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SEVERN TIDAL POWER - PRELIMINARY REVIEW OF POSSIBLE MITIGATION AND COMPENSATION REQUIREMENTS UNDER THE HABITATS DIRECTIVE

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CONTENTS

ABBREVIATIONS

The following abbreviations are used in this Report:

ABPmer	ABP Marine Environmental Research Ltd
ASM	Atlantic Salt Meadow
BTO	British Trust for Ornithology
BV	Black and Veatch
CD	Chart Datum
CHaMP	Coastal Habitat Management Plan
CCW	Countryside Council for Wales
DECC	Department of Energy and Climate Change
EA	Environment Agency
EC	European Commission
EIA	Environmental Impact Assessment
EN	English Nature (now Natural England)
ES	Environmental Statement
FEPA	Food and Environment Protection Act
ha	Hectare
HW	High Water
LiDAR	Light Detection and Ranging
LW	Low Water
MCEU	Marine Consents and Environment Unit
MFA	Marine and Fisheries Agency
MHW	Mean High Water
MLW	Mean Low Water
MLWS	Mean Low Water Springs
NBN	National Biodiversity Network
NE	Natural England
NVC	National Vegetation Classification
OS	Ordnance Survey
OD	Ordnance Datum
PB	Parsons Brinckerhoff
PSA	Particle size analysis
Ramsar	International treaty for the conservation and sustainable utilisation of wetlands
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SCI	Site of Community Importance
SPA	Special Protection Area
SSSI	Sites of Special Scientific Interest
WFD	Water Framework Directive

NON-TECHNICAL SUMMARY

The Severn Tidal Power Feasibility Study is a Cross-Government study exploring the potential for tidal range power generation in the Severn Estuary. A consortium led by Parsons Brinckerhoff has been appointed to undertake an appraisal of tidal power options supported by a Strategic Environmental Assessment (SEA). The studies have been split into two phases with Phase 1 focusing on scoping for the SEA and Phase 2 completing the SEA as part of an overall appraisal of short-listed options and making recommendations on preferred options.

Tidal power development in the Severn Estuary is likely to have significant impacts on a number of internationally designated nature conservation sites including the Severn Estuary candidate Special Area of Conservation (SAC), the Severn Estuary Special Protection Area (SPA), the Severn Estuary Ramsar site and certain features in adjacent river SACs. The Conservation (Natural Habitats & c.) Regulations 1994 (the 'Habitats Regulations') lay down strict procedures that must be followed for plans and projects within or adjacent to such sites. The Sustainable Development Commission (SDC) in its report 'Tidal Power in the UK' identified compliance with the Habitats and Birds Directives as a fundamental pre-requisite for any tidal power option in the Severn Estuary. The terms of reference for the feasibility study include a requirement to '*consider what measures the Government could put in place to bring forward a project that fulfils regulatory requirements, and the steps that are necessary to achieve this*'.

This report has therefore been commissioned as part of Phase 1 studies to provide a high-level evaluation of the feasibility of complying with certain aspects of the Habitats Regulations. In particular, the report focuses on the potential mitigation measures that might be applied to avoid or reduce adverse effects on designated features arising from tidal power options. It also considers options for providing compensatory measures to maintain the overall coherence of the Natura 2000 network in circumstances where impacts may be unavoidable. The scope of the report is limited to the consideration of requirements under the Habitats Regulations. Other ecological effects, while still important, are not considered in this review. A formal Appropriate Assessment will be prepared as part of Phase 2 studies to accompany the SEA. This Phase 1 desk-based assessment does not constitute part of a formal Screening or Appropriate Assessment process at this stage. Instead, this study anticipates, rather than replaces, the work required for a formal Habitats Regulations Appropriate Assessment.

