in sea level and storms may also have important indirect effects on macroalgae, as more sea defences are required. Changes in *Sabellaria* could result from changes in temperature. The physiological response of eelgrass to changing climatic and hydrodynamic conditions is predicted to result in the redistribution of existing habitats. Because much of the Severn Estuary / Môr Hafren is protected under nature conservation legislation, losses of intertidal mudflat, sandflat and saltmarsh that are predicted to occur in the future due to sea level rise should be compensated for through management action, for example intertidal habitat creation. However losses to these habitats as a result of natural processes would not need to be compensated. It is important to note that although the species composition of the Severn may alter due to climate change, the estuary will still fulfil the role of providing a link between marine and freshwater habitats, and provide an important food source of fish and birds.

3.2.14 There are clearly uncertainties associated with predicting the numbers of birds that might occur on the Severn Estuary (or on other sites) during the construction and operation phases. Existing research indicates that the distributions of some waders have shifted in response to climate change and this can be used to broadly predict future trends. The Habitat Association (HA) models, described in Waterbirds Technical Annex 2, that have been developed to predict numbers of birds on the

Severn Estuary following the development of each of the alternative options also incorporate temperature. They have thus also been used in this assessment to predict "baseline" numbers of birds in the absence of the options during the construction and operation phases. Likely trends in numbers can also be inferred by recent trends from WeBS. Species that use intertidal habitat would also be expected to be negatively affected by predicted rises in sea level (UKCP09, 2009).

3.2.15 Due to lack of data on key life-cycle parameters, it was not possible to predict changes to the most fish receptors during the construction phase, and there are uncertainties in those predictions that can be made. Outputs from life-cycle modelling suggest only minor changes from current baseline would occur during the construction phase, with minor reductions for most salmon stocks, and little change to shad and lamprey populations. Some fish species, including shads and lampreys, that are adapted to warmer water may increase in abundance if climate change predictions are fulfilled. It is uncertain whether this would cause any significant change from the baseline during the short timescale of the construction period.

3.2.16 Planned conservation action is thought likely to result in improvements to Natura 2000 features, SSSIs and WFD waterbodies by 2014-2020, leading to improvement in the baseline status of some terrestrial and freshwater ecology receptors. These actions are international or national obligations for UK government. It is not thought likely that climate change would have a significant effect on terrestrial and freshwater ecology over this timescale.

Baseline during operation (2020 – 2140), Decommissioning and Longer Term Trends

3.2.17 There is a high degree of uncertainty associated with climate change predictions both in terms of the magnitude and the timescales over which they might occur. The projected realisation and consequences of such changes to marine ecology receptors is therefore difficult to quantify. The trends identified above are therefore predicted to continue into the future with the timescales attached to these changes and the ability of habitat and species to adapt to a changing environment subject to a high degree of uncertainty.

3.2.18 For waterbirds, the HA models and previous research are based on the national WeBS Core Count dataset. While this scheme has been running for a long time (with data available back to the late 1960s), there is clearly likely to be uncertainty in any predictions made for much greater periods into the future. Thus it is not appropriate in this assessment to give quantitative predictions of the numbers of birds likely to be occurring on the Severn Estuary through to the predicted end of the operation phase.

3.2.19 Overall the main drivers of future baseline numbers for migratory and estuarine fish are stock management issues (such as restoring access to upstream reaches and improving water quality to aid egg and fry survival) and the potential impact of climate change. These parameters have been implemented where possible into the life-cycle models for this study, although there is considerable uncertainty surrounding predictions over such a long time-period. Temperature increases are generally predicted to have positive effects on species currently at the northern limit of their range, and negative effects on species at the southern limit of their range in the Severn.

3.2.20 Over the operational period climate change was identified as a relevant issue for a large number of the terrestrial and freshwater ecology receptors. It was assumed that continued maintenance and enhancement of the designated site network, including those sites within the study areas, will continue to be of high priority for the

Government and statutory agencies. However despite conservation actions it is thought that maintenance of existing terrestrial and freshwater ecosystems is likely to present considerable challenges and increased pressures would be likely to result in a reduction of the overall biodiversity that these sites support. It is possible that the reverse could occur (i.e. there would be an increase in biodiversity), in which case the impacts of a tidal power option could be greater. An assessment over such a long timescale is subject to considerable uncertainty.

3.3 Significant environmental effects

3.3.1 This section considers, within this theme, the likely significant effects on the environment and the certainty of this assessment for each alternative option and the interactions between these effects. The full methodology for identifying these significant environmental effects is set out in the Environmental Report.

3.3.2 Consideration has also been given to the potential effects of combination options and multiple basin options although this has not been subject to the same level of detailed assessment as the individual shortlisted options and does not form part of the SEA assessment.

Alternative Option B3: Brean Down to Lavernock Point Barrage

Construction Phase

3.3.3 The only significant effect predicted for marine ecology receptors during the construction phase is a potential negative effect on *Sabellaria* reefs during the dredge of the barrage line. However, depending on how construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime, but it has been assumed that such effects would be minimal during construction and would only have a significant effect once the barrage becomes operational.

3.3.4 For waterbirds, the only significant effect predicted during the construction phase is disturbance (for example from noise, vibration or the physical presence of construction works). This could have two main effects - changes to behaviour and displacement of birds, and it is assumed that only those birds that are in the area close to the construction site would be disturbed. This effect is therefore considered significant for two of the waterbird receptors within the Severn Estuary whose distributions are concentrated around the footprint of this option (lesser black-backed gull and herring gull), as this option may affect a significant proportion of the populations of these receptors on the estuary.

3.3.5 There is considerable uncertainty surrounding predicted effects to migratory and estuarine fish. Bearing in mind these uncertainties, it is thought likely that significant effects on migratory and estuarine fish receptors predicted during the construction phase could include short to medium term significant alterations to migratory cues for salmon, sea trout, shad, sea lamprey, river lamprey and eel caused by changes in water exchange. There are also likely to be significant disruptions to route of passage of these species, as well as marine migrants, marine stragglers, estuarine residents and freshwater stragglers. This effect depends to some extent on how construction is carried out, although it is likely to be more pronounced towards the end of the construction period. Habitat change or loss caused by changes in water exchange and by the direct loss in the footprint of the option has been assessed has having a significant negative effect on salmon, sea trout, shad, sea lamprey, river lamprey, eel,

marine migrants and estuarine residents. Changes in water exchange could also cause changes to water quality which could have a significant negative effect on all fish species, as could anthropogenic noise disturbance during construction.

3.3.6 The primary construction effects on terrestrial and freshwater ecology receptors would occur around the landfalls at Brean Down and Lavernock Point. At both sites a temporary land take of 10 ha during construction, and a permanent land take of 2.5 ha is predicted (i.e. 20 ha and 5 ha in total at the two sites combined). This effect would result in temporary and permanent habitat loss of some areas of the Mendip Limestone Grasslands SAC, Brean Down SSSI and the Penarth Coast SSSI. There would also be habitat fragmentation, mortality of species associated with the SAC and SSSIs as well as of other species of flora and fauna. Temporary effects associated with the construction works include the effects of disturbance including noise and vibration, visual disturbance and lighting. There are smaller and temporary effects associated with the use of construction materials and chemicals, which could cause habitat degradation due to pollution. There is the possibility of far-field effects to terrestrial and freshwater ecology receptors during the construction phase, depending on where materials are sourced from and whether this affects and terrestrial and freshwater ecology receptors. This would require further investigation if this option were taken forward.

3.3.7 Other effects on marine ecology receptors that would occur, but are not expected to be significant, include loss of habitat within the option footprint, introduction of a new colonising surface, increases in local suspended sediment (potentially causing local smothering of habitats), discharges and accidental spillages that are toxic to receptors, and underwater noise resulting in disturbance to hearing-sensitive receptors. Non-significant effects to waterbirds during construction include the effect of direct habitat loss to the option footprint and the effects of disturbance on species other than the four for which disturbance is considered significant.

Operational Phase

3.3.8 The largest predicted effects of this option on marine ecology receptors are associated with the changes in water levels that would occur once the barrage becomes operational (see the Physicochemical theme paper for details, STP, 2010i). These changes in water levels modify the extent of habitats, most notably reducing the extent of intertidal habitats, which leads to significant negative effects on all intertidal receptors within the marine ecology topic (intertidal mudflat and sandflat, saltmarsh, intertidal shingle and rock, macroalgae *Sabellaria* and *Zostera*) and on the epibenthos.

3.3.9 Because of these changes, there is a predicted loss of 4160 ha (33 %) of the area of intertidal mudflat, 10010 ha (72 %) of intertidal sandflat, and 210 ha (22 %) of saltmarsh. There are also predicted losses of around 1110 ha (49 %) of the intertidal rock and 950 ha (72 %) of intertidal shingle habitats.

3.3.10 Further losses of around 7 % of the total intertidal area (including significant losses of intertidal mudflats and sandflats and saltmarsh) are predicted as a result of long-term morphological changes that are expected to occur, although there is some uncertainty about the extent of this due to uncertainties in the long-term predictions from the hydraulics and geomorphology assessment.

3.3.11 There would be significant losses of intertidal habitats, although it is possible that there may be an increase in the productivity of the remaining habitat. Improvements in the light climate (due to reduced flow and therefore lower levels of suspended

sediment allowing light to penetrate further) are predicted to have significant positive effects for phytoplankton and macroalgae. This increased primary productivity is likely to lead to increased diversity and abundance of zooplankton, and a greater diversity of suspension feeding organisms within benthic invertebrate assemblages. These changes are assessed as significant positive effects for intertidal mud and sandflats and shingle and rocky shores but there is still considered to be an overall negative effect on these receptors as a result of the large extent of habitat loss.

3.3.12 The B3 barrage may reduce nutrient concentrations within the impounded area as a result of changes in salinity and improved peak dilution, although the influence of changes in physical processes in influencing biological transformation and exchanges with the sea-bed remains unclear. Increased light penetration as a function of reduced suspended sediment concentrations could result in algal bloom formation during neap tides. Hence, whilst the predicted increases in primary productivity are assessed as positive effects for some receptors, such changes would alter the unique stressed nature of the environment, which is one of the reasons that the Severn is valued, and thus some of the conservation objectives of the SAC would not be met.

3.3.13 Reductions in the short-term erosion and deposition of mud are also predicted to have significant positive effects on intertidal mud and sandflats and shingle and rocky shores, while reductions in scour are predicted to have significant positive effects for macroalgae and for shingle and rocky shores. These positive effects would not outweigh the significant negative effects to these receptors as a result of the large extent of intertidal habitat loss.

3.3.14 Other significant effects predicted include a significant negative effect on subtidal sandbanks due to changes in sand transport and mud deposition, and a significant negative effect on subtidal *Sabellaria alveolata* reefs due to reductions in flow speed and deposition of fine sediment.

3.3.15 Far-field changes to water levels are predicted as a result of this option, which are considered likely to have a significant negative effect on some marine ecology receptors. Saltmarsh in particular may be affected as a result of increases in the level of high water along much of the south west and west Wales coast and the north Devon and north Cornwall coast. However the extent and magnitude of these changes is considerably less certain than that of changes within the estuary.

3.3.16 There is uncertainty surrounding the predicted changes to marine ecology receptors because the assessment has made a number of simplifying assumptions, and the assessment relies on predicted changes to water levels and water quality from the Physicochemical theme, which have a degree of uncertainty. There is also a lack of knowledge of the present distribution of some receptors in the estuary and limited understanding of the functioning of marine ecosystems so that there is uncertainty regarding the implications of some predicted changes.

3.3.17 These losses of, and changes to, intertidal habitat represent the principal effect of the B3 option for waterbird receptors. While it is predicted that densities of some waterbird species may increase within the option area (because the productivity of the intertidal habitat, and therefore the abundance of the invertebrate that birds feed on, may increase), the scale of habitat loss and the changes to the intertidal exposure period are assessed to have much greater effects than any positive changes in the productivity of intertidal habitat for most waterbird receptors. Thus the numbers of most species are predicted to decline and this is assessed as a significant negative effect for 30 of the 50 waterbird receptors, including the waterbird assemblage, with

the majority of these predicted to show medium magnitude negative effects (declines of 25-49%).

3.3.18 Other significant negative effects predicted for waterbirds under the B3 option include effects of changes to saltmarsh for four receptors (Bewick's swan, European white-fronted goose, shelduck and redshank), due to the short-term loss of saltmarsh and potential for further long-term losses, and significant negative effects on breeding seabirds for three receptors (cormorant, lesser black-backed gull and herring gull).

3.3.19 The effect of displacement to far-field sites was identified as a likely significant negative effect under the B3 option for 15 waterbird receptors on a minimum of three adjacent sites (the Somerset Levels & Moors, Chew Valley Lake and Burry Inlet).

3.3.20 The effect of changes to water levels at far-field sites is also identified as a likely significant effect under the B3 option for two waterbird receptors (Greenland white-fronted goose and greenshank), which are features of the Dyfi Estuary SPA / Cors Fochno & Dyfi Ramsar Site where (far-field) water level changes are predicted to be greatest.

3.3.21 The effect of changes to freshwater wetlands was not identified as a likely significant effect under the B3 option for any waterbird receptor, as the probability and magnitude of effect are both considered low because it is assumed that water levels would be in practice need to be managed to avoid increase in flood risk. Changes to fish populations were not thought likely to have significant negative effects on waterbirds.

3.3.22 There is uncertainty surrounding the predicted changes to waterbird receptors. The relationships between bird numbers and habitat are well understood, but there are uncertainties surrounding predicted changes in the characteristics of the remaining intertidal habitat, on which the waterbird modelling is based. The main uncertainties are the extent to which the remaining intertidal habitat would become mud (rather than sand), and thus support increased densities of invertebrates and birds, and the extent to which productivity would increase. Because of these uncertainties the different modelling approaches give quite different predictions for some waterbird receptors.

3.3.23 There is uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because the magnitude of effects of turbine passage on fish populations is uncertain (due to small number of previous studies) and there is little information available regarding the behaviour of fish within the estuary, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, or the hearing frequencies and range of many species.

3.3.24 Bearing in mind these uncertainties, significant negative effects are predicted for all migratory and estuarine fish receptors as a result of disruptions to routes of passage, altered migratory cues, habitat change or loss, changes to water quality and anthropogenic noise disturbance. Despite these uncertainties it is clear that there would be reductions in the populations of fish species as a result of this option, but the scale of the effects is less certain.

3.3.25 The only effect on migratory and estuarine fish that could be quantified (although with considerable uncertainty) was the disruption to route of passage as a result of turbine passage, and this could only be done for some fish species. Taking into account these predictions and qualitative assessments of other effects on fish (alterations to migratory cues, habitat change and/or loss, changes to water quality and

anthropogenic noise disturbance) it is thought likely that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.

3.3.26 There is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify far-field effects there is potential for effects to be seen within the remaining UK population within the River Tywi. If the implementation of this option resulted in significant population reductions within this river as well then there would be potential for whole UK stock extinction.

3.3.27 There may be reductions in the population size of sea and river lamprey within the Rivers Usk and Wye which may cause reductions in the UK stock of river lamprey and the European stock of sea lamprey.

3.3.28 There is potential for reductions in the outputs of silver eel from these rivers which could make compliance with the EU Eel Regulations and associated escapement targets a significant challenge.

3.3.29 There is a potential risk of reductions in population size or river-specific stock collapse for sea trout and possibly allis shad. Although allis shad were formerly known to spawn in the rivers in the Severn catchment, it is thought that this area no longer supports a viable breeding population as there are no recent records of spawning. There is also a risk of reductions in population size for marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

3.3.30 All operational effects to terrestrial and freshwater ecology receptors are likely to occur rapidly after the start of operation. Land would be taken by the option footprint, and water levels are predicted to increase. This is predicted to lead to permanent habitat loss, fragmentation and degradation that would have significant negative effects on a range of SACs, Annex 1 habitats, SSSIs, NNRs and LNRs. Some of the most important sites affected include the Mendip and Limestone Grasslands and the Rivers Wye and Usk. Otter populations on the Rivers Wye and Usk are predicted to decline as a result of the predicted reductions in migratory and estuarine fish populations.

3.3.31 Conversely some significant positive effects are predicted to terrestrial and freshwater ecology receptors as a result of increased water levels. The increased height of the water table and increased soil wetness is likely to enhance habitats in some areas including the Somerset Levels.

Decommissioning Phase

3.3.32 For all biodiversity receptors, the effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects, except for migratory and estuarine fish where the significant effects that occur during operation are likely to continue through the decommissioning phase. It is, however, unlikely that the study area would return to its original state following decommissioning.

