DECC

SEVERN TIDAL POWER - SEA TOPIC PAPER

Marine Ecology

April 2010

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

In association with
Black and Veatch Limited
and
ABPmer

Prepared for
DECC
3 Whitehall Place
London
SW1A 2HD

ABBREVIATIONS

ABBREVIATIONS

The following abbreviations are used in this Topic Report:

AONB	Areas of Outstanding Natural Beauty
BAP	Biodiversity Action Plan
BERR	Department for Business, Enterprise and Regulatory Reform
BTO	British Trust for Ornithology
CCW	Countryside Council for Wales
Cd	Cadmium
CHaMP	Coastal Habitat Management Plan
cSAC	Candidate Special Area of Conservation
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
G8	Group of 8 Nations
GEP	Good Ecological Potential
GHG	Greenhouse Gases
GIS	Geographical Information System
GW	Gigawatts
Hg	Mercury
HMWB	Heavily Modified Water Body
HRA	Habitats Regulations Assessment
LNR	Local Nature Reserve
MW	Megawatt
NERC	Natural Environment and Rural Communities Act
Ni	Nickel
NNR	National Nature Reserve
NP	National Park
NPS	National Policy Statement
ODPM	Office of the Deputy Prime Minister
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PPG	Planning Policy Guidance
PPS	Planning Policy Statements
PSA	Public Service Agreement
PWS	Public Water Source
RIGS	Regional Important Geological Sites
SAC	Special Area of Conservation
SDC	Sustainable Development Commission
SEA	Strategic Environmental Assessment
SEFRMS	Severn Estuary Flood Risk Management Strategy
SLR	Sea Level Rise
SNCI	Sites of Nature Conservation Importance
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
TAN	Technical Advice Note
TWh	Terrawatt hours
UKCIP	United Kingdom Climate Impacts Programme
UN	United Nations
WeBS	Wetland Bird Survey
WFD	Water Framework Directive

Zn	Zinc

NON TECHNICAL SUMMARY

NON TECHNICAL SUMMARY

Introduction

A strategic environmental assessment (SEA) is being conducted as part of the Severn Tidal Power (STP) feasibility study, in accordance with the requirements of the EU SEA Directive and UK Regulations. The SEA comprises two phases: Phase 1, the scoping stage, has already been undertaken. This Marine Ecology topic paper forms part of the reporting arising from Phase 2, the main assessment of short-listed options.

Consultation

The following consultation activities have been undertaken:

- Scoping consultation in January 2009
- Technical Workshops held in July 2008, June, 2009 and November 2009
- Additional consultation was undertaken with the statutory agencies through several teleconference updates as well as through informal consultation and discussion. Advice was also sought from external experts.

It does not mean that the consultees necessarily endorse or agree with the conclusions of the report, no agreement as to preferred options has been given and the full formal consultation process will still be needed.

SEA Objectives

SEA Objectives have been developed to enable alternative options to be compared. Objectives may not necessarily be met in full by a given alternative option, but the degree to which they do will provide a way of identifying preferences when comparing effects of alternative options. The SEA Objectives for this topic are listed below:

- 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 habitats.

Baseline Environment

Baseline information provides the basis for predicting and monitoring environmental effects, by describing the area that may be affected. Due to the long timescales associated with the construction and operation of alternative options, baseline information is considered over three time periods, to reflect the predicted changes in the area when considered without the development of a Severn Tidal Power project. The baseline therefore also describes the estuary in a ‘do-nothing’ scenario (i.e in the absence of the implementation of a tidal power scheme).

The ecological importance of the estuary is recognised through a number of international, national and local nature conservation designations. The receptors to be assessed within the marine ecology topic were defined in the scoping phase of the SEA process. The list of receptors were defined based on a review of available ecological descriptions and assessments of the study area. They also took account of features of conservation interest and quality elements defined by the Water Framework Directive.