The report documents the findings of a desk-based study which has been progressed through a number of discrete steps:

- Documentation of some of the key long-term trends in some designated features;
- Evaluation of potential impacts of representative tidal power options on designated features;

- Identification of possible mitigation measures to avoid or reduce potential impacts and consideration of their likely effectiveness;
- Consideration of compensatory measures that might be applied to any unavoidable residual impacts and their likely effectiveness;
- Preliminary costing of the mitigation and compensation measures where feasible;
- Overall evaluation of the scope for and potential costs of mitigation and compensation measures that may be required under the Habitats Regulations.

At this stage of the development of tidal power options, scientific understanding of the potential impacts of specific options is low and there is a high level of uncertainty associated with any predictions. As a desk-based exercise, the study has focused on options for which there is some pre-existing information on potential impacts, and draws on this where possible to inform an evaluation of the potential nature and scale of possible impacts across a range of tidal power options. While the study necessarily focuses on those options for which some potential environmental impact information is already available, all of the tidal power options are likely to have major significant effects on the internationally designated sites including:

- Reductions in tidal range particularly upstream of tidal power developments will directly change the extent of intertidal habitats and affect the use of these areas by waterbirds;
- Changes in sediment transport and sediment supply may result in long-term morphological change to intertidal and subtidal areas which, in turn may change the extent and quality of associated habitats;
- The presence and operation of tidal power devices will present major risks to genetically unique populations of migratory fish using the Severn Estuary and its tributary rivers.

More detailed studies are required to refine scientific understanding of these and other potential impacts so that mitigation and compensation measures can be targeted if the study moves to Phase 2.

The initial evaluation of possible mitigation measures has identified a range of potential opportunities that could contribute to reducing impacts to habitat and species features. These include measures to minimise impacts to existing habitats by reducing impacts on tidal range and active management of existing habitats to seek to preserve them in situ. While a reasonably high level of confidence might usually be ascribed to such measures, uncertainties about the future direction of geomorphological change (which on a worst-case basis may undermine some of the potential benefits), reduce the confidence in their effectiveness, in this case, to low. Modifications to barrage, lagoon, fence or reef design to reduce impacts on tidal range could also affect energy yield and thereby the overall economic performance of such projects. The effectiveness of mitigation measures for short-listed schemes and their potential costs therefore require further evaluation if the study progresses to Phase 2.

Various potential mitigation options have also been identified for migratory and estuarine fish. While some of the possible measures appear to hold some promise of reducing impacts, there is very limited certainty in the effectiveness of the measures based on current scientific knowledge. It should also be recognised that further research could either increase or decrease confidence in the certainty of individual measures. Therefore, most measures have been assigned low or very low levels of confidence (very low has also been allocated when effectiveness of measures is unknown). For other measures for which more information is available the confidence in their effectiveness has been considered to be of a medium level for certain species (APEM, in prep). As above, some of the measures could affect energy yield and would require further study if the project progresses to Phase 2.

Significant effort will be needed in Phase 2 of the study, if approved, to explore potential mitigation measures in more detail. This is both a requirement under the Habitats Regulations but might also deliver overall cost savings to the project if such measures reduce the overall requirements for compensation.

The consideration of compensation measures has focused on three main options:

- Creation of new estuarine habitats through managed realignment or other techniques such as Regulated Tidal Exchange at locations within and beyond the Severn Estuary. Such habitats could also provide compensation for potential impacts to waterbirds;
- Scoping the potential for new SAC designations to replace estuarine habitats and migratory fish affected within existing designated sites (and additional Ramsar site designations for non-SAC fish);
- Opportunities for ecological enhancement measures within existing designated sites where such measures are not already required to support achievement of conservation objectives. Such measures might include habitat improvements and also in the case of migratory fish, stock enhancement measures.

At this stage of the evaluation, confidence in the effectiveness of compensatory measures in providing like-for-like replacement of the structure and function of affected features is generally assessed as low (habitat and water bird measures) or low/very low (migratory fish measures). This is largely because of the difficulty in adequately replacing the extreme range of variation in features that occur in the Severn Estuary which are a consequence of the harsh physical regime and the difficulty of compensating for impact on fish.