Alternative Option B4: Shoots Barrage

Construction Phase

3.3.33 There are no significant effects predicted for marine ecology and waterbird receptors during the construction phase for this option. However, depending on how construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime.

3.3.34 Significant negative effects are predicted for all migratory and estuarine fish receptors during the construction phase. These effects are likely to be similar to those described during the operation phase (see below) although most likely of a lower magnitude. There is some uncertainty surrounding the predicted effects during the construction phase as they are largely dependent on how construction is progressed. However it is likely that effects would be heightened during the latter part of the phase.

3.3.35 Construction of the B4 option would result in a temporary land take of 7.5 ha and a permanent land take of 2.5 ha at each of the landfalls at Caldicott and Severn Beach. This temporary and permanent habitat loss represents the primary construction phase effect for terrestrial and freshwater ecology receptors. Notably, the Caldicott landfall would cause habitat loss and fragmentation to parts of the Gwent Levels SSSI.

3.3.36 Other significant construction phase effects on terrestrial and freshwater ecology receptors include disturbance to species using the SSSI and other areas from noise, vibration, visual disturbance and lighting. Some mortality of flora and fauna would be predicted and there is the potential for pollution of terrestrial or freshwater habitats through the use of construction materials and chemicals. There is the possibility of far-field effects to terrestrial and freshwater ecology receptors during the construction phase, depending on where materials are sourced from and whether this affects and terrestrial and freshwater ecology receptors. This would require further investigation if this option were taken forward.

Operational Phase

3.3.37 The largest predicted effects of this option on marine ecology receptors are associated with the changes in water levels that would occur once the barrage becomes operational (see the Physicochemical theme paper for details, STP, 2010i). These changes in water levels modify the extent of habitats, most notably reducing the extent of intertidal habitats, which leads to significant negative effects on most intertidal receptors within the marine ecology topic (intertidal mudflat and sandflat, intertidal shingle and rock, macroalgae and *Zostera*).

3.3.38 Because of these changes, there is a predicted loss of 370 ha (3 %) of the area of intertidal mudflat and 1970 ha (14 %) of intertidal sandflat. There are also predicted losses of around 810 ha (36 %) of the intertidal rock and 300 ha (23 %) of intertidal shingle habitats.

3.3.39 Further losses of around 2 % of the total intertidal area (including significant losses of intertidal mudflats and sandflats) are predicted as a result of long-term morphological changes that are expected to occur, although there is some uncertainty about the extent of this due to uncertainties in the long-term predictions from the hydraulics and geomorphology paper.

3.3.40 In contrast to the B3 option described above, the B4 option is not considered likely to have a significant effect on saltmarsh.

3.3.41 Reductions in short-term erosion and mud deposition are predicted to have a significant positive effect on the remaining intertidal mudflats and sandflats, and on *Zostera*. These positive effects would not negate the significant negative effects to these receptors as a result of the large extent of intertidal habitat loss.

3.3.42 Adult mobile epibenthos are predicted to pass through the option structures, but there is a risk that ovigerous females could be stripped of eggs. This effect is considered significant for species whose distribution is concentrated in the upper estuary (e.g. *Neomysis integer*) but not for species whose distribution is concentrated in the outer parts of the estuary away from the B4 option (e.g. *Crangon*).

3.3.43 In common with the B3 option, the other significant effects predicted for marine ecology receptors include a negative effect on subtidal sandbanks due to changes in sand transport and mud deposition, and a negative effect on subtidal *Sabellaria alveolata* reefs due to reductions in flow speed.

3.3.44 The B4 barrage could potentially result in localised reductions in nutrient concentrations in response to changes in the salinity regime through The Shoots but the dilution characteristics would not change compared to baseline. The dispersion of effluent plumes would be slightly reduced but no significant effects on nutrient concentrations as a result of this are expected. The suspended sediment concentrations are considered likely to remain sufficiently high to prevent algal bloom formation. The influence of changes in physical processes in influencing biological transformation and exchanges with the sea-bed remains unclear. Hence, although phytoplankton productivity in the water column is expected to increase upstream of the barrage this effect is not considered significant for this option.

3.3.45 There is uncertainty surrounding the predicted changes to marine ecology receptors because the assessment has made a number of simplifying assumptions, and the assessment relies on predicted changes to water levels and water quality from the Physicochemical theme, which have a degree of uncertainty. There is also a lack of knowledge of the present distribution of some receptors in the estuary and limited understanding of the functioning of marine ecosystems so that there is uncertainty regarding the implications of some predicted changes.

3.3.46 These changes to or loss of intertidal habitat again represent the principal effect on waterbird receptors for the B4 option. Significant negative effect are likely for 17 of the 50 waterbird receptors as the scale of (immediate) habitat loss and the changes to the intertidal exposure period outweigh any positive changes to the suitability of the remaining intertidal habitat for these bird species. Positive effects were predicted for two waterbird receptors (shoveler and little egret).

3.3.47 Although there are some predicted changes to saltmarsh and freshwater wetlands under the B4 option, these were not identified as likely significant effects for waterbird receptors as there is uncertainty as to whether short-term saltmarsh gain might be outweighed by long-term erosion, and it is assumed that water levels on freshwater wetlands would be managed to control flood risk. Changes to fish populations were not thought likely to have significant negative effects on waterbirds.

3.3.48 The effect of displacement to far-field sites was identified as a likely significant negative effect under the B4 option for one waterbird receptor (pintail) on two adjacent sites (the Burry Inlet and the Somerset Levels and Moors SPA / Ramsar Sites).

3.3.49 There is substantial uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because there is little information available regarding the behaviour of fish within the estuary, the effect of turbine passage on fish populations, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species.

3.3.50 The only effect on migratory and estuarine fish that could be quantified (although with considerable uncertainty) was the disruption to route of passage as a result of turbine passage, and this could only be done for some fish species. Taking into account these predictions and qualitative assessments of other effects on fish (alterations to migratory cues, habitat change and/or loss, changes to water quality and anthropogenic noise disturbance) it is thought likely that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.

3.3.51 There is potential for the extinction of the twaite shad populations within the Rivers, Wye and Severn and possible population size reductions due to far-field effects on the Rivers Usk and Tywi (but these populations are considered likely to be retained).

3.3.52 Predicted losses of sea and river lamprey could potentially put their populations at risk of collapse, in particular on the River Wye and cause reductions in the UK stock of river lamprey and the European stock of sea lamprey.

3.3.53 Population reductions of eel on the Rivers Severn and Wye could place compliance with the EU Eel Regulations at significant risk. However it is considered unlikely that there would be significant reductions in population size on the River Usk.

3.3.54 There is a potential risk of reductions in population size or river-specific stock collapse for sea trout and possibly allis shad. Although allis shad were formerly known to spawn in the rivers in the Severn catchment, it is thought that this area no longer supports a viable breeding population as there are no recent records of spawning. There is also a risk of reductions in population size for marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

3.3.55 All operational effects to terrestrial and freshwater ecology receptors are likely to occur rapidly after the start of operation. Land would be taken by the option footprint, and water levels are predicted to increase, with increased water levels in rivers, reens and ditches. This option is predicted to lead to permanent habitat loss and fragmentation affecting the River Wye SAC and two SSSIs (River Wye and Upper Severn Estuary). These are considered to be significant negative effects.

3.3.56 The B4 option is predicted to have a significant negative effect on species mortality for a wide range of terrestrial and freshwater ecology receptors. The extent to which this would affect the local population trends is uncertain.

3.3.57 No significant effects on terrestrial and freshwater ecology receptors are predicted as a result of changes to water quality or water chemistry.

Decommissioning Phase

3.3.58 For all biodiversity receptors, the effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects, except for migratory and estuarine fish where the significant effects that occur during operation

are likely to continue through the decommissioning phase. There is the potential that some habitat such as grazing marsh would be recreated at this stage and this is considered to be a likely positive effect for terrestrial and freshwater ecology receptors. It is, however, unlikely that the study area would return to its original state following decommissioning.

Alternative Option B5: Beachley Barrage

Construction Phase

3.3.59 There are no significant effects predicted for marine ecology receptors during the construction phase for this option. However, depending on how construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime.

3.3.60 Disturbance during the construction phase was identified as likely to have a significant negative effect on one waterbird receptor within the Severn Estuary, wigeon.

3.3.61 Significant negative effects are predicted for all migratory and estuarine fish receptors during the construction phase. These effects are likely to be similar to those described during the operation phase (see below) although most likely of a lower magnitude. There is some uncertainty surrounding the predicted effects during the construction phase as they are largely dependent on how construction is progressed. However it is likely that effects would be heightened during the latter part of the phase.

3.3.62 Significant construction phase effects on terrestrial and freshwater ecology receptors include a significant negative effects of disturbance to species using the River Wye SAC and SSSI and other receptors using the surrounding areas from noise, vibration, visual disturbance and lighting. Habitat degradation is a likely significant negative effect due to the use of construction materials and chemicals which have the potential for pollution of terrestrial or freshwater habitats.

3.3.63 Construction of the B5 option would result in a permanent land take of 2.5 ha at the Aust landfall. The Beachley landfall is expected to be used for emergency access only. This permanent habitat loss is not considered significant as the land taken is non-designated agricultural habitat. The area is not considered large enough to cause significant habitat fragmentation. There is the possibility of far-field effects to terrestrial and freshwater ecology receptors during the construction phase, depending on where materials are sourced from and whether this affects and terrestrial and freshwater ecology receptors. This would require further investigation if this option were taken forward.

Operational Phase

3.3.64 As with all the options, the largest predicted effects of this option on marine ecology receptors are associated with the changes in water levels that would occur once the barrage becomes operational (see the Physicochemical theme paper for details STP, 2010i). These changes in water levels modify the extent of habitats, most notably reducing the extent of intertidal habitats, which leads to significant negative effects on intertidal mudflats, sandflats, shingle and rock.

3.3.65 Because of these changes, there is a predicted loss of 350 ha (3 %) of the area of intertidal mudflat and 2240 ha (16 %) of intertidal sandflat. There are also predicted losses of around 290 ha (13 %) of the intertidal rock and 20 ha (2 %) of intertidal shingle habitats.

3.3.66 Changes to the short-term erosion and deposition of mud are predicted to have a positive effect on intertidal mudflat and sandflat. These positive effects would not negate the significant negative effects to these receptors as a result of the large extent of intertidal habitat loss.

3.3.67 Long-term morphological changes under this option are predicted to be small (an overall increase in intertidal area of 0.1 %) and not significant. In contrast to some of the larger options, B5 is not predicted to have significant effects on saltmarsh, macroalgae and *Zostera*.

3.3.68 The B5 barrage could potentially result in localised reductions in nutrient concentrations in response to changes in the salinity regime through The Shoots but the dilution characteristics would not change compared to baseline. The dispersion of effluent plumes would be slightly reduced but no significant effects on nutrient concentrations as a result of this are expected. The suspended sediment concentrations are considered likely to remain sufficiently high to prevent algal bloom formation. The influence of changes in physical processes in influencing biological transformation and exchanges with the sea-bed remains unclear. Hence, although phytoplankton productivity in the water column is expected to increase upstream of the barrage, this effect is not considered significant for this option.

3.3.69 The other significant effects predicted for marine ecology receptors include a negative effect on subtidal sandbanks in the Welsh and English Grounds due to changes in sand transport and mud deposition, and a negative effect on subtidal *Sabellaria alveolata* reefs due to reductions in flow speed.

3.3.70 Adult mobile epibenthos are predicted to pass through the option structures, but there is a risk that ovigerous females could be stripped of eggs. This effect is considered significant for species whose distribution is concentrated in the upper estuary (e.g. *Neomysis integer*) but not for species whose distribution is concentrated in the outer parts of the estuary away from the B5 option (e.g. *Crangon*).

3.3.71 There is uncertainty surrounding the predicted changes to marine ecology receptors because the assessment has made a number of simplifying assumptions, and the assessment relies on predicted changes to water levels and water quality from the Physicochemical theme, which have a degree of uncertainty. There is also a lack of knowledge of the present distribution of some receptors in the estuary and limited understanding of the functioning of marine ecosystems so that there is uncertainty regarding the implications of some predicted changes.

3.3.72 The effect of changes to or loss of intertidal habitat was identified as a likely significant negative effect under the B5 option for 15 of the 50 waterbird receptors.

3.3.73 The effects of changes to saltmarsh, freshwater wetlands, changes to fish populations and displacement to far-field sites were not identified as likely significant effects for any waterbird receptors under the B5 option.

3.3.74 There is substantial uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because there is little information available regarding the behaviour of fish within the estuary, the effect of turbine passage on fish populations, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species.

3.3.75 The only effect on migratory and estuarine fish that could be quantified (although with considerable uncertainty) was the disruption to route of passage as a result of turbine passage, and this could only be done for some fish species. Taking into account these predictions and qualitative assessments of other effects on fish (alterations to migratory cues, habitat change and/or loss, changes to water quality and anthropogenic noise disturbance) it is thought likely that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations in the Rivers Wye, Severn and Usk.

3.3.76 There is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify far-field effects there is potential for effects to be seen within the remaining UK population within the River Tywi. If the implementation of this option resulted in significant population reductions within this river as well then there would be potential for whole UK stock extinction.

3.3.77 Predicted losses of sea and river lamprey could potentially put their populations at risk of collapse on the Rivers Wye and Usk and cause reductions in the UK stock of river lamprey and the European stock of sea lamprey.

3.3.78 Population reductions of eel on the Rivers Severn and Wye could place compliance with the EU Eel Regulations at significant risk. However it is considered unlikely that there would be significant reductions in population size on the River Usk.

3.3.79 There is a potential risk of reductions in population size or river-specific stock collapse for sea trout and possibly allis shad. Although allis shad were formerly known to spawn in the rivers in the Severn catchment, it is thought that this area no longer supports a viable breeding population as there are no recent records of spawning. There is also a risk of reductions in population size for marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

3.3.80 All operational effects to terrestrial and freshwater ecology receptors are likely to occur rapidly after the start of operation. Water levels are predicted to increase, with increased water levels in rivers, reens and ditches. This option is predicted to have a significant positive effect on the Upper Severn Estuary SSSI as it would be predicted to lead to permanent habitat enhancement due to increased water levels.

3.3.81 A significant negative effect on otter populations is predicted as a result of the predicted declines in fish abundance outlined in the migratory and estuarine fish topic paper (Severn Tidal Power 2010e).

Decommissioning Phase

3.3.82 For all biodiversity receptors, the effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects, except for migratory and estuarine fish where the significant effects that occur during operation are likely to continue through the decommissioning phase. It is, however, unlikely that the study area would return to its original state following decommissioning. For terrestrial and freshwater ecology the habitat enhancement that occurred during operation due to increased water levels is likely to be reversed, leading to permanent habitat loss.

Alternative Option L2: Welsh Grounds Lagoon

Construction Phase

3.3.83 There are no significant effects predicted for marine ecology receptors during the construction phase for this option. However, depending on how construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime.

3.3.84 The effect of disturbance during construction is predicted to affect a larger number of waterbird receptors under the two lagoon options than under the three barrage options as the lagoons cross much larger areas of intertidal habitats used by waterbirds. This was identified as a likely significant negative effect under the L2 option for 11 waterbird receptors within the Severn Estuary.

3.3.85 Significant negative effects are predicted for all migratory and estuarine fish receptors during the construction phase. These effects are likely to be similar to those described during the operation phase (see below) although most likely of a lower magnitude. There is some uncertainty surrounding the predicted effects during the construction phase as they are largely dependent on how construction is progressed. However it is likely that effects would be heightened during the latter part of the phase.

3.3.86 Construction of the L2 option would result in a permanent land take of 5 ha at the Uskmouth landfall, but little habitat loss at the Sudbrook Landfall. This land take would be predicted to cause a significant negative effect through permanent habitat loss and fragmentation affecting parts of the Newport Wetlands NNR and possibly the Gwent Levels SSSI.

3.3.87 Other significant construction phase effects on terrestrial and freshwater ecology receptors include disturbance to species using the River Usk SAC and SSSIs from noise, vibration, visual disturbance and lighting. Some mortality of flora and fauna would be predicted and there is the potential for pollution of terrestrial or freshwater habitats due to the use of construction materials and chemicals. There is the possibility of far-field effects to terrestrial and freshwater ecology receptors during the construction phase, depending on where materials are sourced from and whether this affects and terrestrial and freshwater ecology receptors. This would require further investigation if this option were taken forward.