The resulting list of receptors comprises:

- Plankton;
- Macroalgae;
- Intertidal mud and sandflats flats and associated species;
- Saltmarshes;
- Shingle and rocky shore;
- Subtidal sandbanks;
- Sabellaria reefs;
- Eelgrass
- Other subtidal habitats and associated species;
- Epibenthos
- Cephalopods;
- Marine mammals and turtles.

The topic paper has also considered risks associated with the introduction of non-native species. While the topic paper focuses on individual receptors, the assessment also highlights key linkages between marine ecological receptors and with other topics where relevant.

Baseline environment up to 2009
A wide range of both intertidal and subtidal habitats occur within the Bristol Channel and Severn Estuary. There are extensive areas of intertidal mud and sandflats throughout the study area, which vary in size and composition as a result of the hydrodynamic and morphological processes operating on them. Most of the mudflats occur within middle reaches of the estuary whereas the sandflats tend to occur at the head and outer estuary. The Severn Estuary also supports a range of saltmarsh types. *Zostera* beds are known to occur on some of the more sheltered mud and sand banks around the Welsh side of the Severn Crossing, close to Sudbrook Point. Shingle habitats occur between Minehead and Dunster, Stolford and Steart Point at the mouth of the River Parrett and in the vicinity of the Severn Crossing and on the Welsh bank. There are extensive areas of rocky shore including a range of different habitat types namely boulders, expanses of rock platforms, mussel/cobble scars and rocky pools. Subtidal habitats occur across a range of substrate types and include subtidal sandbanks. In addition a number of studies have identified the location of extensive *Sabellaria* reefs throughout the Bristol Channel and Severn Estuary.

Many studies describe the strong association that exists between the biota and the physically harsh conditions of this estuarine system. Generally, the benthic community is relatively impoverished compared to other estuarine systems in the UK. This has been largely attributed to the extreme natural suspended sediment loads, mobility of sediment and tidal currents (Warwick, 1984; Mettam *et al.,* 1994; Kirby *et al*., 2004), although, salinity is also an important factor determining distribution patterns as no marine species is found permanently higher upstream than Sharpness (MNCR, 1995).

Seasonal distribution and abundance of planktonic organisms are strongly influenced by extreme physical and chemical conditions which typify the Bristol Channel and Severn Estuary. Macroalgae within the study area is considered impoverished particularly with regard to red algae. At Hinkley Point, there is an isolated and locally important red algal community known as the *Corallina* run-offs which have created a complex habitat that support a relatively high diversity of invertebrate species.

The Severn Estuary and Bristol Channel is an important habitat for a range of epibenthic species such as the large and self-sustaining population of brown shrimp, *Crangon crangon* (Henderson & Holmes, 1987; Henderson *et al.,* 1990). Little is known about the cephalopod populations within the Bristol Channel and Severn Estuary. There are no resident cetacean species found in the Bristol Channel, and although some species use the estuary as a feeding area during different times of the year the area is not considered important as a breeding ground for marine mammals.

Future baseline during construction: 2014-2020
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 the 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.

Recent studies have predicted the loss of intertidal mudflat and sandflats and saltmarsh habitats over the next century in response to projected sea level rise. There are not anticipated to be any major changes to the physical regime of the estuary that would effect the distribution of *Sabellaria*. The largest contribution to changes in *Sabellaria* could therefore 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.

Changes in the extent and distribution of habitat types within the estuary will affect the species supported by the system. Species composition and abundance will also be determined by physiological tolerances to the changing environmental conditions and the corresponding changes in species interactions. There is limited information with respect to projected future trends in cephalopod populations. Squid are, however, highly sensitive to environmental conditions and populations are considered to be vulnerable to the effects of climate change. The main potential effects to marine mammals UK wide associated with climate can be summarised as changes in range, physical habitats, the food web and susceptibility to disease and contaminants.

Future baseline during operation 2020-2140, decommissioning and longer term trends
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 each of the 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.