Potential locations for additional SAC designations would need to be evaluated against the site selection criteria laid down in the Habitats Directive and in relation to the potential contribution they might make in compensating for impacts of tidal power development in the Severn Estuary.

It is recognised that there are a number of very significant challenges surrounding the identification, agreement and delivery of an acceptable package of compensation measures. Intertidal habitat creation as compensation at the scale required for most of the options considered is unprecedented. This increases uncertainty and potential risk of delivery.

The study has documented the many significant uncertainties concerning the scale of potential impacts associated with tidal power development in the Severn Estuary and identified many challenges in developing and delivering the mitigation and compensation measures that would potentially be required. The potential scale of measures required is likely to be unprecedented and in a number of areas there is currently a low or very low level of confidence in their effectiveness. While it will not be possible to compensate for all impacts on a strict like-for-like basis, it remains unclear the extent to which possible measures might contribute to protecting the overall coherence of the Natura 2000 network. Pending further evaluation of both the potential impacts and the mitigation and compensation opportunities it is not possible at this stage to categorically determine whether any of the tidal power option could or could not comply with the requirements of the Habitats and Birds Directives.

The report makes a number of recommendations for taking forward mitigation and compensation issues in relation to the Habitats and Birds Directives. In particular, the STP Project will need to determine how best to take forward the issues to explore in more detail some of the areas of greatest uncertainty. While a number of the uncertainties relating to potential impacts will be addressed through Phase 2 studies for the SEA, many of the issues concerning compensatory measures will need separate consideration.

Evaluation of Potential Impacts

Phase 2 studies should particularly seek to address the following key uncertainties:

- Effect of tidal power options on physical processes and long-term geomorphological change;
- Usage of the estuary by some species of migratory fish whose behaviour is currently poorly understood (e.g. shad, lamprey).

The assessment of effects on physical process will require a substantive programme of modelling and assessment. In the case of effects on migratory fish, technical challenges mean that it will probably not be practicable to execute fish-related fieldwork within Phase 2. Assessments of impacts upon fish within Phase 2 will therefore most likely need to be based upon desk-study.

Evaluation of Mitigation Measures

For each short-listed option, Phase 2 studies should explore:

- The scope, cost and effectiveness of measures to minimise impacts to the existing tidal range, particularly existing high water levels; and
- The scope of potential measures to minimise impacts to migratory fish and their cost-effectiveness.

Evaluation of Compensation Measures

A number of proposals for additional studies are identified including:

- A feasibility study of the potential for delivering very large scale managed realignment;
- Desk-based evaluation of likely habitats that could be created in sites >500ha;
- An evaluation of the effectiveness of possible managed realignment options in compensating for impacts to waterbirds;
- Evaluation and prioritisation of potential sites for inclusion in the SAC list (new SAC designations for intertidal and subtidal habitats and migratory fish and/or new Ramsar designations (eel, sea trout)).
- Exploration of options for enhancing river habitats for migratory fish spawning and nursery areas in the three River SACs and for stock enhancement measures.

The nature of these studies, their priority, and potential for their inclusion within the Phase 2 package of work is currently under consideration.

As this Phase 1 desk-based assessment anticipates the formal Screening or Appropriate Assessment process, in making these recommendations it is assumed that other aspects of the Habitats Regulations requirements will be progressed separately including:

- Consideration of far-field effects on designated features not explicitly discussed in this report;
- Consideration of issues of the need for the project, alternatives and imperative reasons of overriding public interest;
- Clarification of the compensation requirements to protect the 'overall coherence' of the Natura 2000 network;
- Development of a policy approach to designating new SACs or Ramsar sites.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Project Background

This report has been prepared to inform a programme of work to support the Severn Tidal Power Feasibility Study, including a Strategic Environmental Assessment (SEA) that has been commissioned by a Cross-Government Project Team. The SEA study as a whole includes engineering, technical and environmental assessments of options, and is divided into two phases. Phase 1 includes assessment of potential tidal power options, and scoping of the SEA. Phase 2 is provisional, depending on the outcome of Phase 1. If pursued Phase 2 is likely to extend to early 2010 covering the preparation of the SEA itself and the associated Environmental Report.