Operational Phase

3.3.88 As with all the options, the largest predicted effects of this option on marine ecology receptors are associated with the changes in water levels that would occur within the lagoon once it becomes operational (see the Physicochemical theme paper for details, STP, 2010i). These changes in water levels modify the extent of habitats, which leads to significant negative effects on intertidal mudflats and sandflats, *Zostera* and epibenthos. Long-term morphological changes under this option are predicted to be small (an overall increase in intertidal area of 0.7 %) and not significant.

3.3.89 Because of these changes, there is a predicted loss of 940 ha (7 %) of the area of intertidal mudflat and 6130 ha (44 %) of intertidal sandflat. There are also predicted losses of around 30 ha (2 %) of the intertidal rock and 230 ha (17 %) of intertidal shingle habitats.

3.3.90 As with the other options, there is a risk that ovigerous female epibenthos passing through the structure could be stripped of eggs. This change alone is not assessed as

significant as only a small proportion of the estuary population is expected to pass through this structure. However if an option is taken forward, there is a need for assessment of possible cumulative effects on epibenthos associated with the proposed new nuclear power station at Hinkley, which is likely to have negative effects on epibenthos.

3.3.91 In contrast to some of the other options, L2 is not predicted to have significant effects on intertidal shingle and rock, saltmarsh, macroalgae, or subtidal *Sabellaria* reefs.

3.3.92 The L2 lagoon would not affect nutrient concentrations within the main estuary. The predicted changes in salinity within the lagoon could potentially reduce nutrient concentrations locally. Changes in suspended sediment concentration within the lagoon would allow sufficient light penetration for algal bloom formation during neap tides. However, the large flushing capacity of the lagoon would prevent these blooms from accumulating.

3.3.93 There is significant uncertainty surrounding the predicted changes to marine ecology receptors because the assessment has made a number of simplifying assumptions, and the assessment relies on predicted changes to water levels and water quality from the Physicochemical theme, which have a degree of uncertainty. There is also a lack of knowledge of the present distribution of some receptors in the estuary and limited understanding of the functioning of marine ecosystems so that there is uncertainty regarding the implications of some predicted changes.

3.3.94 The effect of changes to or loss of intertidal habitat was identified as a likely significant negative effect under the L2 option for 13 of the 50 waterbird receptors, as the scale of (immediate) habitat loss and the changes to the intertidal exposure period outweigh any positive changes to the suitability of the remaining intertidal habitat for these bird species.

3.3.95 The effects of changes to saltmarsh, freshwater wetlands, changes to fish populations and displacement to far-field sites were not identified as likely significant effects for any waterbird receptors under the L2 option.

3.3.96 There is substantial uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because there is little information available regarding the behaviour of fish within the estuary, the effect of turbine passage on fish populations, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species.

3.3.97 The only effect on migratory and estuarine fish that could be quantified (although with considerable uncertainty) was the disruption to route of passage as a result of turbine passage, and this could only be done for some fish species. Taking into account these predictions and qualitative assessments of other effects on fish (alterations to migratory cues, habitat change and/or loss, changes to water quality and anthropogenic noise disturbance) it is thought likely that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations in the Rivers Wye, Severn and Usk.

3.3.98 There is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify far-field effects there is potential for effects to be seen within the remaining UK population within the River Tywi. If the implementation of this option resulted in significant

population reductions within this river as well then there would be potential for whole UK stock extinction.

3.3.99 Predicted losses of sea lamprey could potentially put its population at risk of collapse on the River Usk and cause reductions in the population size on the Wye and the European stock size. There may be reductions in the population size of river lamprey within the Rivers Usk and Wye which may cause reductions in the UK stock.

3.3.100 There is potential for reductions in the outputs of silver eel from the rivers Severn, Wye and Usk which could make compliance with the EU Eel Regulations and associated escapement targets a significant challenge.

3.3.101 There is a potential risk of reductions in population size or river-specific stock collapse for sea trout and possibly allis shad. Although allis shad were formerly known to spawn in the rivers in the Severn catchment, it is thought that this area no longer supports a viable breeding population as there are no recent records of spawning. There is also a risk of reductions in population size for marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

3.3.102 All operational effects to terrestrial and freshwater ecology receptors are likely to occur rapidly after the start of operation. Water levels are predicted to increase to the extent that some terrestrial receptors are likely to be partially or completely inundated and habitat would be lost. This would be considered to be a significant negative effect and would include areas within the Newport Wetlands NNR and Gwent Levels SSSI. A significant negative indirect effect is predicted for otter due to predicted declines in the abundance of fish.

Decommissioning Phase

3.3.103 For all biodiversity receptors, the effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects, except for migratory and estuarine fish where the significant effects that occur during operation are likely to continue through the decommissioning phase. It is, however, unlikely that the study area would return to its original state following decommissioning.

Alternative Option L3d: Bridgwater Bay Lagoon

Construction Phase

3.3.104 There are no significant effects predicted for marine ecology receptors during the construction phase for this option. However, depending on how construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime.

3.3.105 Disturbance was identified as a likely significant negative effect for three waterbird receptors (wigeon, ringed plover and grey plover), as this option may affect a high proportion of the populations of these receptors on the estuary

3.3.106 Significant negative effects are predicted for all migratory and estuarine fish receptors during the construction phase. These effects are likely to be similar to those described during the operation phase (see below) although most likely of a lower magnitude. There is some uncertainty surrounding the predicted effects during the construction

phase as they are largely dependent on how construction is progressed. However it is likely that effects would be heightened during the latter part of the phase.

3.3.107 Construction of the L3d option would result in permanent land take of 2.5 ha at both the Hinkley and Brean Down landfalls. A temporary land take of 10 ha is also predicted at Brean Down. This would cause significant negative effects on terrestrial ecology receptors due to habitat loss at both landfalls, which would affect areas including parts of the Mendip Limestone Grasslands SAC and the Brean Down SSSI.

3.3.108 Other significant construction phase effects on terrestrial and freshwater ecology receptors include disturbance to species using the SAC and SSSI and other areas from noise, vibration, visual disturbance and lighting. Some mortality of flora and fauna would be predicted and there is the potential for habitat degradation through pollution due to the use of construction materials and chemicals. There is the possibility of far-field effects to terrestrial and freshwater ecology receptors during the construction phase, depending on where materials are sourced from and whether this affects and terrestrial and freshwater ecology receptors. This would require further investigation if this option were taken forward.

Operational Phase

3.3.109 As with all the options, the largest predicted effects of this option on marine ecology receptors are associated with the changes in water levels that would occur both within the lagoon and in the wider estuary once it becomes operational (see the Physicochemical theme paper for details, STP, 2010i). These changes in water levels modify the extent of habitats, which leads to significant negative effects on intertidal mudflats and sandflats.

3.3.110 Because of these changes, there is a predicted loss of 1710 ha (14 %) of the area of intertidal mudflat and 780 ha (6 %) of intertidal sandflat. There are also predicted losses of around 120 ha (5 %) of the intertidal rock and 170 ha (13 %) of intertidal shingle habitats.

3.3.111 There are additional negative effects predicted for intertidal mudflat and sandflat as a result of long-term morphological changes, which predict further losses of around 1 % of the total intertidal area. The predicted level of annual maintenance dredging may also reduce intertidal habitat quality (by exposing mudflats to erosion and affecting the maintenance or development of invertebrate communities).

3.3.112 The predictions of intertidal loss due to water level changes do not take account of the sub-estuaries, and therefore they underestimate the total area of intertidal habitat loss. Assuming that losses in the Parrett Estuary are similar to those in the neighbouring parts of the Severn it is likely that around 65 ha of intertidal habitat could be lost in the Parrett Estuary under this option. This estimate is subject to considerable uncertainty as it has not been modelled using bathymetric data in the same way as the main Severn estuary.

3.3.113 There is the potential for far-field significant negative effects on saltmarsh habitats due to predicted declines in water levels in Kenfig SAC. The predicted changes in the Kenfig SAC are small, approximately -0.05 m, and uncertain.

3.3.114 Changes in habitat characteristics as a result of changes in erosion and deposition are predicted to cause significant positive effects for intertidal mud and sandflats, but significant negative effects for subtidal sandbanks.

3.3.115 In contrast to some of the other options, L3d is not predicted to have significant effects on *Zostera*, and macroalgae. Although initial changes to water levels could affect saltmarsh, this effect is not predicted to be significant. However long-term erosion and accretion may have a significant effect on saltmarsh, but this is highly uncertain.

3.3.116 The L3 lagoon is not expected to affect nutrient concentrations either inside the lagoon or elsewhere as a result of changes to either salinity or dilution/dispersion. Changes to the suspended sediment regime within the lagoon would allow sufficient light penetration for algal bloom formation during neap tides. The large flushing capacity of the lagoon would prevent the blooms from accumulating and therefore the potential risk of eutrophication effects remains low.

3.3.117 There is uncertainty surrounding the predicted changes to marine ecology receptors because the assessment has made a number of simplifying assumptions, and the assessment relies on predicted changes to water levels and water quality from the Physicochemical theme, which have a degree of uncertainty. There is also a lack of knowledge of the present distribution of some receptors in the estuary and limited understanding of the functioning of marine ecosystems so that there is uncertainty regarding the implications of some predicted changes.

3.3.118 The effect of changes to or loss of intertidal habitat was identified as a likely significant negative effect under the L3d option for nine waterbird receptors (pintail, golden plover, grey plover, lapwing, dunlin, black-tailed godwit, bar-tailed godwit, spotted redshank and redshank).

3.3.119 Effects on breeding seabirds were also identified as a likely significant negative effect under the L3d option for two waterbird receptors (lesser black-backed gull and herring gull).

3.3.120 The effects of changes to saltmarsh, fish populations, freshwater wetlands and displacement to far-field sites were not identified as likely significant effects for any waterbird receptors under the L3d option.

3.3.121 There is substantial uncertainty surrounding the magnitude of effects on migratory and estuarine fish. This is because there is little information available regarding the behaviour of fish within the estuary, the effect of turbine passage on fish populations, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, or the hearing frequencies and range of many species.

3.3.122 The only effect on migratory and estuarine fish that could be quantified (although with considerable levels of uncertainty) was the disruption to route of passage as a result of turbine passage, and this could only be done for some fish species. Taking into account these predictions and qualitative assessments of other effects on fish (alterations to migratory cues, habitat change and/or loss, changes to water quality and anthropogenic noise disturbance) it is thought likely that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.

3.3.123 There is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify far-field effects there is potential for effects to be seen within the remaining UK population within the River Tywi. If the implementation of this option resulted in significant

population reductions within this river as well then there would be potential for whole UK stock extinction.

3.3.124 There may be reductions in the population size of sea and river lamprey within the Rivers Usk and Wye which may cause reductions in the UK stock of river lamprey and the European stock of sea lamprey.

3.3.125 Although there is a predicted reduction to the eel population size, with potential implications for compliance with the EU Eel Regulations for the Severn, it is considered very unlikely that the effects associated with the L3d plan alternative would affect the status of the European eel stock.

3.3.126 There is a potential risk of reductions in population size or river-specific stock collapse for sea trout and possibly allis shad. Although allis shad were formerly known to spawn in the rivers in the Severn catchment, it is thought that this area no longer supports a viable breeding population as there are no recent records of spawning. There is also a risk of reductions in population size for marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

3.3.127 All operational effects to terrestrial and freshwater ecology receptors are likely to occur rapidly after the start of operation. Water levels are predicted to increase, with increased water levels in rivers, reens and ditches. These increases in water levels are predicted to have a significant positive effect on terrestrial and freshwater ecology receptors due to habitat enhancement. This effect is predicted to be relatively widespread, affecting the Somerset Levels Ramsar site, 11 SSSIs, six NNRs and one LNR.

3.3.128 A significant negative indirect effect is predicted for otter due to predicted declines in the abundance of fish.

Decommissioning Phase

3.3.129 For all biodiversity receptors, the effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects, except for migratory and estuarine fish where the significant effects that occur during operation are likely to continue through the decommissioning phase. It is, however, unlikely that the study area would return to its original state following decommissioning.

Combinations

3.3.130 One multiple basin and two combinations of options have been identified as variants for further review, as described in section 2.3. These have not been studied in the same detail as the other five options, and therefore effects are only described as being likely to be greater or lesser than the effects of other options. It is important to note that the sum of the effects of the two options could result in some non-significant effects becoming significant (for example if two non-significant declines in the population size of a particular species are predicted, these might be classed as a significant decline when summed due to the larger overall effect). If one of the combinations or multiple basin options were taken forward it would be necessary to conduct the same detailed modelling that has already been done for the five main short-listed options.

Double-basin version of L3d

3.3.131 Construction phase effects of this option variant are considered likely to have greater negative effects on marine ecology, waterbirds and terrestrial and freshwater ecology receptors compared to the standard L3d option due to the additional landfall point at Berrow, construction of an additional length of rockfill embankment and the increased civil engineering requirements of this option. Construction effects on migratory and estuarine fish would be likely to be equal to the standard L3d option as long as the timescale of construction activities was equal. However if construction time was longer then there is the potential for effects on fish to be greater than the standard L3d option.

3.3.132 Operational phase effects are likely to be greater than the standard L3d option for marine ecology receptors due to the greater loss of intertidal area that is predicted as a result of the double-basin option. However, for waterbirds it is uncertain whether effects would be greater or lesser than the standard L3d option, because although there is more intertidal loss, the exposure time of the remaining intertidal habitat would be higher than under the standard L3d option and there would always be some intertidal habitat exposed, allowing constant opportunities for feeding. The uncertainties surrounding effects on waterbirds could be reduced by quantitative modelling of the effects of this option. Operational effects on migratory and estuarine fish are likely to be greater than with the standard L3d option, because a minimum of three passes through the structure would be required for fish to enter and leave the area, compared to two with the standard L3d option. Effects on terrestrial and freshwater ecology receptors would also be likely to be greater than under the standard L3d option due to the additional landfall point at Berrow which would be likely to cause increased habitat loss and degradation.

3.3.133 Decommissioning effects are considered likely to be greater than the standard L3d option for marine ecology and migratory and estuarine fish receptors, but they are likely to be similar to the standard L3d option for waterbirds and terrestrial and freshwater ecology receptors.

Combination of B4 and L3d (built concurrently)

3.3.134 Construction phase effects on marine ecology, waterbirds and terrestrial and freshwater ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However, it is considered likely than construction phase effects on fish could be greater than the sum of the individual effects of the two options because there would be concurrent disturbance to fish that utilise the waters around B4 and L3d. This could potentially result in an increased level of maximum disturbance and reduced feeding areas for fish during construction.

3.3.135 Operational phase effects on terrestrial and freshwater ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However, for all other biodiversity topics (marine ecology, waterbirds and migratory and estuarine fish) it is considered likely that the operational phase effects would be greater than the sum of the individual effects of the options. For marine ecology and waterbirds, this is because there is predicted to be a greater loss of intertidal habitats compared to the sum of the two options, including increased loss of mudflats and sandflats that are important feeding habitats for waterbirds. It is considered likely that the presence of both options on the estuary would result in a relatively greater risk of local extinction of fish species (and potentially extinction of the entire UK spawning stock of twaite shad) compared to the sum of the individual effects.

3.3.136 During the decommissioning phase, it is thought that effects would be likely to be approximately equal to the sum of the individual effects of the options for marine ecology, waterbirds and terrestrial and freshwater ecology, but could potentially be greater than the sum of the effects of the two options for migratory and estuarine fish.

Combination of B4 and L3d (built sequentially)

3.3.137 Construction phase effects on waterbirds and terrestrial ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However it is possible that there may be a greater effect on marine ecology receptors due to marginally greater effects on the loss of intertidal habitat during the construction of the latter option. It is considered possible that construction phase effects on migratory and estuarine fish could be greater than the sum of the individual effects.

3.3.138 Operational phase effects on biodiversity due to the presence of B4 and L3d would be the same whether built sequentially or concurrently (see above).

3.3.139 During the decommissioning phase, it is thought that effects would be likely to be approximately equal to the sum of the individual effects of the options for marine ecology, waterbirds and terrestrial and freshwater ecology, but could potentially be greater than the sum of the effects of the two options for migratory and estuarine fish.

Combination of B3 and L3d (built sequentially)

3.3.140 Construction phase effects on waterbirds and terrestrial ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However it is possible that there may be a greater effect on marine ecology receptors due to marginally greater effects on the loss of intertidal habitat during the construction of the latter option. It is considered possible that construction phase effects on migratory and estuarine fish could be greater than the sum of the individual effects.