Key Environmental Issues and Problems
While management policies in relation to biodiversity will support the long-term maintenance of intertidal habitats, such actions will not be effective in addressing rising sea temperatures or ocean acidification. There is already evidence of rising sea temperatures and accompanying shifts in the distribution of some marine species. In particular, species at their southernmost limit of distribution are being displaced northwards while species at their northernmost extent are shifting further north. Ocean acidification is likely to pose significant challenges for many marine species particularly marine molluscs, crustacean and echinoderms.

Separately, under the Water Framework Directive a large number of transitional and coastal water bodies in the estuary and inner Bristol Channel are identified as being heavily modified for reasons of flood and coast protection. In addition. inputs of nutrients, particularly nitrogen, to coastal waters have long been recognised as contributing to problems of eutrophication.

A range of well-documented further problems affect the marine environment, in particular relating to habitat loss and damage as a result unsustainable human development activities.

The Marine Strategy Framework Directive is due to be transposed into UK law by the end of 2010. Once enacted, the new powers will enable additional measures to be taken to protect marine habitats and species where required. The Marine and Coastal Access Act 2009 provides for nationally important habitats and species to be protected through site based designations termed Marine

Conservation Zones. Implementation of the provisions of this Act over the next few years will provide an opportunity to afford additional protection to seabed features within the study area where necessary. The marine planning provisions of the Act will also provide a clearer management framework of objectives and targets for our seas, including ecosystem-based objectives to address damaging activities where necessary.

Overall, the range of measures currently being implemented or which will be implemented in the future will lead to improvements in the biological quality of the marine environment. However, it is likely to continue to be difficult to tackle effects arising from temperature increases or ocean acidification.

Evaluation of Plan Alternatives

Assessment Methodology
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. This topic paper therefore considers the characteristics of the effects and of the area likely to be affected.

This topic has also used the following specific assessment methods. Various different methods and approaches have been used to assess potential effects including desk-based assessments using available literature and model-based assessments of:

- Changes to the distribution of broad habitats in relation to the different alternative options in the short-term. This analysis was based on the application of a habitat model developed and applied for the purposes of the Severn CHaMP (ABPmer, 2007).
- Changes to the distribution of biotopes in relation to the different alternative options in the short-term.
- Changes to the extent of broad habitats in relation to the different alternative options in the long-term.
- An evaluation of the long-term sustainability of saltmarsh areas in relation to the different alternative options.

The topic paper is supported by four annexes:

- Marine Ecology Annex 1 – Baseline Information;
- Marine Ecology Annex 2 – Evaluation of options: supporting information;
- Marine Ecology Annex 3 – Habitat Modelling;
- Marine Ecology Annex 4 – Ecological (logistic regression & HABMAP) modelling based predictions.

Alternative Options
There are five shortlisted alternative options that are being assessed within Phase 2 of the SEA for their likely significant effects. These alternative options and key parameters associated with the alternative options are:

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B3: Brean Down to Lavernock Point Barrage	Lavernock Point to Brean Down	16km	Ebb only	Bulb-Kapeller	216 (40MW)	15.1 to 17.0 TWh/year	129	2

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B4: Shoots Barrage	West Pill to Severn Beach	7km	Ebb only	Bulb-Kapeller	30 (35MW)	2.7 to 2.9 TWh/year	46	1
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

Assessment of Likely Significant Effects on the Environment within the context of the SEA process

Alternative Option B3: Brean Down to Lavernock Point Barrage (also known as Cardiff to Weston)

The largest effects are associated with changes in water levels once the barrage becomes operational which modify the extent of habitats. This gives rise to significant negative effects on all intertidal receptors (intertidal mudflat and sandflat, saltmarsh, intertidal shingle and rock, macroalgae and *Zostera*) and epibenthos. Further significant negative effects on intertidal mudflat and sandflats and saltmarsh are predicted as a result of long-term morphological changes.

There is also the potential for far-field and transboundary significant negative effects, particularly for saltmarsh 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/North Cornish coast.

Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on intertidal mudflats and sandflats, intertidal shingle and rock, macroalgae, *Zostera* and subtidal habitats. However changes in sand transport and mud deposition are predicted to have significant negative effects on the subtidal sandbanks in the estuary and Bristol Channel. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria alveolata* reefs. Reductions in scour are predicted to have significant positive effects for macroalgae and shingle and rocky shores. Improvements in the light climate are predicted to have significant positive effects for plankton and macroalgae.

While adult mobile epibenthos are expected to pass through the barrage structures unscathed, there is a risk that ovigerous females will be stripped of eggs during their passage and is assessed as a significant negative effect. There is also the possibility of a cumulative effect on mobile epibenthos associated with the proposed new nuclear power station at Hinkley. The station will entrain significant numbers of adult and juvenile epibenthos on cooling water intake screens and kill larval stages in abstracted cooling water through (presumed) chlorination.

Increases in water column phytoplankton abundance and productivity are expected to lead to increases in the diversity and abundance of zooplankton resulting in a significant positive effect for this receptor. Increased water column primary productivity, coupled with reductions in suspended sediment concentration are also expected to lead to a greater diversity of suspension feeding organisms within benthic invertebrate assemblages. These changes have been assessed as significant positive effects for intertidal mud and sandflats and shingle and rocky shores.

No significant effects are predicted during the construction phase, with the exception of a potential negative effect on *Sabellaria* reefs during the dredge associated with the B3 option. However, depending on how barrage construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime. The effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects.

Alternative Option B4: Shoots Barrage

The largest effects are associated with changes in water levels once the barrage becomes operational which modify the extent of habitats. This gives rise to significant negative effects on most intertidal receptors (intertidal mudflat and sandflat, intertidal shingle and rock, macroalgae and *Zostera*) although the effects on saltmarsh are not assessed as being significant. Further significant negative effects on intertidal mudflat and sandflats are predicted as a result of long-term morphological changes. No significant far-field or transboundary effects are anticipated for this option.

Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on intertidal mudflats and sandflats and *Zostera*. However changes in sand transport and mud deposition are predicted to have significant negative effects on the subtidal sandbanks in the estuary and Bristol Channel. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria alveolata* reefs.

While adult mobile epibenthos are expected to pass through the barrage structures unscathed, there is a risk that ovigerous females will be stripped of eggs during their passage and is assessed as a significant negative effect for species such as *Neomysis integer* which predominantly occur in the upper estuary, but not significant for species such as *Crangon* which predominantly occur in the main estuary and Bridgwater Bay. There is also the possibility of a cumulative effect on mobile epibenthos associated with the proposed new nuclear power station at Hinkley. The station will entrain significant numbers of adult and juvenile epibenthos on cooling water intake screens and kill larval stages in abstracted cooling water through (presumed) chlorination.

Increases in water column phytoplankton abundance and productivity are expected to lead to increases in the diversity and abundance of zooplankton upstream of the barrage, but the limited extent of this change means that it is not assessed as being significant.

No significant effects are predicted during the construction phase. However, depending on how barrage construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime. The effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects.

Alternative Option B5: Beachley Barrage

The largest effects are associated with changes in water levels once the barrage becomes operational which modify the extent of habitats. This is assessed as giving rise to significant negative effects on the following intertidal receptors: intertidal mudflat and sandflat, intertidal shingle and rock. The long-term effects of morphological change on mudflats and sandflats under this option are predicted to be very small and not significant.

No significant far-field or transboundary effects are anticipated for this option.

Changes in habitat quality are predicted to give rise to significant effects through a number of different mechanisms. Reductions in the short-term erosion and deposition of mud are predicted to have significant positive effects on intertidal mudflats and sandflats. However changes in sand transport and mud deposition are predicted to have significant negative effects on the subtidal sandbanks in the estuary at Welsh and English Grounds. Predicted reductions in flow speed are assessed as having significant negative effects on subtidal *Sabellaria alveolata* reefs.