This report assesses, at a high level, the extent, availability and viability of potential habitat compensation. It explores possible options to mitigate and/or compensate for potential impacts associated with four generic tidal power options – an inner barrage, a middle barrage, an outer barrage and the Generic Lagoon Concept. These options have been used for illustrative purposes in advance of the formal short-listing of options, on the basis that there is some pre-existing information on barrages in particular, and this can where suitable be applied to consideration of a lagoon concept. It is recognised that other options such as a tidal reef or tidal fence have been proposed and may be included amongst the short-listed options. These options have not been evaluated in this study because there is a lack of information on their potential impacts, although in general terms it might be expected that the impacts on physical processes might be similar to other tidal power options, depending on the extent to which these schemes affected the natural tidal range (Parsons Brinckerhoff and Black & Veatch, in prep). A map illustrating the long-list options is provided in Figure 1.

In contemplating possible compensation options, the study assumes substantial effects will remain following application of mitigation measures. It is recognised that the study also makes important assumptions about the need for the project, alternative solutions and possible grounds for 'Imperative Reasons of Over-riding Public Interest' (IROPI) under the Habitats and Birds Directives.

This initial desk-based assessment does not constitute part of a formal Screening or Appropriate Assessment process at this stage. Instead, this

study anticipates, rather than replaces, the work required for a formal Habitats Regulations Appropriate Assessment.

1.2 Designated Sites

The nature conservation importance of the Severn Estuary is recognised through a large number of designations at international, national and local level. The main internationally designated sites that are potentially at risk from tidal power development in the Severn Estuary comprise:

- Severn Estuary Special Protection Area (SPA);
- Severn Estuary Ramsar Site;
- Severn Estuary/Môr Hafren Candidate Special Area of Conservation (cSAC);
- River Usk/Afon Wysg SAC;
- River Wye/Afon Gwy SAC;
- Afon Tywi/River Tywi SAC.

The locations of these sites are shown in Figures 2 to 4 and an overview of each of these designated sites and their relevant interest features is presented in the following sections. There is a risk of sites much further away being affected, and the Appropriate Assessment will need to consider such risks of far-field effects on designated features not explicitly discussed in this report.

1.2.1 Severn Estuary SPA

The Severn Estuary was classified as an SPA (under the EC Birds Directive) in 1995 and, as quoted within its site citation, has an overall size of approximately 24,700ha. It contains extensive intertidal mudflat and sandflat, 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 sandbanks. The site is of importance during the spring and autumn migration periods for waders moving up the west coast of Britain, as well as in winter for large numbers of waterbirds, especially swans, ducks and waders. The estuary qualifies as an SPA, under Article 4.1 of the Birds Directive, because it supports populations of the following regularly occurring Annex I bird species of European importance:

- Bewick's Swan *Cygnus columbianus bewickii*;

It also qualifies under Article 4.2 of the Birds Directive by virtue of supporting the following:

- regularly occurring migratory species in numbers of European importance; and
- an internationally important assemblage of waterfowl.

Sub-features of the SPA, which support these bird species include:

- Intertidal mudflats and sandflats;
- Saltmarsh; and
- Shingle and rocky shore.