3.3.141 Operational phase effects on terrestrial and freshwater ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However, for all other biodiversity topics (marine ecology, waterbirds and migratory and estuarine fish) it is considered likely that the operational phase effects could be greater than the sum of the individual effects of the options. For marine ecology and waterbirds, this is because there is predicted to be a greater loss of intertidal habitats compared to the sum of the two options, including increased loss of mudflats and sandflats that are important feeding habitats for waterbirds. It is considered likely that the presence of both options on the estuary would result in a relatively greater risk of local extinction of fish species (and potentially extinction of the entire UK spawning stock of twaite shad) compared to the sum of the individual effects.

3.3.142 Decommissioning phase effects on terrestrial and freshwater ecology receptors are considered likely to be approximately equal to the sum of the individual effects of the two options. However for all other biodiversity topics (marine ecology, waterbirds and migratory and estuarine fish) it is considered possible that decommissioning phase effects could be greater than the sum of the individual effects of the options. Due to the close proximity of the two structures, decommissioning effects may result in marginally greater effects on water levels, if carried out concurrently, compared to the sum of the individual effects. A more rapid change in high and low water levels may have a greater effect on marine ecology receptors including intertidal habitats such as

mudflats and saltmarsh, compared to the sum of the individual effects. The effects of disturbance to waterbirds using the area during decommissioning could be greater than the sum of the individual effects if decommissioning was concurrent. Similarly, it is considered that decommissioning effects to migratory and estuarine fish could be greater than the sum of the individual effects.

SECTION 4

INTERRELATIONSHIPS

4 INTERRELATIONSHIPS

4.1.1 The SEA Directive requires that the interrelationships between likely significant effects are described (SEA Directive Annex 1 (f)). This theme paper therefore summarises the interactions between related topics and thereby ensures that the many complex issues that are not self-contained within a given topic are recognised and their implications understood. Each theme paper also examines the relationships between this theme and other themes within the STP SEA.

4.1.2 Further details of the likely significant effects of interrelationships between topics and themes are included in the assessment of the likely significant effects of the tidal power options. This section simply provides a summary of the key issues.

4.2 Interrelationships between topics within biodiversity theme

4.2.1 As ecosystems are, by definition, interrelated there are many interrelationships between the topics within the biodiversity theme. Predicted changes in one part of the ecosystem have consequences for other biodiversity receptors.

4.2.2 The marine ecology assessment is critical in informing the assessments of the other biodiversity topics. Changes to habitat extent and quality, and the abundance of invertebrates that are prey species for birds and fish (assessed by marine ecology) are key parameters in predicting the effects for waterbird and migratory and estuarine fish receptors. Because of these strong linkages, the uncertainties in the predictions of changes to marine ecology receptors can cause further uncertainties in the predictions of effects for birds and fish. For example, it is uncertain how intertidal invertebrate populations might respond to changes in the tidal regime as a result of a tidal power option, therefore the food availability for birds and fish that feed on these invertebrates is uncertain, with consequent uncertainty in the predictions of bird numbers. This was particularly a challenge for the individual-based modelling of changes to waterbird numbers, where assumptions had to be made regarding the future invertebrate abundance if a tidal power option were implemented, because predictions were not available.

4.2.3 Predicted changes in phytoplankton productivity as a result of the implementation of some of the tidal power options could have significant knock-on effects that alter the rest of the ecosystem. The likely magnitude of these effects is highly uncertain.

4.2.4 The migratory and estuarine fish assessment interrelates with all three of the other biodiversity topics. Some marine ecology receptors (marine mammals such as seals), waterbird receptors (e.g. cormorant and grey heron), and terrestrial and freshwater ecology receptors (otter) feed on fish. Thus any changes to the abundance or distributions of fish populations predicted in the migratory and estuarine fish assessment are important in determining the effects of the options on each of these receptors. For example, as a result of predicted declines to fish populations otter populations are predicted to decline as a result of all options.

4.2.5 Although the key ecological links between receptors have been made in the assessment of effects in section 3, the complexities of ecosystems means that some indirect links are likely to have been missed, or the effects of these links cannot be accurately predicted. Furthermore, where receptors have links with many other changing parts of an ecosystem it is very difficult to predict the overall effect of these

combined changes. The result of this complexity is that the estimates of effects on most biodiversity receptors are associated with significant levels of uncertainty.

4.3 Interrelationships between biodiversity and other themes

4.3.1 Predicted effects of each option on biodiversity receptors are largely dependent on the predictions of future changes to the physical environment, and as such the most important interrelationship is with the Physicochemical theme.

4.3.2 Within the Physicochemical theme, predicted changes (particularly to water levels) from the hydraulics and geomorphology topic were critical in informing the modelling conducted by the biodiversity theme. As such, any uncertainties inherent in the hydraulics and geomorphology results lead to uncertainties in the predicted effects on biodiversity receptors. Predicted changes to the hydrology and geomorphology of the estuary lead to a very high proportion of all the significant effects that have been predicted for biodiversity receptors.

4.3.3 Because the biodiversity theme relies so heavily on information from the Physicochemical theme, limitations of the assessments conducted as part of the Physicochemical theme necessarily lead to limitations within the biodiversity assessment. For example, because the effects of the options on the sub-estuaries were not included in the detailed hydraulics and geomorphology modelling, the marine ecology topic could not assess the effects of the alternative options on receptors in the sub-estuaries in the same detail as the main estuary. This in turn lead to limitations for the waterbirds and migratory and estuarine fish topics which required information on changes to habitat extent (from marine ecology) to inform the assessment of effects on waterbird and fish receptors. The result of this limitation is that some effects on biodiversity receptors may be underestimated.

4.3.4 Results from the marine water quality topic (also a component of the Physicochemical theme) were also required to inform the marine ecology and migratory and estuarine fish topic assessments.

4.3.5 The other topics within the Physicochemical theme (freshwater environment and associated interfaces, and flood risk and land drainage) are also important in informing the assessments conducted by the biodiversity theme topics. The flood risk and land drainage assessment has been important in informing the likely changes to water levels on land surrounding the options, which is an important consideration, particularly regarding effects on terrestrial and freshwater ecology receptors.

4.3.6 Any uncertainties inherent in the Physicochemical theme results lead to uncertainties in the predicted effects on biodiversity receptors. In some cases the uncertainty from the Physicochemical theme would compound with the uncertainty within the biodiversity theme. In others the uncertainty within the Physicochemical theme is expressed as a component of the uncertainty in the biodiversity topics. This needs to be borne in mind when considering the overall uncertainty of predictions within the biodiversity theme.

4.3.7 Some parts of the biodiversity theme assessment may be important in informing the effects on other themes. For example changes in wildlife populations or distribution may affect some receptors assessed in the society and economy theme (for example birdwatching, fishing). These effects are considered in the society and economy theme paper.

4.4 Interrelationships with the Habitats Regulations Assessment

4.4.1 The main interrelationship between the biodiversity theme and the Habitats Regulations Assessment (HRA) relates to the various biodiversity topics supplying data and information from their modelling and assessment work to inform the Habitats Regulations Assessment. The Habitats Regulations Assessment (STP, 2010h) does not generate new data, but uses the data and assessments provided by the various biodiversity (and Physicochemical) topics to inform the HRA assessment. However, the SEA and HRA differ in their approaches such that the results and conclusions derived from these data may differ. The SEA presents estimates of the most likely predicted effects on the receptors within the biodiversity theme. The HRA takes a precautionary approach in that, for example, where modelling the effects of an option on a receptor predicts a range of outcomes, the most likely estimates from these predictions would be used in the SEA but the worst case of the possible outcomes would be taken as the precautionary value used in the HRA. The HRA may use sub-sets of the data used in the SEA to assess effects on protected sites that form part of the SEA study area.

4.4.2 At the start of the assessment process a series of meetings was conducted between those working on the SEA and the HRA to ensure that the biodiversity topics were generating the data required to assess the qualifying features of all sites included in the HRA and identify any gaps. Throughout the process the teams working on the biodiversity topics and HRA have had regular contact to ensure that the methods used and data and assessments generated are appropriate for the requirements of both the HRA and the biodiversity theme of the SEA.

SECTION 5

MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5 MEASURES TO PREVENT, REDUCE AND AS FULLY AS POSSIBLE OFFSET ANY SIGNIFICANT ADVERSE EFFECTS

5.1.1 The SEA Directive requires that information is provided on the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme (SEA Directive Annex I). These measures are considered within this theme paper in terms of the interrelationships between topics within this theme.

5.1.2 In this SEA, and in line with UK practice, these measures are split into those to prevent or reduce effects, and measures to as fully as possible offset any significant adverse effects on the environment. Offsetting measures make good for loss or damage to the environment, without directly reducing that loss/damage.

5.2 Measures to prevent or reduce significant negative effects

Optimisation

5.2.2 The optimisations process took place during the early stages of the SEA. It identified the short-list of tidal power options considered in this study from a longer list of variants, and took into account effects on biodiversity as part of this process.

5.2.3 During optimisation of the tidal power options the effects on waterbirds were taken into account by assessing the likely area of saltmarsh and intertidal flats remaining for each variant of an option being considered. This together with an assessment of the average time that the intertidal was predicted to be exposed for each tidal cycle acted as a proxy for the likely effects on waterbirds. For intertidally feeding waterbirds, the optimal variants were those with the smallest reduction in intertidal area and longest intertidal exposure period. For species that also use saltmarsh extensively, the optimal variants were those that maintained the most extensive areas of this habitat. These effects on waterbirds were used as a surrogate for the main effects on marine ecology at the optimisation stage of the assessment (though clearly when assessing the short-listed options following optimisation marine ecology has been assessed independently of waterbirds).

5.2.4 Measures considered during optimisation to reduce adverse effects associated with fish passage past an option centred upon:

- Turbine and sluice design:
  - Larger turbines with slower rotation speeds and fewer blades;
  - Double regulated turbine units and automated regulation.
- Operational regime:
  - Ebb only generational mode preferred where possible;
  - Periods of generation cessation during key sensitive periods.
- Fish passage mechanisms:
  - Increase permeability of the structure to maximise areas of free passage.

5.2.5 No specific measures to prevent or reduce effects to terrestrial and freshwater ecology receptors were undertaken at the optimisation stage.

Measures to prevent or reduce significant adverse effects during construction

5.2.6 A number of potential measures could be applied to reduce the effects of the alternative options on receptors (Severn Tidal Power 2010g). During construction, as a matter of good practice, standard measures such as pollution prevention controls to minimise effects on biodiversity would be recommended. Measures to prevent or reduce the effects on during the construction phase include:

- Careful timing of construction activities to minimise risks during sensitive periods for specific receptors, for example to reduce disturbance effects on wintering waterbirds, restricting work during the midwinter period, and stopping work completely close to intertidal areas during severe weather would be beneficial. Careful timing of terrestrial parts of the construction activities, particularly site clearance, could be effective in reducing or preventing significant negative effects to terrestrial and freshwater ecology receptors. However it should be noted that different timings for parts of the construction activity may be required to reduce effects on different receptors, therefore it may not be possible to implement the ideal construction timings for all species and additional measures may be required to prevent and reduce these effects.
- Management of dredging and piling activities to limit resuspension of sediments and noise could reduce effects on marine ecology and migratory and estuarine fish receptors.
- Minor adjustments to the location or alignment of options to avoid specific features within the footprint of the devices may reduce some negative effects for some marine ecology receptors. However, major physical changes would be likely to occur in the vicinity of tidal power structures which may also give rise to significant effects on features adjacent to those structures. The benefit of this measure may therefore be limited.
- Adjustments to the landfall and onshore works locations may be effective in preventing or reducing many of the significant effects on terrestrial and freshwater ecology receptors.
- There may be opportunities, through the careful selection of construction materials to enhance colonisation of new structures by marine ecology receptors. However, in addition to enhancing conditions for native species, this may also increase the settlement potential of non-native species.

Measures to prevent or reduce significant adverse effects during operation

5.2.7 A number of measures have been identified that may reduce effects on biodiversity receptors within the study area (Severn Tidal Power 2010g).

5.2.8 The following measures could provide particular benefit in preventing or reducing effects on intertidal habitats and saltmarsh within the study area:

- Preliminary investigations have identified a number of possibilities for large scale creation of intertidal areas within the estuary which could be used to reduce effects of predicted losses for all alternative options. Topographical modification both within and outwith the areas of the alternative options could lessen the effect of loss of intertidal area (Severn Tidal Power 2009c). The proposals mostly aim to 'recreate' intertidal habitat lost due to increased low water levels within the areas of the tidal power options. New intertidal habitat might also be formed by raising existing subtidal habitat, though clearly this could have a knock-on negative effect on some receptors because some subtidal habitat loss would occur. Based on other studies, it is likely that such areas could achieve a biological quality comparable with other intertidal mudflats within 3 to 5 years (Severn Tidal Power

2010c), but it could take longer for some features to develop. However, the proposed habitat creation does not completely prevent or reduce the loss of intertidal habitat and intertidal habitat creation at this scale is untried and thus its efficacy at compensating for the effect of intertidal habitat loss on biodiversity is highly uncertain and would depend on the sustainability of the habitat created, its quality and its exposure.

- Management of sluices, e.g. sluicing after the generation period on a spring tide, combined with early commencement of turbine generation for those options (B3, B4, B5 and L2) where ebb only options are presently proposed, could reduce predicted spring low tide levels and thus increase the intertidal exposed on these tides. The effectiveness of this would vary depending on the arrangement of sluices, but could reduce some negative effects on marine ecology and waterbird receptors. There is reasonable certainty that this measure would be effective, but it is only likely to have a small effect in relation to the area of intertidal habitat lost.
- Pumping at end of the generation period on flood tides to minimise the decrease in high water levels on flood tides could reduce effects to saltmarsh. This could help maintain the quality of the remaining saltmarsh, though not negate its loss, but could reduce adverse effects on marine ecology and waterbird receptors. There may be issues surrounding the sustainability and maintenance of this measure and it is recommended that the issue is investigated further if any tidal power option is taken forward.
- Introduction of new refuges or bird roost areas within the estuary could help to reduce the effects of loss of bird roosting areas on saltmarsh for all alternative options.

5.2.9 Other measures that could prevent or reduce effects on marine ecology and waterbird receptors include:

- Minor option alignment adjustments could be effective at avoiding eelgrass beds, which are particularly rich waterbird feeding habitats, in the vicinity of the L2, B3 and B4 options. This measure could have some (limited) benefit for some marine ecology and waterbird receptors.
- Alignment adjustments could ensure that the B3 barrage is sufficiently far from Flat Holm and Steep Holm to limit disturbance to breeding birds and prevent sediment connecting the islands. If the B3 option became connected to or was too close to these islands, this could potentially lead to colonisation by rats (which, through predation of eggs and young, can lead to large decline in numbers of breeding seabirds). A rat control programme would also be considered necessary to negate this risk. It is assumed that this measure would be implemented for the B3 option and it has the potential to prevent to prevent this effect entirely. Specific waterbird receptors that could benefit from this measure are lesser black-backed gull and herring gull.
- While all of the options are predicted to have significant effects on subtidal sandbanks, and most of the options are predicted to have significant effects on subtidal *Sabellaria alveolata* reefs, no effective measures can be identified to reduce these effects if one of the proposed tidal power options were implemented.

5.2.10 Potential measures to prevent or reduce effects on migratory and estuarine fish include:

- Altering the operating regime to increase the permeability of the barrage or lagoon by diverting water through safer passage routes such as sluices, free-wheeling turbines or free gaps.

- Industry standard measures to minimise noise and vibration levels during construction, operation and decommissioning.
- Fish passage mechanisms such as altering the type, size and number of sluices. Other fish passage mechanisms such as fish bypasses, lifts and locks could offer some potential for reducing effects to fish but it is uncertain if they could be operated successfully within the Severn Estuary, and so these measures cannot be recommended at this stage. However, it is suggested that further research is undertaken into these possibilities to reduce effects associated with disruption to route of passage.
- Predator control (piscivorous birds) through physical exclusion techniques close to the structure and/or the use of deterrent and exclusion systems (including visual and auditory scarers).

5.2.11 The effectiveness of all of these measures is uncertain as the scale that would be required is unprecedented. It is considered that they may be only partially effective or ineffective, and some may prove not to be feasible on the scale required in the Severn. For effects on fish to be addressed effectively, a major programme of long-term research would be required to identify which of these measures could be effective in preventing or reducing effects on fish. A research programme to identify further measures to prevent or reduce effects on fish would also be useful, as there are some additional potential measures that are promising but not currently ready for application without substantial further investigation. These include cessation of generation during peak migration periods for 'at-risk' species and fish passage management (e.g. bypasses or fish lifts and locks). It would be necessary to conduct research to determine whether any of these measures to prevent or reduce effects to fish could be effective before the decision to implement a tidal power option. However, it may not be possible to complete this research before the proposed start of construction in 2014, which would lead to a high risk that effects on migratory and estuarine fish may not be adequately mitigated.