While adult mobile epibenthos are expected to pass through the barrage structures unscathed, there is a risk that ovigerous females will be stripped of eggs during their passage and is assessed as a significant negative effect for species such as *Neomysis integer* which predominantly occur in the upper estuary, but not significant for species such as *Crangon* which predominantly occur in the main estuary and Bridgwater Bay.

There is also the possibility of a cumulative effect on mobile epibenthos associated with the proposed new nuclear power station at Hinkley. The station will entrain significant numbers of adult and juvenile epibenthos on cooling water intake screens and kill larval stages in abstracted cooling water through (presumed) chlorination.

Increases in water column phytoplankton abundance and productivity are expected to lead to increases in the diversity and abundance of zooplankton upstream of the barrage, but the limited extent of this change means that it is not assessed as being significant.

No significant effects are predicted during the construction phase. However, depending on how barrage construction is progressed there could be the potential for significant negative effects associated with changes in the hydrodynamic and sediment transport regime. The effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects.

Alternative Option L2: Welsh Grounds Lagoon

The largest effects are associated with changes in water levels within the lagoon once it becomes operational which modify the extent of habitats within it. This is assessed as giving rise to significant negative effects on intertidal mudflat and sandflat habitats, *Zostera* and epibenthos. The long-term effects of morphological change on mudflats and sandflats under this option are predicted to be very small and not significant. Table 3.16 summarises the predicted changes in intertidal extent in both the short-term and over the operational life of the barrage (long-term).

No significant far-field or transboundary effects are anticipated for this option.

Changes in habitat quality are predicted to give rise to significant effects on the subtidal sandbanks in the estuary at Welsh and English Grounds as a result of reductions in sand transport. Predicted reductions in flow speed are not assessed as having significant negative effects on subtidal *Sabellaria alveolata* reefs.

While adult mobile epibenthos are expected to pass through the turbine structures unscathed, there is a risk that ovigerous females will be stripped of eggs during their passage. Only a relatively small proportion of total individuals within the estuary would be expected to make use of the lagoon area. Exposure and the magnitude of change are therefore assessed as low. Alone, the change is assessed as not significant. There is also the possibility of a cumulative effect on mobile epibenthos associated with the proposed new nuclear power station at Hinkley. The station will entrain significant numbers of adult and juvenile epibenthos on cooling water intake screens and kill larval stages in abstracted cooling water through (presumed) chlorination.

No significant changes in phytoplankton production are predicted for the estuary as a whole. The high level of flushing within the lagoon will also greatly limit the potential for phytoplankton growth within the structure. The changes are therefore not considered to be significant.

No significant effects are predicted during the construction phase. The effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects.

Alternative Option L3d: Bridgwater Bay Lagoon

The largest effects are associated with changes in water levels within the lagoon and wider estuary which modify the extent of habitats. This is assessed as giving rise to significant negative effects for intertidal mudflat and sandflat habitats. The long-term effects of morphological change on intertidal mudflats and sandflats under this option are also assessed as a significant negative effect. Table 3.20 summarises the predicted changes in intertidal extent in both the short-term and over the operational life of the lagoon (long-term).

There is also the potential for far-field significant negative effects, particularly for saltmarsh as a result of decreases in the level of high water in the vicinity of the Kenfig SAC.

The predictions do not take account of intertidal areas in sub-estuaries. Little change is predicted to occur in the sub-estuaries of the Usk, Wye or Avon. For the Parrett there will be some increases in low water level and some reduction in high water levels. Applying the same loss factor to the intertidal area of the Parrett as calculated for geo-subunit 2e indicates a potential loss of around 65ha as a result of changes in water levels.

Changes in habitat quality are predicted to give rise to significant positive effects on intertidal mudflat and sandflat and significant negative effects on subtidal sandbanks as a result of changes in erosion and deposition.

There is the possibility of a cumulative effect on mobile epibenthos associated with the proposed new nuclear power station at Hinkley. The station will entrain significant numbers of adult and juvenile epibenthos on cooling water intake screens and kill larval stages in abstracted cooling water through (presumed) chlorination – need to address cumulative risk.