1.2.2 Severn Estuary cSAC

The Severn Estuary has been recommended as a cSAC (under the EC Habitats Directive) because it contains habitat types and species that are threatened within a European context. The European Interest features for which the site has been proposed are as follows:

- Atlantic salt meadow (*Glauco-Puccinellietalia maritimae*) – low to mid marsh and mid to upper marsh communities contain the National Vegetation Classification (NVC) communities which fall within the Atlantic salt meadow in the EU Interpretation Manual;
- Estuaries - semi enclosed bodies of water which have a free connection with the open sea and within which the seawater is measurably diluted by freshwater from the surrounding land;
- Mudflats and sandflats not covered by seawater at low tide - these are mud and sand sediments that are exposed at low tide but submerged at high tide;
- Reefs - areas of rock or biological concretions formed by various invertebrate species; and
- Sandbanks which are slightly covered by sea water all the time;
- *Lampetra fluviatilis* - river lamprey;
- *Alosa fallax* - twaite shad;
- *Petromyzon marinus* - sea lamprey.

1.2.3 Severn Estuary European Marine Site

Special Areas of Conservation and Special Protection Areas are defined as European Sites in the Conservation (Natural Habitats &c.) Regulations 1994. Where the European Site lies below highest astronomical tide, i.e. land covered (continuously or intermittently) by tidal waters, or any part of the sea, in or adjacent to Great Britain, up to the seaward limit of territorial waters, it is described as a European Marine Site.

In 2005, English Nature (now Natural England) and the Countryside Council for Wales (CCW) produced interim advice for the Severn Estuary European Marine Site under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994 (English Nature and the Countryside Council for Wales, 2005) in relation to the Severn Estuary SPA. The Advice outlines the conservation objectives for the European Marine Site in respect of the SPA and advises relevant authorities as to any operations which may cause deterioration of natural habitats or the habitats and species, or disturbance of species for which the site has been designated.

In 2008, Natural England and CCW published comparable advice in relation to the Severn Estuary cSAC (NE and CCW, 2008).

1.2.4 Ramsar Site

The Severn Estuary is also a Ramsar Site (a wetland site of international importance under the 1972 Ramsar Convention). It is contiguous with, and thus has the same overall area as the SPA (approximately 24,663ha), and qualifies for such designation by virtue of meeting the following qualifying criteria:

- Criterion 1 - due to its immense tidal range;
- Criterion 3 - due to its unusual estuarine communities, reduced species diversity and high productivity;
- Criterion 4 - as it is particularly important for the run of migratory fish between the sea rivers via the estuary;
- Criterion 5 - by regularly supporting in winter over 20,000 waterfowl;
- Criterion 6 - by regularly supporting, during the same period, internationally important populations of five species of waterfowl; and
- Criterion 8 - supporting one of the most diverse estuarine and river system fish communities in Britain, with over 110 species recorded, including key migratory species (salmon *Salmo salar*, sea trout *Salmo trutta*, sea lamprey *Petromyzon marinus*, river lamprey *Lampetra fluviatilis*, allis shad *Alosa alosa*, twaite shad *Alosa fallax*, and eel *Anguilla Anguilla*)

The UK government policy statement on Ramsar states that sites designated under the Convention on Wetlands of International Importance especially as waterfowl habitat (namely Ramsar sites) are afforded the same protection under the Habitats Regulations at a policy level of designated SACs and SPAs.

Planning Policy Guidance note PPG9 states that all development proposals likely to have a significant effect on a Ramsar site shall be subject to an

appropriate assessment of the implications for the site in view of that site's conservation objectives. In order to fully meet that policy obligation, the authority will need to ensure that its assessment takes into account the full range of Ramsar interests for which the site has been designated and their vulnerabilities to any effects of the proposed development. Article 4 of the Ramsar Convention requires Contracting Parties which delete sites or restrict site boundaries to provide compensatory measures for the loss of conservation interests.

The Ramsar Convention on Wetlands is an intergovernmental treaty of which the UK is a contracting party which provides the framework for national action and international cooperation for the conservation and wise use of wetlands. The UK implements the Convention through the Birds and Habitats Directives and other measures under national legislation.