5.2.12 Operational effects on important terrestrial and freshwater ecology habitat or species receptors due to altered freshwater and seawater levels could be prevented or reduced by management of freshwater and seawater levels. Measures that could be adopted principally revolve around freshwater and seawater level management including targeted pumping to manage water levels.

Interactions

5.2.13 Improvement of existing flood defences and erosion prevention measures have been proposed by the flood risk and land drainage topic. Such measures could potentially have negative effects on marine ecology habitats associated with the upper shore (although if marginal habitat creation is included as part of the development process this may potentially improve some habitats) and would also limit any potential positive effects on terrestrial and freshwater ecology and waterbird receptors in the study area floodplain. The flood risk and land drainage topic also proposed measures to prevent or reduce the effects of decreased drainage and thus increased flood risk upstream of the options, which would also reduce the potential positive effects of increased water tables on waterbird and terrestrial and freshwater ecology receptors in the study area floodplain.

5.2.14 Dredging for the benefit of navigation could have a low level negative effect on the extent and quality of intertidal habitats used by waterbirds, unless dredgings were used for intertidal habitat creation. Dredging is also considered likely to result in negative effects on marine ecology and migratory and estuarine fish.

5.2.15 Measures to prevent or reduce the scale of the reflection of waves identified in the Hydrology and Geomorphology topic could be have significant negative effect-reduction for waterbirds and fish as they could help reduce the erosion of intertidal and saltmarsh habitats.

5.2.16 Measures to minimise noise and vibration levels during construction and operation for human benefit, minimising the extent of lighting, particularly at night-time for the benefit of landscape and seascape receptors and measures identified in the marine water quality topic to reconfigure intakes / outfalls at Hinkley Point could also potentially be of low-level negative effect-reduction for waterbirds and reduce negative effects on migratory and estuarine fish.

5.2.17 Changes in the operating regime to mitigate reductions in exposure time (for birds) are unlikely to result in significant negative effect-reduction on marine ecology receptors.

5.2.18 Changes in the number, location and distribution of sluices and non-generation periods (measures for migratory fish) may have some minor negative effect-reduction for marine ecology receptors such as mobile epibenthos, but this is highly uncertain. Similarly, additional sluicing, as proposed for marine ecology and waterbirds, is likely to reduce some effects on migratory and estuarine fish receptors. Measures aimed at managing freshwater and seawater levels for the benefit of terrestrial and freshwater ecology receptors, such as pumping and changing low water levels through sluicing, could also have a significant negative effect-reduction for waterbirds.

5.2.19 Measures identified in the migratory and estuarine fish topic that might potentially reduce fish injury or mortality on passage through the barrages or could potentially affect the tidal regime and so also affect waterbirds and marine ecology receptors either positively or negatively.

5.2.20 Minor alignment adjustments for the benefit of terrestrial and freshwater ecology and historic environment receptors, and adjustments to locations of onshore works for the benefit of terrestrial and freshwater ecology receptors, could affect waterbirds either positively or negatively.

5.2.21 Alteration of ebb-only schemes to ebb-flood generation, which is proposed as a potential measure to reduce negative effects on marine ecology and waterbird receptors, is likely to result in significant negative effects on migratory and estuarine fish.

5.2.22 Topographic modification, inclusion of locks, installation of training walls, increasing water exchange through the structure and timing construction to avoid other large construction projects are all considered likely to be beneficial for some species of migratory and estuarine fish, and therefore reduce the magnitude of the negative effects predicted for these species. However it could introduce additional barriers to some species that migrate selectively up the intertidal parts of the estuary which may result in negative effects to these populations.

5.3 Measures to as fully as possible offset significant negative effects

5.3.1 Offsetting measures within this SEA are measures to as fully as possible offset any significant negative effects on the environment. These measures therefore make good for loss or damage to an environmental receptor, without directly reducing that

loss/damage. In this SEA 'compensation', a subset of offsetting, is only used in relation to those measures needed under the Habitats Directive.

5.3.2 To offset the reductions in populations of non-statutorily protected fish species, one potential measure would be monetary compensation in return for reduction in fishing activities. The species affected would be Bass, Plaice, Sole, Cod, Dab, Whiting & Herring. However the likely effectiveness of this measure is uncertain as the links between the Severn and wider populations are not fully understood. There is a need for further research to better understand these linkages and therefore the likely effect of this measure. Another measure to offset reductions in these species' populations could be habitat, creation, modification and ecological enhancement in other areas, targeted to be of benefit to these marine estuarine species. However while this measure is technically feasible it is likely to require some research and development before it can be implemented successfully (Severn Tidal Power 2010g).

5.3.3 All other offsetting measures identified for biodiversity effects at this strategic scale of study are also considered to be compensation measures under the Habitats Directive and are therefore described in section 5.4 on compensation need.

5.4 Compensation need

5.4.1 In this SEA, 'compensation', is only used in relation to those measures needed under Directive 92/43/EEC (the Habitats Directive).

5.4.2 Compensation needs identified here relate to the predicted residual effects on SEA receptors. This does not represent an assessment of all compensation requirements that would be required under the Habitats Directive. A full assessment of such measures is given in the Habitats Regulations Assessment (STP, 2010h).

Marine Ecology

5.4.3 It is likely that a major programme of compensation measures would be required for marine ecology receptors. For all options except L3d, the area of habitat that might be created under measures to prevent or reduce effects is less than the predicted loss. While the area that might be created for L3d exceeds the predicted area of loss, the quality of the habitat created may be affected by the wider changes in physical processes such that the measure may not be effective in fully mitigating the effect. For effects on subtidal sandbank habitat and subtidal *Sabellaria alveolata* reef, no effective measures have been identified and therefore compensation measures can be considered.

5.4.4 The Habitats Regulations Assessment has estimated the residual loss of intertidal area of the Severn Estuary/Môr Hafren SAC, following the application of measures to prevent or reduce significant adverse effects. This is provided in Table 5.1 below.

Table 5.1: Summary of estimated area losses of designated intertidal habitat within the Severn Estuary / Môr Hafren SAC

Alternative Option	Estimated area loss of designated intertidal habitat *before* application of potential measures to prevent or reduce significant adverse effects		Estimated area loss of designated intertidal habitat *after* application of potential measures to prevent or reduce significant adverse effects	
	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)	Potential Lower-bound Loss (ha)	Potential Upper-bound Loss (ha)
B3	14,800	18,000	11,800	16,300
B4	3,300	4,000	2,700	3,700
B5	2,700	3,300	2,100	3,000
L2	7,300	8,700	6,100	8,200
L3d	2,500	3,000	1,600	2,600

Table notes:

a) Estimates rounded to nearest 100 ha.

b) Intertidal area is defined as HAT-LAT.

c) Calculations are for the area within the Severn Estuary SAC only, i.e. excluding SEA Hydraulics and Geomorphology model units 2a, 2b and 2c. These habitat area losses are small by comparison.

d) Calculations do not include sub-estuaries; habitat area losses are uncertain and small by comparison.

e) Estimates are for intertidal habitats that are a qualifying feature or sub-feature of the SAC only. These are: intertidal hard substrate communities; mudflats and sandflats not covered by seawater at low tide; Atlantic saltmeadow. The calculations for Atlantic salt meadow do not include the modelled intertidal grassland: this transitional habitat is not considered to be part of the SAC habitat.

f) Estimates include habitat losses from barrage footprints and from changes in tidal regime.

g) Calculations are based on model outputs of intertidal habitat extents at closure, provided by the Marine Ecology Topic Paper, Annexe 3 (Severn Tidal Power, 2010c).

h) Calculations for Atlantic saltmeadow are based on the predicted short-term losses at commencement of operations due to changes in water levels. Potential longer-term term colonisation of new areas of suitable habitat by saltmarsh communities is excluded.

i) Calculations do not include uncertain estimates of long-term morphological change.

j) The range of values is calculated by applying the following to the central output provided by SEA Marine Ecology Topic Paper (Severn Tidal Power, 2010c):

- Uncertainty around model output: +/-10% predicted area change.
- Mitigation methods where quantifiable, as per the SEA Environmental Report (Severn Tidal Power, 2010a): pumping at high water (only quantified for B3); additional sluicing on ebb tide (only quantified for B3); topographic modification (quantified for all options with a predicted range of effectiveness).

k) The 'Minimum Loss' value = minimum loss (model output -10%) minus the maximum mitigation (greatest value for mitigation effectiveness).

l) The 'Maximum Loss' value = maximum loss (model output +10%) minus the minimum mitigation (lowest value for mitigation effectiveness).

m) This approach is consistent with that applied to individual habitat types to generate the residual effects quoted in the Habitats Regulations Assessment reporting.

5.4.5 The creation of replacement intertidal mud and sandflat habitat to compensate for the predicted losses of intertidal habitat (see Table 5.1) is likely to be a key focus for the package of compensation measures. There may also be a requirement to provide compensation measures for effects to saltmarsh, particularly for option B3 but also possibly for other options within particular parts of the estuary. Other specific requirements may include measures for saltmarsh, eelgrass, epibenthos, subtidal sandbanks and subtidal *Sabellaria alveolata* reef.

5.4.6 Managed realignment is now widely recognised as an effective mechanism for creating new intertidal habitats. The majority of schemes to date have focused on the creation of saltmarsh rather than mud and sandflats, although some realignments

have created mudflat habitat. Within the Severn Estuary, however, there is limited opportunity for the creation of mudflat behind the existing seawalls unless significant land lowering is undertaken. Under the B3 option the potential for managed realignment would be removed due to the effect of lowering of water levels predicted under this option, making it almost impossible to inundate the adjoining land. Implementation of the B3 option would also remove the possibility of implementing the programme of managed realignment identified to address coastal squeeze under the Severn CHaMP.

5.4.7 Managed realignment to create saltmarsh adjoining the Severn Estuary is one measure that could be used to compensate for loss of SAC habitats. However it is considered unlikely to be feasible to fully compensate for all schemes using this method, and it is considered unlikely to be possible to use managed realignment to create mudflat adjoining the Severn Estuary under any of the schemes. Therefore managed realignment to create mudflat and saltmarsh at a distance from the Severn Estuary is considered a potential compensation measure.

5.4.8 While it is technically possible that realignment schemes may be able to support eelgrass and provide functional habitat for epibenthos this is again considered unlikely in the context of the Severn Estuary. It is not likely to be possible to create new subtidal *Sabellaria alveolata* reefs (the subtidal reefs in the Severn Estuary are unique) or subtidal sandbanks. It may be possible to designate additional sites for subtidal sandbank features but the subtidal *S. alveolata* reefs that would be lost under a Severn Tidal Power option could not be replaced directly. If intertidal *Sabellaria* reefs could be found elsewhere it may be possible to designate additional sites, however this is highly uncertain and would require further study to establish whether other sites exist. As there are only two other known sites with subtidal *S. alveolata* reefs in the entire north-east Atlantic the loss of this habitat would be of international significance.

Waterbirds

5.4.9 The majority of the measures to prevent and reduce effects on waterbirds aim to reduce or prevent the principal effect of change or loss of intertidal habitat. The efficacy of these measures, particularly intertidal habitat creation (topographic modification) is uncertain on the scale proposed and while it would undoubtedly be of benefit, the need for further compensation cannot be discounted until much more detailed studies are undertaken. The provision of new habitat to support waterbirds that could no longer be supported on the Severn is likely to be the principal compensation requirement for waterbirds.

5.4.10 Some of the compensation measures outlined for the marine ecology topic (above) may also be effective for some waterbird receptors. Managed realignment to create saltmarsh adjoining the Severn Estuary may be effective compensation for some waterbird species where loss of saltmarsh is the only negative effect.

5.4.11 Managed realignment to create mudflat and saltmarsh at a distance from the Severn Estuary (proposed compensation for marine ecology receptors) is unlikely to be fully effective in compensating for waterbird losses on the Severn Estuary, as sites far from the Severn may not support the same migratory populations. However it is likely that some waterbird species could be supported at such sites, and distributions of some species may slowly shift to new sites over time. This measure is arguably not ‘like for like’ (more properly known as within European Commission guidance) but is conditionally included in the overall framework of possible compensatory measures as it may be partially effective in compensating for losses of some species.

5.4.12 The creation of freshwater wetlands close to the Severn Estuary may be effective in compensating for effects of habitat loss caused by the implementation of a tidal power option on some of the SPA waterbird species. However this would only be effective for species that readily utilise freshwater sites. For species that primarily feed on intertidal habitats, freshwater wetlands are unlikely to support comparable densities of birds as the intertidal habitat that would have been lost, and therefore this would not be effective compensation for all waterbird species. If this measure were considered as part of any compensation package, it would be necessary to consider the impacts on existing protected sites such as SSSIs when identifying potential sites for the creation of freshwater wetlands.

Migratory and Estuarine Fish

5.4.13 It is likely that when combined the proposed measures to avoid or reduce the effects of an STP option may only be partially effective or ineffective for migratory and estuarine fish. As such, compensation measures would be required. Potential measures that could be employed include fish stocking and translocation and habitat enhancement or creation. For example the translocation or introduction of twaite shad to a new location could be employed to compensate for some of the losses predicted for this species. However, for this measure to be successful a combination of measures is likely to be required, including habitat improvements.

5.4.14 A number of other compensation measures for migratory and estuarine fish are being considered for conditional inclusion in the overall package of compensation. The translocation or introduction of allis shad to other sites is a possibility but the inclusion of this measure would be dependent on further study to determine its likely effectiveness and feasibility, which is currently uncertain. Translocation of other species such as lamprey and salmon is not considered a feasible measure. Stocking of salmon or twaite shad in rivers outside the Severn and its tributaries could be included as compensation measures if these are considered as additional to existing conservation measures for these species. As above, such measures are likely to be successful only if combined with other measures such as habitat enhancement, and the likelihood of success is highly uncertain. Another measure that could be conditionally included in the package of compensation for fish, if it were considered additional compared to existing conservation measures, would be freshwater habitat enhancement or creation schemes and improvements to other population limiting factors. This could help to compensate for population declines of a range of migratory fish species by increasing their populations elsewhere. Any stocking or translocation programme would have to be assessed under IUCN guidance, and there is a risk that it may not be possible to comply with this guidance and thus this measure may not be possible.

5.4.15 The inclusion of additional sites in the SAC list may be effective in protecting some fish populations at other sites, but would not alter the reduction in the overall population size due to negative effects on the Severn. This measure would not be possible for some species, such as shad, where all other known spawning sites in the UK are already designated. The policy implications of this measure would need to be considered before it were implemented, therefore it is uncertain if this measure would be possible.

5.4.16 The measures proposed for migratory and estuarine fish are unprecedented on the scale that would be required were a tidal power option taken forward. Significant further research would be required in order to develop these measures, and better understand the likely combined effectiveness of them. There is a significant risk that

the measures proposed may not be effective in compensating for losses to fish populations as a result of any tidal power option.

Terrestrial and Freshwater Ecology

5.4.17 Compensation needs for terrestrial and freshwater ecology receptors are only anticipated where measures to prevent and reduce cannot be successfully implemented. Likely examples would include legally protected sites and species. Effects on these sites and species, owing to their location, may be unavoidable and as such legal process would require that appropriate measures are undertaken. In the case of European Protected Species and designated sites this would be likely to include the provision of alternative habitats through either creation and/or enhancement/extension. Methods for the creation of terrestrial and freshwater habitats are generally better established than those for the creation of intertidal or marine habitats.

Interactions

5.4.18 It is possible that managed realignment could be proposed as a compensation measure for areas within the Severn Estuary for some options (though not B3, as outlined above). While this may have potential to create additional estuary habitat, the implementation of such schemes might also have effects on existing marine ecology receptors. However, the scale of the changes to existing receptors would not be expected to give rise to significant negative effects.

5.4.19 Various measures proposed to prevent, reduce or offset effects for the migratory and estuarine fish topic would mostly be expected to be of low-level benefit for waterbirds.

5.4.20 The marine water quality topic has proposed controls on inputs of contaminants from other sources in the Estuary. This measure would be expected to result in positive effects on the migratory and estuarine fish receptors, and be of low- to medium-level benefit for waterbirds.

SECTION 6

SEA OBJECTIVE COMPLIANCE

6 SEA OBJECTIVE COMPLIANCE

6.1 Compliance with SEA objectives

6.1.1 The SEA Objectives which were drafted and consulted upon as part of the Phase 1 SEA scoping stage are set out in Section 2.2. This theme paper identifies any interactions or inconsistencies between topics within this theme with regards to the assessment against SEA Objectives.