No significant changes in phytoplankton production are predicted for the estuary as a whole. The high level of flushing within the lagoon will also greatly limit the potential for phytoplankton growth within the structure. The changes are therefore not considered to be significant.

No significant effects are predicted during the construction phase. The effects of decommissioning are predicted to be similar to construction effects and the converse of operational effects.

Assumptions, Limitations and Uncertainty

The assessments have been undertaken based on the following key assumptions:

- The construction phase is progressed in such a way that there are no significant changes to the hydrodynamic and sediment transport regime;
- Source noise levels associated with construction piling activity do not exceed 190dB re: 1μPa;
- Simplifying assumptions used in habitat and morphological models, for example, saltmarsh will establish in all areas predicted by the habitat model;
- The calculation of long-term intertidal area has assumed a constant slope in the intertidal;
- Egg-stripping of ovigerous mobile epifauna during passage through turbines affects a significant proportion of the population;

- Predicted reductions in suspended sediment concentration will establish conditions for net positive photosynthesis in the estuary;
- Climate change projections for sea level rise and temperature are accurate
- The range of cumulative and consequential developments identified is complete;
- A range of assumptions are inherent from other topics. In particular:
    - Suspended sediment concentrations upstream of the barrage will reduce by an order of magnitude to around 100mg/l;
    - Other water quality parameters are subject to only marginal changes;
    - Long-term erosion occurs uniformly over the intertidal profiles.

Key limitations common to all options include:

- There is a general lack of information on the distribution and abundance of cephalopods;
- The habitat models are only able to provide generalised predictions of potential changes;
- The habitat models do not incorporate the sub-estuaries;
- The models used to predict long-term morphological changes are not able to fully capture processes governing long-term erosion and deposition.

Many of the uncertainties relate to the assumptions and limitations identified above. In addition, there are a number of additional uncertainties relating to our limited understanding of the functioning of marine ecosystems for example:

- The extent to which primary production in the estuary might give rise to eutrophication effects;
- The significance of primary productivity within the estuary as an alternative food source to allocthonous detritus;
- The implications of changes in the physical forcing factors for overall ecosystem structure and function and the quality of habitats.

In addition, there is particular uncertainty about the scale, extent and nature of far-field effects that might arise as a result of predicted changes in water levels.

Measures to prevent, reduce and as fully as possible offset any significant adverse effects

The measures identified within the SEA process to prevent or reduce likely significant adverse effects identified within this topic are described below.

A number of potential measures could be applied to reduce the effects of the alternative options on marine ecology receptors. During construction, it is assumed that, as a matter of good practice, standard measures to minimise effects will be taken, for example:

- careful timing of construction activities to minimise risks during sensitive periods for specific receptors;
- pollution prevention controls to minimise accidental spillages;
- management of dredging and piling activities to limit resuspension of sediments.

As part of option design it may be possible to make minor adjustments to the location or alignment of options to avoid specific features within the footprint of the devices. However, it is of note that major physical changes will 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.

There may also be opportunities, through the careful selection of construction materials to enhance colonization of new structures. However, in addition to enhancing conditions for native species, this may also increase the settlement potential of non-native species. While the above measures will be required as a condition of any permit to construct the alternative options, construction effects are not assessed as being significant in the context of the SEA and therefore the benefit of applying the measures in reducing the effects will be correspondingly small.

Further measures to prevent or reduce effects might be applied to the operation of the alternative options. The following measures could provide particular benefit in mitigating effects on intertidal habitats and saltmarsh:

- Creation of new intertidal mudflat or saltmarsh (through topographic modification) within the Severn Estuary, which could be used to partially mitigate predicted losses for all alternative options;
- Management of water levels upstream of options B3, B4 and B5 and within L2 to minimise overall loss of intertidal habitat. Through early turbine generation and additional sluicing of water once energy generation has completed, it may be possible to lower low water levels for the ebb-only alternative options (B3, B4, B5 and L2);
- Maintenance of baseline MHWS levels upstream of options B3, B4 and B5 and within L3d could successfully conserve existing saltmarsh in the Severn Estuary.
- 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 measures to prevent or reduce effects were implemented to improve existing flood defences, such measures could potentially affect habitats associated with the upper shore. Changes in the operating regime to mitigate reductions in exposure time (for birds) are unlikely to result in significant effects on marine ecology receptors. While the level of predation by birds on intertidal invertebrates might increase slightly, it might be expected that there would be a corresponding reduction in prey consumption by fish and mobile epibenthos. Changes in the number, location and distribution of sluices (measures for migratory fish) may have some minor benefit for marine ecology receptors such as mobile epibenthos, but this is highly uncertain.

Offsetting measures within this SEA are measures to as fully as possible offset any significant adverse 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.

Notwithstanding the potential for implementing measures to reduce significant effects on marine ecology receptors, it is likely that a major programme of offsetting measures will also be required as, for all options except L3, the area of habitat that might be created is less than the predicted loss. While the area that might be created for L3 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 offsetting measures will need to be considered.

The creation of replacement intertidal mud and sandflat habitat to offset the predicted losses of intertidal habitat is likely to be a key focus for the package of offsetting measures. There may also be a requirement to provide offsetting measures for effects to saltmarsh, particularly for option B3 but also possibly for other options within particular geo-units. Other specific requirements may include measures for saltmarsh, eelgrass, epibenthos, subtidal sandbanks and subtidal Sabellaria alveolata reef. While such measures 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.

Measures are also potentially required to offset more specific effects on features and sub-features of the designated sites as part of a specific package of measures to secure compliance with the Habitats Regulations[1].

Managed realignment is now widely recognised as an effective mechanism for creating new intertidal habitats, although the majority of schemes to date have focused on the creation of saltmarsh rather than mud and sandflats. Within the Severn Estuary, however, there is limited opportunity for the creation of mudflat behind the existing seawalls unless significant land lowering is undertaken. 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 could not be replaced directly.

Assessment against SEA Objectives

This topic paper includes a full assessment of how each alternative option performs against each SEA Objective over the course of its entire life-cycle.

In summary:

SEA Objective 1 - to avoid adverse effects on designated marine wildlife sites and protected habitats of international and national importance.
All of the tidal power options have been assessed as having a major negative performance against SEA Objective 1. In this respect all of the tidal power options, which, in essence, act to reduce the energy within the system, are predicted to result in significant effects on multiple features and sub-features within the SAC and SSSI. In broad terms, the scale of effects is related to the amount of energy extracted.

SEA Objective 2 - To avoid adverse effects on valuable marine ecosystems.
All of the tidal power options have been assessed as having a major negative performance against SEA Objective 2. The tidal power options are predicted to give rise to a number of significant effects on marine ecology receptors within designated sites. Some of these effects will also affect habitats and species outside of the designated areas.

SEA Objective 3 - To avoid adverse effects on other protected marine species and their habitats.
Marine mammals and turtles are protected under the Habitats Regulations and Wildlife & Countryside Act. None of the options is predicted to give rise to significant effects on these features.

SEA Objective 4 - To avoid adverse effects on national and local biodiversity target features that include marine habitats and species.
The tidal power options are predicted to give rise to a number of significant effects on marine ecology receptors within and beyond the designated sites. This includes the majority of BAP habitats and species occurring in the study area. It is unlikely to be possible to avoid adverse effects on many of these features for any of the options.

SEA Objective 5 - To avoid deterioration in status class of WFD water bodies.
If all practicable and cost-effective measures were implemented as part of a tidal power project in conformance with WFD Article 4(7) requirements, such development should not compromise achievement of WFD objectives for any of the corresponding water bodies.

[1] Formerly the Conservation (Natural Habitats, &c.) Regulations 1994 (SI 1994/ 2716). From 1 April 2010, the regulations were replaced by The Conservation Of Habitats And Species Regulations, 2010.