Table 6.1 Summary of SEA Objective Compliance for Biodiversity.

Key

Performance is based on number or proportion of receptors linked to each SEA Objective for which significant effects have been predicted, and informed by consideration of SEA Assessment Criteria. More than one symbol has been used in cases where there are both negative and positive performances against the SEA objectives for different receptors.			
Major negative performance against SEA Objective	--	Major positive performance against SEA Objective	++
Minor negative performance against SEA Objective	-	Minor positive performance against SEA Objective	+
No Effects	0		

SEA Topic	SEA Objective	B3	B4	B5	L2	L3d
Marine Ecology	1. To avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance.	--	--	--	--	--
	2. To avoid adverse effects on valuable marine ecosystems.	--	--	--	--	--
	3. To avoid adverse effects on other protected marine species and their habitats.	0	0	0	0	0
	4. To avoid adverse effects on national and local biodiversity target features that include marine habitats and species.	--	--	--	--	--
	5. To avoid deterioration in status class of WFD water bodies.	?	0	0	0	?
	6. To minimise the risk of introduction of non-native invasive marine species.	-	0	0	-	-
	7. To conserve and enhance designated marine site features.	--	--	-	--	-
	8. To restore and enhance marine BAP species populations and/or BAP habitat.	--	--	-	--	-
Waterbirds	1. To avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance.	--	-- / +	-- / +	--	--
	2. To avoid adverse effects on other protected bird habitats and species.	-- / +	-- / +	-- / +	--	--
	3. To avoid adverse effects on national and local biodiversity target features that include bird habitats and species.	-- / +	-- / +	-- / +	--	--

SEA Topic	SEA Objective	B3	B4	B5	L2	L3d
Migratory and Estuarine Fish	1. To avoid adverse effects on designated wildlife sites for fish of international and national importance.	--	--	--	--	--
	2. To avoid adverse effects on the populations of other protected fish species and habitats.	--	--	--	--	--
	3. To avoid adverse effects on national and local biodiversity target features that include fish habitats and species.	--	--	--	--	--
	4. To avoid adverse effects on recreational and heritage fishing.	--	--	--	--	--
	5. To avoid adverse effects on commercial fish resources.	--	--	--	--	-
	6. To minimise the risk of introduction of non-native fish species.	0	0	0	0	0
Terrestrial and Freshwater Ecology	1. To avoid adverse effects on designated terrestrial and freshwater wildlife sites of international and national importance.	+	+	+	+	+
	2. To avoid adverse effects on valuable terrestrial and freshwater ecological networks.	+	+	+	+	+
	3. To avoid adverse effects on other protected terrestrial and freshwater habitats and species.	+	+	+	+	+
	4. To avoid adverse effects to national and local biodiversity target features including terrestrial and freshwater habitats and species.	+	+	+	+	+
	5. To minimise the risk of introduction of non-native invasive terrestrial and freshwater species.	0	0	0	0	0
	6. To conserve and enhance designated freshwater and terrestrial site features.	+	-	+	-	+
	7. To restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat.	++	+	++	+	++

Alternative Option B3: Brean Down to Lavernock Point Barrage

6.1.2 Marine ecology SEA Objectives 1, 2 and 4 (to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance, to avoid adverse effects on valuable marine ecosystems, and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species), were not considered to be met for this alternative. For these objectives the magnitude of effects and number of receptors affected is broadly proportional to the amount of energy generated in ebb-only options (but smaller for the L3d option which operates an ebb-flood regime). Thus B3 performs worse than other options in relation to these three objectives. Objective 6 (to minimise the risk of introduction of non-native invasive marine species) was also not considered to be met. The likelihood of introductions occurring is related to the size of the new colonising surface provided by the option, thus B3 is considered to present a higher risk than B4 and B5, but a lower risk than the two lagoons. There is also a risk of the spread of *Spartina* which would need to be assessed in more detail if this option were taken forward. However B3 also poses an additional risk of the spread of *Spartina anglica* because of the downshore extension of saltmarsh predicted under this option. This alternative option was assessed as having a major negative performance against marine ecology Objective 7, and also failed to meet Objective 8 (to conserve and enhance designated marine site features, and to restore and enhance marine BAP species populations and/or BAP habitat). Although offsetting measures at locations within the Severn may

contribute to conserving or enhancing protected species and habitats, it remains unlikely that all significant effects can be addressed.

6.1.3 Marine ecology SEA objective 3 (to avoid adverse effects on other protected marine species and their habitats) is considered to be met for this option. The receptors considered as part of this objective are marine mammals and turtles, which are protected under the Habitats Regulations and Wildlife and Countryside Act. This option is not predicted to give rise to significant effects on these features. It is uncertain whether SEA objective 5 for marine ecology (to avoid deterioration in status class of WFD water bodies) would be met for this option. Although there may be some minor reductions in high water level and reduced current speeds under the B3 option, it is considered unlikely to change the status of WFD water bodies. However there is a risk of eutrophication which could potentially cause deterioration in the six water bodies upstream of the B3 Barrage, but it is uncertain whether this will occur.

6.1.4 None of the SEA objectives for waterbirds are considered likely to be met for this option. Assuming the success of measures to prevent and reduce adverse effects, there are likely to be significant negative residual effects for 27 of the 43 receptors relating to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance), 30 of the 45 receptors relating to SEA Objective 2 (to avoid adverse effects on other protected bird habitats and species) and 27 of the 40 receptors relating to SEA Objective 3 (to avoid adverse effects on national and local biodiversity target features that include bird habitats and species). Changes to or loss of intertidal habitat within the Severn Estuary represents the principal effect of this option on waterbirds. Other significant negative effects include changes to saltmarsh, effects on breeding seabirds, and far-field effects of changes in water levels and displacement. There is uncertainty as to the likely success of the key measures that have been proposed to prevent or reduce effects for waterbird receptors within the area of the Severn Estuary. Even if new intertidal habitat can be successfully created through operational changes and topographic modification, existing habitat would still be lost and waterbirds disturbed and displaced. Based on other studies, it is likely that areas of intertidal habitat creation could achieve a biological quality comparable with other intertidal mudflats within 3 to 5 years, but it could take longer for some features to develop. It is concluded that there is likely to be a significant negative residual effect on waterbirds as a result of this option.

6.1.5 Despite the uncertainty surrounding predicted effects on fish outlined earlier in this document, it is almost certain that the first five SEA Objectives for migratory and estuarine fish could not be met for this option (to avoid adverse effects on designated wildlife sites for fish of international and national importance; to avoid adverse effects on the populations of other protected fish species and habitats; to avoid adverse effects on national and local biodiversity target features that include fish habitats and species; to avoid adverse effects on recreational and heritage fishing; and to avoid adverse effects on commercial fish resources). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding the magnitude of effects underpinning these predictions). Measures to prevent or reduce effects could reduce the magnitude of effects on fish populations, but it is considered unlikely that such measures could avoid any adverse effects upon the fish receptors and as such there is a high risk that these SEA objectives may not be met.

6.1.6 SEA objective 6 for migratory and estuarine fish (to minimise the risk of introduction of non-native fish species) is considered likely to be met for this alternative option, as the risk of introduction of non-native fish species is considered to be low.

6.1.7 It is considered possible that all of the SEA objectives for terrestrial and freshwater ecology can be met for this option. In order to meet objectives 1-4, measures to prevent, reduce or as fully as possible offset significant effects would need to be applied, but this is considered feasible. For objective 5 (to minimise the risk of introduction of non-native invasive terrestrial and freshwater species) it is considered that there are no apparent effects. It is considered likely that objectives 6 and 7 (to conserve and enhance designated freshwater and terrestrial site features, and to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat) can be met for some designated terrestrial and freshwater site features.

Alternative Option B4: Shoots Barrage

6.1.8 Marine ecology SEA Objectives 1, 2 and 4 (to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance, to avoid adverse effects on valuable marine ecosystems, and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species), were not considered to be met for this alternative. For these objectives the magnitude of effects and number of receptors affected is broadly proportional to the amount of energy generated in ebb-only options (but smaller for the L3d option which operates an ebb-flood regime) Thus B4 performs better than B3 but worse than smaller options such as B5 and L3d in relation to these three objectives. Objective 6 (to minimise the risk of introduction of non-native invasive marine species) was also not considered to be met. The likelihood of introductions occurring is related to the size of the new colonising surface provided by the option, thus B4 is considered to present a lower risk than all other options except B5 because of the small area of new colonising surface, and because this option would be located upstream of the salinity tolerance of some invasive non-native species. There is also a risk of the spread of *Spartina* which would need to be assessed in more detail if this option were taken forward. This alternative option was assessed as having a major negative performance against marine ecology Objective 7, and also failed to meet Objective 8 (to conserve and enhance designated marine site features, and to restore and enhance marine BAP species populations and/or BAP habitat). Although offsetting measures at locations within the Severn may contribute to conserving or enhancing protected species and habitats, it remains unlikely that all significant effects can be addressed.

6.1.9 Marine ecology SEA objective 3 (to avoid adverse effects on other protected marine species and their habitats) is considered to be met for this option. The receptors considered as part of this objective are marine mammals and turtles, which are protected under the Habitats Regulations and Wildlife and Countryside Act. This option is not predicted to give rise to significant effects on these features. It is also considered that SEA objective 5 for marine ecology (to avoid deterioration in status class of WFD water bodies) would be achieved, assuming all practicable and cost-effective measures were implemented as part of a tidal power project in conformance with WFD Article 4(7) requirements. Of the 10 WFD water bodies most likely to be affected by tidal power development, eight of these are candidate Heavily Modified Water Bodies, and thus have the target of achieving Good Ecological Potential (GEP). These water bodies are currently assessed as being at moderate status based on the 'alternative approach' for determining GEP. Further modification of these water bodies would not lead to deterioration in status as the alternative approach does not recognise classes other than High, Good or Moderate. However there may be deteriorations of some components of the WFD water bodies. For the other two water bodies, Bridgwater Bay and Bristol Channel Inner North, the target is to achieve Good Ecological Status. The status of these sites is considered unlikely to change.

6.1.10 None of the SEA objectives for waterbirds are considered likely to be met for this option. Assuming the success of measures to prevent and reduce adverse effects, there are still likely to be significant negative residual effects for 16 of the 43 receptors relating to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance), 15 of the 45 receptors relating to SEA Objective 2 (To avoid adverse effects on other protected bird habitats and species) and 13 of the 40 receptors relating to SEA Objective 3 (To avoid adverse effects on national and local biodiversity target features that include bird habitats and species). Changes to or loss of intertidal habitat within the Severn Estuary represents the principal effect of this option on waterbirds. Displacement to far-field sites is predicted to be a significant negative effect for one receptor. There is uncertainty as to the likely success of the key measures that have been proposed to prevent or reduce effects for waterbird receptors within the area of the Severn Estuary. Even if new intertidal habitat can be successfully created through operational changes and topographic modification, existing habitat would still be lost and waterbirds disturbed and displaced. Based on other studies, it is likely that areas of intertidal habitat creation could achieve a biological quality comparable with other intertidal mudflats within 3 to 5 years, but it could take longer for some features to develop. It is concluded that there is likely to be a significant negative residual effect on waterbirds as a result of this option. Positive effects in relation to all waterbird objectives are predicted for two waterbird receptors under this option.

6.1.11 Despite the uncertainty surrounding predicted effects on fish outlined earlier in this document, it is almost certain that the first five SEA Objectives for migratory and estuarine fish could not be met for this option (to avoid adverse effects on designated wildlife sites for fish of international and national importance; to avoid adverse effects on the populations of other protected fish species and habitats; to avoid adverse effects on national and local biodiversity target features that include fish habitats and species; to avoid adverse effects on recreational and heritage fishing; and to avoid adverse effects on commercial fish resources). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding these predictions). Measures to prevent or reduce effects could reduce the magnitude of effects on fish populations, but it is considered unlikely that such measures could avoid any adverse effects upon the fish receptors and as such there is a high risk that these SEA objectives may not be met.

6.1.12 SEA objective 6 for migratory and estuarine fish (to minimise the risk of introduction of non-native fish species) is considered likely to be met for this alternative option, as the risk of introduction of non-native fish species is considered to be low.

6.1.13 It is considered possible that all but one of the SEA objectives for terrestrial and freshwater ecology can be met for this option. In order to meet objectives 1-4, measures to prevent, reduce or as fully as possible offset significant effects would need to be applied, but this is considered feasible. For objective 5 (to minimise the risk of introduction of non-native invasive terrestrial and freshwater species) it is considered that there are no apparent effects. It is considered likely that objective 7 (to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat) can be met for some designated terrestrial and freshwater site features.

6.1.14 It is not considered possible in this option to meet terrestrial and freshwater ecology Objective 6 (to conserve and enhance designated freshwater and terrestrial site features) because no opportunities to enhance designated site features were identified.

Alternative Option B5: Beachley Barrage

6.1.15 Marine ecology SEA Objectives 1, 2 and 4 (to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance, to avoid adverse effects on valuable marine ecosystems, and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species), were not considered to be met for this alternative. For these objectives the magnitude of effects and number of receptors affected is broadly proportional to the amount of energy generated in ebb-only options (but smaller for the L3d option which operates an ebb-flood regime). Thus B5 performs better than most other options in relation to these three objectives. Objective 6 (to minimise the risk of introduction of non-native invasive marine species) was also not considered to be met. The likelihood of introductions occurring is related to the size of the new colonising surface provided by the option, thus B5 is considered to present a lower risk than all other options because of the small area of new colonising surface, and because this option would be located upstream of the salinity tolerance of some invasive non-native species. This alternative option was assessed as having a minor negative performance against marine ecology Objective 7, and also failed to meet Objective 8 (to conserve and enhance designated marine site features, and to restore and enhance marine BAP species populations and/or BAP habitat). Although offsetting measures at locations within the Severn may contribute to conserving or enhancing protected species and habitats, it remains unlikely that all significant negative effects can be addressed.

6.1.16 Marine ecology SEA objective 3 (to avoid adverse effects on other protected marine species and their habitats) is considered to be met for this option. The receptors considered as part of this objective are marine mammals and turtles, which are protected under the Habitats Regulations and Wildlife and Countryside Act. This option is not predicted to give rise to significant effects on these features. It is also considered that SEA objective 5 for marine ecology (to avoid deterioration in status class of WFD water bodies) would be achieved, assuming all practicable and cost-effective measures were implemented as part of a tidal power project in conformance with WFD Article 4(7) requirements. Of the 10 WFD water bodies most likely to be affected by tidal power development, eight of these are candidate Heavily Modified Water Bodies, and thus have the target of achieving Good Ecological Potential (GEP). These water bodies are currently assessed as being at moderate status based on the 'alternative approach' for determining GEP. Further modification of these water bodies would not lead to deterioration in status as the alternative approach does not recognise classes other than High, Good or Moderate. However there may be deteriorations of some components of the WFD water bodies. For the other two water bodies, Bridgwater Bay and Bristol Channel Inner North, the target is to achieve Good Ecological Status. The status of these sites is considered unlikely to change.

6.1.17 None of the SEA objectives for waterbirds are considered likely to be met for this option. Assuming the success of measures to prevent and reduce adverse effects, there are still likely to be significant negative residual effects for 14 of the 43 receptors relating to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance), 13 of the 45 receptors relating to SEA Objective 2 (To avoid adverse effects on other protected bird habitats and species) and 10 of the 40 receptors relating to SEA Objective 3 (To avoid adverse effects on national and local biodiversity target features that include bird habitats and species). Changes to or loss of intertidal habitat within the Severn Estuary represents the principal effect of this option on waterbirds. There is uncertainty as to the likely success of the key measures that have been proposed to prevent or reduce effects for waterbird receptors within the area of the Severn

Estuary. Even if new intertidal habitat can be successfully created through operational changes and topographic modification, existing habitat would still be lost and waterbirds disturbed and displaced. Based on other studies, it is likely that areas of intertidal habitat creation could achieve a biological quality comparable with other intertidal mudflats within 3 to 5 years, but it could take longer for some features to develop. It is concluded that there is likely to be a significant negative residual effect on waterbirds as a result of this option.

6.1.18 Despite the uncertainty surrounding predicted effects on fish outlined earlier in this document, it is almost certain that the first five SEA Objectives for migratory and estuarine fish could not be met for this option (to avoid adverse effects on designated wildlife sites for fish of international and national importance; to avoid adverse effects on the populations of other protected fish species and habitats; to avoid adverse effects on national and local biodiversity target features that include fish habitats and species; to avoid adverse effects on recreational and heritage fishing; and to avoid adverse effects on commercial fish resources). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding these predictions). Measures to prevent or reduce effects could reduce the magnitude of effects on fish populations, but it is considered unlikely that such measures could avoid any negative effects upon the fish receptors and as such there is a high risk that these SEA objectives may not be met.

6.1.19 SEA objective 6 for migratory and estuarine fish (to minimise the risk of introduction of non-native fish species) is considered likely to be met for this alternative option, as the risk of introduction of non-native fish species is considered to be low.

6.1.20 It is considered possible that all of the SEA objectives for terrestrial and freshwater ecology can be met for this option. In order to meet objectives 1-4, measures to prevent, reduce or as fully as possible offset significant effects would need to be applied, but this is considered feasible. For objective 5 (to minimise the risk of introduction of non-native invasive terrestrial and freshwater species) it is considered that there are no apparent effects. It is considered likely that objectives 6 and 7 (to conserve and enhance designated freshwater and terrestrial site features, and to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat) can be met for some designated terrestrial and freshwater site features.

Alternative Option L2: Welsh Grounds Lagoon

6.1.21 Marine ecology SEA Objectives 1, 2 and 4 (to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance, to avoid adverse effects on valuable marine ecosystems, and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species), were not considered to be met for this alternative. For these objectives the magnitude of effects and number of receptors affected is broadly proportional to the amount of energy generated in ebb-only options (but smaller for the L3d option which operates an ebb-flood regime). Thus L2 performs better than B3 but worse than smaller options such as B5 and L3d in relation to these three objectives. Objective 6 (to minimise the risk of introduction of non-native invasive marine species) was also not considered to be met. The likelihood of introductions occurring is related to the size of the new colonising surface provided by the option, thus L2 is considered to present a higher risk than all other options. This alternative option was assessed as having a major negative performance against marine ecology Objective 7, and also failed to meet Objective 8 (to conserve and enhance designated marine site features, and to restore and enhance marine BAP species populations and/or BAP habitat). Although offsetting measures at locations within the Severn may contribute to

conserving or enhancing protected species and habitats, it remains unlikely that all significant negative effects can be addressed.

6.1.22 Marine ecology SEA objective 3 (to avoid adverse effects on other protected marine species and their habitats) is considered to be met for this option. The receptors considered as part of this objective are marine mammals and turtles, which are protected under the Habitats Regulations and Wildlife and Countryside Act. This option is not predicted to give rise to significant effects on these features. It is also considered that SEA objective 5 for marine ecology (to avoid deterioration in status class of WFD water bodies) would be achieved, assuming all practicable and cost-effective measures were implemented as part of a tidal power project in conformance with WFD Article 4(7) requirements. Of the 10 WFD water bodies most likely to be affected by tidal power development, eight of these are candidate Heavily Modified Water Bodies, and thus have the target of achieving Good Ecological Potential (GEP). These water bodies are currently assessed as being at moderate status based on the 'alternative approach' for determining GEP. Further modification of these water bodies would not lead to deterioration in status as the alternative approach does not recognise classes other than High, Good or Moderate. However there may be deteriorations of some components of the WFD water bodies. For the other two water bodies, Bridgwater Bay and Bristol Channel Inner North, the target is to achieve Good Ecological Status. The status of these sites is considered unlikely to change.

6.1.23 None of the SEA objectives for waterbirds are considered likely to be met for this option. Assuming the success of measures to prevent and reduce adverse effects, there are still likely to be significant negative residual effects for 14 of the 43 receptors relating to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance), 13 of the 45 receptors relating to SEA Objective 2 (To avoid adverse effects on other protected bird habitats and species) and 12 of the 40 receptors relating to SEA Objective 3 (To avoid adverse effects on national and local biodiversity target features that include bird habitats and species). Changes to or loss of intertidal habitat within the Severn Estuary represents the principal effect of this option on waterbirds. Disturbance (mainly during construction and decommissioning) is also likely to be of particular significance. There is uncertainty as to the likely success of the key measures that have been proposed to prevent or reduce effects for waterbird receptors within the area of the Severn Estuary. Even if new intertidal habitat can be successfully created through operational changes and topographic modification, existing habitat would still be lost and waterbirds disturbed and displaced. Based on other studies, it is likely that areas of intertidal habitat creation could achieve a biological quality comparable with other intertidal mudflats within 3 to 5 years, but it could take longer for some features to develop. It is concluded that there is likely to be a significant negative residual effect on waterbirds as a result of this option.

6.1.24 Despite the uncertainty surrounding predicted effects on fish outlined earlier in this document, it is almost certain that the first five SEA Objectives for migratory and estuarine fish could not be met for this option (to avoid adverse effects on designated wildlife sites for fish of international and national importance; to avoid adverse effects on the populations of other protected fish species and habitats; to avoid adverse effects on national and local biodiversity target features that include fish habitats and species; to avoid adverse effects on recreational and heritage fishing; and to avoid adverse effects on commercial fish resources). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding these predictions). Measures to prevent or reduce effects could reduce the magnitude of effects on fish populations, but it is considered unlikely

that such measures could avoid any adverse effects upon the fish receptors and as such there is a high risk that these SEA objectives may not be met.

6.1.25 SEA objective 6 for migratory and estuarine fish (to minimise the risk of introduction of non-native fish species) is considered likely to be met for this alternative option, as the risk of introduction of non-native fish species is considered to be low.

6.1.26 It is considered possible that all but one of the SEA objectives for terrestrial and freshwater ecology can be met for this option. In order to meet objectives 1-4, measures to prevent, reduce or as fully as possible offset significant effects would need to be applied, but this is considered feasible. For objective 5 (to minimise the risk of introduction of non-native invasive terrestrial and freshwater species) it is considered that there are no apparent effects. It is considered likely that objective 7 (to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat) can be met for some designated terrestrial and freshwater site features.

6.1.27 It is not considered possible in this option to meet terrestrial and freshwater ecology Objective 6 (to conserve and enhance designated freshwater and terrestrial site features) because no opportunities to enhance designated site features were identified.

Alternative Option L3d: Bridgwater Bay Lagoon

6.1.28 Marine ecology SEA Objectives 1, 2 and 4 (to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance, to avoid adverse effects on valuable marine ecosystems, and to avoid adverse effects on national and local biodiversity target features that include marine habitats and species), were not considered to be met for this alternative. For these objectives the magnitude of effects and number of receptors affected is broadly proportional to the amount of energy generated in ebb-only options (but smaller for the L3d option which operates an ebb-flood regime). Thus L3d performs better than most other options in relation to these three objectives. Objective 6 (to minimise the risk of introduction of non-native invasive marine species) was also not considered to be met. The likelihood of introductions occurring is related to the size of the new colonising surface provided by the option, thus L3d is considered to present a higher risk than all other options except L2 because of the large area of new colonising surface. This alternative option was assessed as having a minor negative performance against marine ecology Objective 7, and also failed to meet Objective 8 (to conserve and enhance designated marine site features, and to restore and enhance marine BAP species populations and/or BAP habitat). Although offsetting measures at locations within the Severn may contribute to conserving or enhancing protected species and habitats, it remains unlikely that all significant effects can be addressed.

6.1.29 Marine ecology SEA objective 3 (to avoid adverse effects on other protected marine species and their habitats) is considered to be met for this option. The receptors considered as part of this objective are marine mammals and turtles, which are protected under the Habitats Regulations and Wildlife and Countryside Act. This option is not predicted to give rise to significant effects on these features. It is uncertain whether SEA objective 5 for marine ecology (to avoid deterioration in status class of WFD water bodies) would be met. A proportion of the Bridgwater Bay water body would lie within the L3d lagoon and the water body would be transacted by the lagoon wall. Changes to physical processes and intertidal habitat extent may cause deterioration in the status of hydromorphological and biological quality elements in the Bridgwater Bay water body, but it is uncertain whether this will occur.

6.1.30 None of the SEA objectives for waterbirds are considered likely to be met for this option. Assuming the success of measures to prevent and reduce adverse effects, there are likely to be significant negative residual effects for 12 of the 43 receptors relating to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for birds and protected habitats of international and national importance), 12 of the 45 receptors relating to SEA Objective 2 (To avoid adverse effects on other protected bird habitats and species) and 12 of the 40 receptors relating to SEA Objective 3 (To avoid adverse effects on national and local biodiversity target features that include bird habitats and species). Negative effects of this option on waterbirds include disturbance (mainly during construction and decommissioning), negative effects on breeding seabirds and loss of or changes to intertidal habitat. However, the only significant negative effect of this option for 14 of the affected species is disturbance during the construction phase, which although significant is likely to have a much lower impact than the long-term effects of other schemes. Therefore the magnitude of effects on waterbirds is lower for this option compared to others. There is uncertainty as to the likely success of the key measures that have been proposed to prevent or reduce effects for waterbird receptors within the area of the Severn Estuary, therefore it is concluded that there is likely to be a significant negative residual effect requiring compensation.

6.1.31 Despite the uncertainty surrounding predicted effects on fish outlined earlier in this document, it is almost certain that the first five SEA Objectives for migratory and estuarine fish could not be met for this option (to avoid adverse effects on designated wildlife sites for fish of international and national importance; to avoid adverse effects on the populations of other protected fish species and habitats; to avoid adverse effects on national and local biodiversity target features that include fish habitats and species; to avoid adverse effects on recreational and heritage fishing; and to avoid adverse effects on commercial fish resources). This is because the assessment predicts major negative effects on fish populations (although there is considerable uncertainty surrounding these predictions). Measures to prevent or reduce effects could reduce the magnitude of effects on fish populations, but it is considered unlikely that such measures could avoid any adverse effects upon the fish receptors and as such there is a high risk that these SEA objectives may not be met.

6.1.32 SEA objective 6 for migratory and estuarine fish (to minimise the risk of introduction of non-native fish species) is considered likely to be met for this alternative option, as the risk of introduction of non-native fish species is considered to be low.

6.1.33 It is considered possible that all of the SEA objectives for terrestrial and freshwater ecology can be met for this option. In order to meet objectives 1-4, measures to prevent, reduce or as fully as possible offset significant effects would need to be applied, but this is considered feasible. For objective 5 (to minimise the risk of introduction of non-native invasive terrestrial and freshwater species) it is considered that there are no apparent effects. It is considered likely that objectives 6 and 7 (to conserve and enhance designated freshwater and terrestrial site features, and to restore and enhance freshwater and terrestrial BAP species populations and/or BAP habitat) can be met for some designated terrestrial and freshwater site features.

SECTION 7

IMPLEMENTATION

7 IMPLEMENTATION

7.1 Proposals for monitoring

7.1.1 The SEA Directive requires that measures to monitor the significant environmental effects are described within the environmental reporting. Monitoring allows the actual significant environmental effects of implementing a Severn Tidal Power alternative option to be tested against those predicted.

7.1.2 This section sets out suggestions for the framework for the monitoring of the plan against the predicted significant effects within this theme which can be applied to all of the Severn Tidal Power Schemes under consideration. Table 7.1 includes a brief summary of monitoring recommended for this theme and identifies any interactions or inconsistencies between the topics within this theme.

7.1.3 Much of the work outlined in this section would be extremely valuable whether or not a Severn Tidal Power option is taken forward, as conducting this work would ensure that any future proposals are much better informed.

7.1.4 It would be recommended that a range of measures were implemented prior to plan implementation to aid assessment of effects and option development. This is particularly important for marine ecology and migratory and estuarine fish receptors in order to better understand the baseline populations and the likely effects of the alternative options. It would not be possible to implement all of the recommended measures before 2014, when it is currently proposed that construction would commence if a tidal power option is taken forward.

7.1.5 By establishing a sound and long-term monitoring programme from the outset, a firm evaluation of the changes consequent of construction of any of the alternative options would be possible. This could also be important in informing any future proposals for other tidal power options.

7.1.6 The magnitude and spatial extent of predicted effects on the full range of marine ecology receptors would necessarily require the development and implementation of a detailed, intensive and long-term monitoring programme to assess actual changes relative to predictions. This programme would need to include extensive long-term monitoring of changes in habitat extent and habitat quality as well as population level responses of key receptors to changes in ecosystem functioning associated with changes in food supply and biological interaction. Additional studies would be required to assess the effects of obstruction on mobile epibenthos and possibly also marine mammals as well as any effects associated with reduced larval transport. Some monitoring of construction effects may also be necessary, for example, in relation to underwater noise.

7.1.7 Comprehensive monitoring of the waterbirds of the Severn Estuary would be recommended for a number of years prior to the proposed start of construction in 2014. This monitoring would comprise counts (complete coverage of WeBS Core and low-tide counts, as well as through-the-tide and nocturnal surveys), breeding season surveys and studies of survival, recruitment and condition of waterbirds. A minimum of five years comprehensive monitoring would provide the five-year mean peak data required to establish a firm baseline, but this would not be possible if construction begins in 2014 as currently proposed. It would be recommended that this monitoring continues through the proposed 2014-2020 construction period and for a minimum of

10 years after option implementation, or until environmental conditions and bird numbers on the estuary have stabilised if this takes more than 10 years. As the estuary is predicted to continue to evolve over the full period of operation (2020-2140) under all options, then waterbird populations are predicted to continue to be affected and continued monitoring (though perhaps at a lower intensity) would be recommended for this whole period.

7.1.8 To assess changes in fish populations and identify appropriate levels of measures to prevent or reduce adverse effects and compensation from the installation of an STP scheme it would be necessary to monitor migratory and estuarine fish populations pre and post construction. The pre-construction monitoring period would ideally be at least five years, but this would not be possible if construction began in 2014 as currently proposed. Sufficient post construction monitoring would be required to distinguish between temporary construction and longer term operation effects and assess the effectiveness of measures to prevent or reduce adverse effects and the outcome of offsetting and compensation measures. Where historical monitoring of a sufficient nature to determine a significant change exists, it is suggested that this monitoring be continued. However it is likely that this would need to be conducted on a more regular basis and annual sampling is suggested. Methods of sampling may need to be adapted to enable, where feasible, a quantitative assessment of whole stocks (not just site-based monitoring) and integrity of all species and utilised habitats. This is particularly pertinent for the two shad species. It may be necessary to supplement existing sampling with additional techniques, sites and where necessary, frequency. In addition to monitoring stocks at those sites where effects may be felt it would also be necessary to monitor stocks at sites at which compensation measures were intended to be implemented. It is suggested that statistical tools such as Bohlin and Power Analysis are used to determine an appropriate number of sites to be monitored in order to detect as a minimum, a change equivalent to a halving or doubling of the population. It would be important to gather information on demographic processes such as survival and fecundity as part of this monitoring programme.

7.1.9 To monitor significant effects on terrestrial and freshwater ecology receptors an accurate and detailed baseline must be established; this would be a likely requirement of any subsequent detailed assessments if an alternative option is taken forward. A complete baseline assessment of areas where effects are predicted and an appropriate buffer for all receptors would be required. This would be of particular importance for non-designated areas where the baseline conditions are usually far less thoroughly documented. It is likely that two years of baseline data would be required to provide a condition assessment against which effects could be monitored. Prior to construction it is envisaged that measures to prevent, reduce and offset would be implemented; these measures would need monitoring to ensure they achieve the desired objectives. Monitoring would be required for sensitive receptors throughout the construction phase and in particular for those areas where measures to prevent, reduce and offset have been implemented. A monitoring period for ten consecutive years following commencement of operation would be appropriate; continued with a strategic monitoring programme throughout the operational life of the scheme.

7.1.10 The monitoring and research suggested here would represent by far the largest programme of its kind, and would involve the development of some untested tools and techniques. It is strongly suggested that liaison with a range of relevant specialists is undertaken to assist in the development this programme of monitoring and research, if it is taken forward.