SEA Objective 6 - To minimise the risk of introduction of non-native invasive marine species.
The introduction of new colonization surfaces through the placement of tidal power structures in the Severn Estuary and changes in estuary physical processes have the potential to facilitate the spread of invasive non-native species. It is difficult to quantify how the risk of introduction of invasive non-native species might change in response to tidal power options. On the assumption that the current spread of such species is limited by the prevailing physical regime in the estuary and lack of new colonizing substrate, the options which cause the greatest change in physical processes and provide the greatest colonizing space would be expected to pose the greatest risk.

Option B3 causes widespread changes in the estuary physical regime extending into the Bristol Channel. The significant reduction in the level of MHWS upstream of the barrage within the Severn Estuary may also result in a downshore extension of saltmarsh. This may lead to an expansion of *Spartina anglica*. The two lagoon options provide the greatest area of new colonizing surface. Options B4 and B5 are considered to pose lower levels of risks because they provide relatively little new colonizing surface and are located well upstream in the estuary, beyond the salinity tolerance of some invasive non-native species. Their effects on estuary physical processes are also more limited particularly compared to option B3.

SEA Objective 7 - To conserve and enhance designated marine site features.
The effects on designated site features are described under objective 1. Offsetting measures at locations within the Severn and elsewhere may contribute to conserving and enhancing features for which the marine sites are designated. Notwithstanding the scope for implementing and offsetting measures, it remains unclear whether all significant effects can be addressed. It is unlikely to be possible to provide preventative, reducing or offsetting measures for subtidal *Sabellaria alveolata* reefs. Options B5 and L3 have been assessed as having a minor negative performance against SEA Objective 7, whereas options B3, B4 and L2 have been assessed as a major negative performance against this SEA Objective.

SEA Objective 8 - To restore and enhance marine BAP species populations and/or BAP habitat.
The effects on BAP habitats and species are described under objective 4. Offsetting measures at locations within the Severn and elsewhere may contribute to restoring and enhancing marine BAP species populations and/or BAP habitat. Notwithstanding the scope for implementing preventative, reducing and offsetting measures, it remains unclear whether all significant effects can be addressed. It is unlikely to be possible to provide preventative, reducing or offsetting measures for subtidal *Sabellaria alveolata* reefs.

Plan Implementation

Legislation and policy compliance

This paper contains a review of legislation and policy that is specifically relevant to this topic. An assessment has been made as to whether each alternative option would be compliant with existing relevant legislation and policy.

There is the potential for all of the options to give rise to significant effects on a wide range of marine ecology receptors within the Bristol Channel and Severn Estuary, including various designated features and sub-features within the Severn Estuary/Môr Hafren SAC, SPA, Ramsar Site and SSSI. The predicted magnitudes of effects within the Severn Estuary and Bristol Channel are greatest for the B3 Option.

Through the implementation of the B3 Option, in particular, there is also the potential to generate far-field effects on designated features within a number of other SACs and SSSIs. The identification of significant effects on designated features does not necessarily mean that the option cannot comply with relevant nature conservation legislation. Rather, the legislation requires that in such circumstances a series of strict tests and requirements are applied before such developments can be consented.

Each option is also predicted give rise to significant effects on biological quality elements that are used to assess water body status under the Water Framework Directive.

Article 4(7) of the Water Framework Directive sets strict conditions on new development activities that might have an effect on the status of water bodies. Such developments can only proceed if a series of specific tests are met.

Monitoring of significant environmental effects

The SEA Directive requires that monitoring measures are described within the environmental reporting. The monitoring proposals contained within this paper are applicable to all of the alternative options under consideration, if taken forward.

If a preferred option is taken forward, the magnitude and spatial extent of predicted effects on the full range of marine ecology receptors will necessarily require the development and implementation of a detailed, intensive and long-term monitoring programme to assess actual changes relative to predictions. This programme will 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 will 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. The monitoring programme would also need to be able to determine the effectiveness of the measures to prevent or reduce adverse effects and compensation measures that were required for the respective tidal power alternative.