Table 7.1: Potential Monitoring Summary for Theme Reporting

Monitoring suggestion for significant environmental effects	Receptor	Topics covered	Comment
Assessment of changes in habitat extent in response to: water levels • initial mud deposition • tidal curve • long-term morphology	Mudflat and sandflat, Intertidal rock, shingle, saltmarsh, grassland, eelgrass, macroalgae, subtidal habitats including subtidal sandbanks and *Sabellaria alveolata* reefs	Marine ecology	-
Changes in habitat quality in response to: • short-term erosion/deposition, scour, currents, waves • long-term morphology	Mudflat and sandflat, intertidal rock, shingle, saltmarsh, grassland, subtidal habitats including subtidal sandbanks and *Sabellaria alveolata* reefs	Marine ecology	-
Changes in upstream/downstream movements of receptors: • population dynamics of mobile epibenthos and marine mammals • long-term distributions of receptors dependant on larval transport	Epibenthos, cephalopods, marine mammals, larval transport (plankton, macroalgae, saltmarsh, intertidal mudflats and sandflats, subtidal habitats)	Marine ecology	Monitors obstruction effects
Changes in biological interactions: • primary productivity • population dynamics of benthic invertebrates, epibenthos	Plankton, intertidal and subtidal habitats	Marine ecology	-
Responses to construction noise: • distribution of mobile epibenthos, marine mammals	Mobile epibenthos, marine mammals	Marine ecology	-

Monitoring suggestion for significant environmental effects	Receptor	Topics covered	Comment
WeBS Core Counts of the Severn Estuary to monitor non-breeding populations	Bewick's swan, European white-fronted goose, shelduck, wigeon, teal, mallard, pintail, shoveler, pochard, tufted duck, little egret, oystercatcher, ringed plover, golden plover, grey plover, lapwing, knot, dunlin, snipe, black-tailed godwit, bar-tailed godwit, whimbrel, curlew, spotted redshank, greenshank, redshank, turnstone, black-headed gull, lesser black-backed gull, herring gull, waterbird assemblage	Waterbirds	Monitors a number of effects including: • Disturbance during construction and decommissioning • Changes to or loss of intertidal habitat • Changes to saltmarsh
WeBS Low Tide Counts of the Severn Estuary, and through-the-tide counts and nocturnal surveys, to inform on changes in distributions	Bewick's swan, European white-fronted goose, shelduck, wigeon, teal, mallard, pintail, shoveler, pochard, tufted duck, little egret, oystercatcher, ringed plover, golden plover, grey plover, lapwing, knot, dunlin, snipe, black-tailed godwit, bar-tailed godwit, whimbrel, curlew, spotted redshank, greenshank, redshank, turnstone, black-headed gull, lesser black-backed gull, herring gull, waterbird assemblage	Waterbirds	Monitors a number of effects including: • Disturbance during construction and decommissioning • Changes to or loss of intertidal habitat • Changes to saltmarsh
Breeding season surveys of seabirds on Flat Holm and Steep Holm	Lesser black-backed gull, herring gull	Waterbirds	Monitors a number of effects including: • Disturbance during construction and decommissioning • Effects on breeding seabirds
Marking and tracking studies to inform on movements and survival of individuals and recruitment. Condition studies.	Shelduck, wigeon, teal, mallard, pintail, shoveler, pochard, tufted duck, little egret, oystercatcher, ringed plover, golden plover, grey plover, lapwing, knot, dunlin, snipe, black-tailed godwit, bar-tailed godwit, whimbrel, curlew, spotted redshank, greenshank, redshank, turnstone, black-headed gull, lesser black-backed gull, herring gull, waterbird assemblage	Waterbirds	Monitors effects of changes to or loss of intertidal habitat
Breeding season surveys of nesting waders	Redshank	Waterbirds	Monitors changes to saltmarsh

Monitoring suggestion for significant environmental effects	Receptor	Topics covered	Comment
Evaluation of WeBS Core Count data from other key sites to monitor non-breeding populations	Greenland white-fronted goose, shelduck, wigeon, teal, pintail, shoveler, little egret, grey plover, knot, dunlin, curlew, spotted redshank, greenshank, waterbird assemblage.	Waterbirds	Monitors far-field effects including: • Displacement • Changes in water levels
Monitor fish migration to identify any increased straying or delay	All diadromous fish receptors	Migratory and Estuarine Fish	Monitors effects of alterations to migratory cues
Monitor fish losses, population sustainability, delay to passage, effects upon reproductive success	All fish receptors	Migratory and Estuarine Fish	Monitors effects of disruption to route of passage
Monitor species distribution and abundance within key habitats	All fish receptors	Migratory and Estuarine Fish	Monitors effects of habitat change and/or loss
Monitor water quality parameters and assess against key fish receptor thresholds. Monitor fish behaviour and distribution.	All fish receptors	Migratory and Estuarine Fish	Monitors effects of changes to water quality
Monitor background, construction, operation and decommissioning noise levels and assess potential effects upon the thresholds of key fish receptors. Monitor distribution of key fish receptors during noise generating activities.	All fish receptors	Migratory and Estuarine Fish	Monitors effects of anthropogenic noise disturbance
Assess and monitor potential effects resulting from those identified above	Freshwater, estuarine and marine fish species	Migratory and Estuarine Fish	Monitors effects upon freshwater, estuarine and marine fish species
Monitor rod catches and landings. Liaise with fishery owners and commercial crafts	Target fish species	Migratory and Estuarine Fish	Monitors effects upon recreational, heritage, commercial and shell fisheries

Monitoring suggestion for significant environmental effects	Receptor	Topics covered	Comment
Terrestrial and freshwater habitat and species monitoring compared against baseline conditions to identify negative or positive changes in abundance, distribution and diversity of all relevant receptors	SACs and Annex 1 habitats, Ramsar Sites (non waterbird interest), SSSIs & NNRs (non geological), LNRs, habitats and landscape corridors, lichen and fungi, plants, crustaceans and molluscs, invertebrates, herpetiles, birds (non waterbird species), mammals	Terrestrial and Freshwater Ecology	Monitors a number of effects including: • Habitat loss / fragmentation / degradation during construction, operation, decommissioning • Disturbance / mortality during construction and decommissioning • Reduction in species abundance during operation • Habitat enhancement

7.2 Suggestions for further research

7.2.1 This section includes some suggestions for research to support further consideration of tidal power in the Severn Estuary.

7.2.2 Further research is required to establish a better understanding of the baseline conditions for all biodiversity receptors, as outlined in the proposals for monitoring above.

7.2.3 Assessment of some of the effects on biodiversity receptors could be greatly improved if further research were conducted to gather data and information to inform these assessments, and ideally this would be done before the decision is made to implement an option.

7.2.4 Further studies could be conducted to gather baseline information on the distribution and abundance of some marine ecology receptors, particularly cephalopods, and to get a better understanding of the variability of *Sabellaria* distributions within the Severn Estuary.

7.2.5 As many of the data used to inform the marine ecology study are old (derived from studies in the 1970s or 1980s), limited to certain receptors or site specific, it would be pertinent to conduct a programme of research to update and expand these data to gather comprehensive information on all receptors from a wide range of sites within the Severn Estuary. Updated data on the intertidal invertebrate community would be particularly valuable in informing the both the marine ecology assessment and the assessment of other biodiversity receptors that feed on intertidal invertebrates, such as birds and fish.

7.2.6 Coverage of WeBS Core Counts of waterbirds in years prior to 2008/09 was incomplete, so the five-year mean peak values for some species may provide underestimates. Therefore complete WeBS core counts would need to be conducted for a period of five years, in order that the five-year mean peak values used to represent the baseline are accurate.

7.2.7 Further development of modelling techniques for waterbirds could reduce the levels of uncertainty surrounding predictions. Specifically, developing habitat association models to made predictions at the mudflat scale rather than the whole-estuary scale could improve certainty surrounding predictions of effects. Work to compare the habitat association and individual-based models, so that differences between their predictions can be better understood in the future, would also be of considerable benefit in reducing uncertainty surrounding predicted effects on waterbirds.

7.2.8 It would greatly improve the levels of certainty surrounding the migratory and estuarine fish assessment if research were conducted to determine the behaviour of fish within the estuary, habitat utilisation by fish species and their prey, the effects of water quality on fish populations, the cumulative and synergistic effects of contaminants, and to understand the hearing frequencies and range of many species. Research is also required to gather data describing important life stages in many species' life-history within the Severn Estuary.

7.2.9 For effects on fish to be addressed effectively, a major programme of long-term research would be required to develop a strategy to prevent, reduce and offset effects on migratory and estuarine fish. This could include research to identify which of the proposed measures to prevent, reduce and offset effects on fish could be effective. A long-term research programme to identify further measures to prevent or reduce effects on fish would also be useful, as there are some additional potential measures that are promising but not currently ready for application without substantial further investigation. These include cessation of generation during peak migration periods for 'at-risk' species and fish passage management (e.g. bypasses for transporting downstream-migrating fish past a structure or fish lifts and locks for transporting migrating fish in both directions), as it is currently uncertain whether these measures could be effective.

7.2.10 The baseline for the terrestrial and freshwater ecology topic has been developed entirely through desk based study. A programme of field research to establish an accurate and detailed baseline could improve the levels of certainty surrounding this topic assessment.

SECTION 8

GLOSSARY

8 GLOSSARY

Term	Definition
Barrage	A manmade obstruction across a watercourse to retain a head of water on the rising tide, and then run the water through turbines when the tide level drops.
Bristol Channel	The area seaward of the headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast (see Severn Estuary and also Inner Bristol Channel and Outer Bristol Channel)
Bulb Kapeller type turbines	The Kapeller Bulb turbine is a turbine regulated only by its adjustable runner blades (single regulation). It has fixed wicket gates. It is adaptable to pumping as well as generation but only suited to one way generation. Kapeller Bulb turbine technology has largely been superseded by Bulb Kaplan turbines.
Bulb Kaplan turbines	The Kaplan turbine is a propeller-type water turbine that has adjustable blades and adjustable wicket gates (double regulation). It is adaptable to pumping as well as generation. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The Kaplan turbine is suited to one or two way generation.
Bulb turbines	The generator is mounted in a bulb on the main turbine axis upstream of the runner blades for one way generation. Bulb turbines can be used for one or two way generation depending on the type (see above).
Caissons	Prefabricated concrete units used to construct parts of a barrage, lagoon or other offshore structures. Caissons can be used to house turbines, sluices or to construct navigation locks, or they may just be plain units used for impoundment construction.
Coastal Squeeze	Process whereby the coastal margin is squeezed between a fixed landward boundary and the rising sea level
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage. Only used in relation to the Habitats Directive (see offsetting, below).
Consequential development	It is conceivable that a major tidal power scheme would facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as ‘consequential developments’.
Conservative	A conservative approach has been used in the waterbirds topic paper, where two modelling approaches were used. The greater adverse effect of the two predictions was taken through into the assessment.
Cumulative effects	Effects arise, for instance, where several developments each have insignificant effects but together have a significant effect, or where several individual effects of the plan have a combined effect.
Diadromous fish	Fish species that migrate between freshwater and saltwater at different stages in their life-cycle.

Term	Definition
Direct effects	The original effect as a result of an option (see indirect effects)
Ebb	When the sea or tide ebbs, it moves away from the coast and falls to a lower level
Ebb mode	One way generation on ebb tides only i.e. during the period between high tide and the next low tide in which the sea is receding.
Ebb and flood mode	Two way generation during the ebb and flood tides
Effect	Used to describe changes to the environment as a result of an option (see also direct effects, indirect effects, far-field effects and cumulative effects)
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorus). This in turn can lead to 'eutrophication effects' – an increase in an ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
Far-field effects	Effects that are felt outside the Severn Estuary study area.
Flood	The inward flow of the tide - this is the opposite of ebb. This refers to a mode of operation for a STP alternative option
Future baseline	Baseline during construction (2014-2020) and operation (2020-2140), decommissioning and longer term trends.
Geomorphology	The study of the changing form of the estuarine environment and its components in relation to physical forcing.
Hydrodynamics / hydraulics	The science of physical forces acting on the water.
Impoundment	A body of water, such as a reservoir, made by impounding
Indicator	A measure of variables over time, often used to measure achievement of objectives.
Indirect effects	Those effects which occur away from the original effect or as a result of a complex pathway.
Lagoon(s)/ Land-connected lagoons	A man-made enclosed body of water that retains a head of water on the rising tide and then runs the water through turbines when the tide level drops. A land connected lagoon uses the shoreline to make the enclosure.
Long-listed options	All options identified in the SDC report, Call for Proposals and other strategically selected proposals as well as the Interim Options Analysis Report.
Measures to prevent or reduce effects	Measures to prevent, or reduce any significant adverse effects on the environment

Term	Definition
Natura 2000	Natura 2000 is the European Union-wide network of protected areas, recognised as 'sites of Community importance' under the EC Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). The Natura 2000 network includes two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Negative effects	Changes which are unfavourable for a receptor. Can sometimes be referred to as 'adverse'.
Offsetting	Measures to as fully as possible offset any significant adverse effects on the environment. Such measures would aim to make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. Not used in relation to the Habitats Directive (see compensation, above).
One way generation	The operating mode whereby power is generated on only one phase of the tidal cycle. For Severn tidal power, one way generation is typically ebb mode.
Original scheme	The form of the scheme when it was shortlisted at the end of phase 1
Permanent effect	An effect which would last at least for 50 years.
Phase 1	The first stage of the STP Feasibility Study - i.e. the Decision Making Assessment Framework (to develop a short-list of options) and SEA Scoping.
Phase 2	The second stage of the STP Feasibility Study - i.e. short-listed options appraisal and main assessment stage of the SEA.
Positive effects	Changes which are favourable for a receptor. Can sometimes be referred to as 'beneficial'.
Pumping	Operating turbines in reverse to pump water from lower to higher levels. Pumping can be used during one way generation to raise impounded water levels so that more energy can be generated when the ebb tide is receding.
Ramsar site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Reversible	If the timescale for a receptor's return to baseline condition is less than 50 years then it will be considered reversible.
Scoping	The process of deciding the scope and level of detail of an SEA, including the environmental effects and alternatives which need to be considered, the assessment methods to be used, and the structure and contents of the Environmental Report.
SEA objective	A statement of what is intended, specifying the desired direction of change in trends.

Term	Definition
Seabed	The areas permanently covered by the sea, i.e. Lowest Astronomical Tide. Sometimes referred to as subtidal.
Severn Estuary	This is the physical extent of the Estuary and does not reflect the Study Area (see below) or nature conservation designations. Downstream limit - headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast passing through the small island features of Flat Holm and Steep Holm. Upstream limit – Haw Bridge, upstream of Gloucester on the River Severn (based on 1 in 100 year flood risk area and also used by Shoreline Management Plan (SMP) (Gifford, 1998) and Coastal Habitat Management Plan (CHaMP) (ABPmer 2006)). N.B. The tidal limit, which for the Severn is at Maisemore (West Parting) and Llanthony (East Parting) weirs, near Gloucester.
Severn Tidal Power Study Area	The general study area used for the project broadly extends 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 the River Usk. Study areas for individual topics for Phase 2 may extend beyond this area and these are defined separately according to topic.
Short-listed options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.
Significant environmental effects	Effects on the environment which are significant in the context of a plan or programme. Criteria for assessing significance are set out in Annex II of the SEA Directive (2001/42/EC).
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Sluice caissons	Prefabricated concrete structures placed into the water to house a sluice.
Special Area of Conservation (SAC)	Strictly protected site designated under the EC Habitats Directive 92/43/EEC. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).
Special Protection Area (SPA)	Strictly protected site classified in accordance with Article 4 of the EC Directive on the Conservation of Wild Birds (79/409/EEC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.

Term	Definition
Straflo type turbines	A more compact turbine compared to Bulb turbine technology. Instead of containing the generator in a bulb, it is located and designed for ebb only operation and not suited to pumping.
Strategic Environmental Assessment (SEA)	Term used to describe environmental assessment as applied to policies, plans and programmes. 'SEA' is used to refer to the type of environmental assessment required under the SEA Directive.
Subtidal	Areas (particularly with reference to habitats) that lie below the level of the lowest astronomical tide.
Synergistic effects	Effects which interact to produce a total effect greater than the sum of the individual effects, so that the nature of the final impact is different to the nature of the individual effects. Included within cumulative effects (see above).
Temporary effects	An effects which only lasts part of the project lifetime, e.g. is confined to the construction period.
The Shoots	The downstream boundary extends from Undy along the Welsh coast to Severn Beach along the English coast, just to the south of the M4 motorway crossing. The upstream limit extends just to the north of the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary
Transboundary Effects	An environmental effect upon another EU Member State.
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
TWh/year	A unit used to describe how much energy generated, sold, consumed, etc. A terawatt-hour refers to generating or using power at a capacity of 1 terawatt (1012 watts) for one hour. A terawatt-hour per year means the equivalent amount of power sometime within the period of a year.
Two way generation	The operating mode whereby power is generated on both phases of the tidal cycle (ebb and flood)
Upper Severn Estuary	Upstream from the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast, to the tidal limit along the River Severn at Maisemere, Gloucestershire.
Variant	A modified version of the original shortlisted scheme.

SECTION 9

REFERENCES

9 REFERENCES

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