1.2.5 River Usk SAC

The River Usk drains a medium-sized catchment in south Wales, and flows eastwards along the Brecon Beacons, meandering through Monmouthshire to the tidal waters of the Severn Estuary. The River Usk SAC was designated in 2004 and is considered to be one of the best areas in the UK for river, brook and sea lamprey and for Twaite shad which are known to spawn in the river. It is also well known as a spawning ground for Atlantic salmon as there are no significant obstructions to migration, good quality spawning gravels and a diversity of habitats with good water quality.

The River Usk SAC extends over a total area of 1008ha and supports the following qualifying features:

- Annex I habitats:
  - Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
- Annex II species:
  - *Petromyzon marinus* - sea lamprey.
  - *Lampetra planeri* - brook lamprey.
  - *Lampetra fluviatilis* - river lamprey;
  - *Alosa fallax* - twaite shad;
  - *Alosa alosa* – allis shad
  - *Salmo salar* – Atlantic salmon;
  - *Cottus gobio* – Bullhead;
  - *Lutra lutra* – Otter

CCW published conservation objectives for the site as part of a core management plan in March 2008 (CCW, 2008a).

1.2.6 River Wye SAC

The River Wye, flows through England and Wales, and is a largely unmodified river with a total area of 2235ha. . The geologically-mixed catchment shows clear transitions between the upland reaches with characteristic bryophyte-dominated vegetation, and the lower reaches, with extensive *Ranunculus* beds. The River Wye SAC was designated in 2005 for its unique habitats and associated species. The lower reaches of the river SAC are tidal and contiguous with the tidal waters of the Severn Estuary.

The River Wye SAC supports the following qualifying features:

- Annex I habitats:
  - Water courses of plain to montane levels with submerged or floating vegetation *Ranunculion fluitantis* (River Water crow-foot) and *Callitricho-Batrachion* (chalk stream habitat);
  - Transition mires and quaking bogs
- Annex II species:
  - *Petromyzon marinus* - sea lamprey.
  - *Lampetra planeri* - brook lamprey.
  - *Lampetra fluviatilis* - river lamprey;
  - *Alosa fallax* - twaite shad;
  - *Alosa alosa* – allis shad;
  - *Salmo salar* – Atlantic salmon;
  - *Cottus gobio* – Bullhead;
  - *Lutra lutra* – Otter;
  - *Austropotamobius pallipes* – White-clawed crayfish

1.2.7 River Tywi SAC

The Tywi River SAC covers an area of 364ha that extends upstream of a point some 6 to 7 miles from the mouth of the Tywi estuary. At this point it abuts the large 66,101ha Carmarthen Bay and Estuaries SAC that covers the remainder of the Tywi Estuary as well as the majority of Carmarthen Bay and the Taf Estuary (as shown in Figure 2).

The River Tywi SAC supports the following qualifying features:

- Annex II species:
  - *Petromyzon marinus* - sea lamprey.

- *Lampetra planeri* - brook lamprey.
- *Lampetra fluviatilis* - river lamprey;
- *Alosa fallax* - twaite shad;
- *Alosa alosa* – allis shad
- *Cottus gobio* – Bullhead;
- *Lutra lutra* – Otter

CCW published conservation objectives for the site as part of a core management plan in April 2008 (CCW, 2008c).

1.3 Project Objectives and Outline Approach

The Sustainable Development Commission's report 'Tidal Power in the UK' (SDC, 2007) emphasised that any tidal power option progressed should clearly demonstrate compliance with the requirements of the EC Habitats and Birds Directives. The report recommended, in particular, that further consideration should be given to the feasibility of providing compensatory measures to offset the possible impacts of tidal power development in the Severn Estuary and in any other designated sites that could be affected. More broadly it was also recognised that there was potential to minimize potential impacts through careful scheme design and the implementation of mitigation measures.

This study forms part of the feasibility study announced on 25th September 2007 by the Secretary of State for Business, Enterprise and Regulatory Reform. Terms of Reference for the Study were published on 22 January 2008, which are as follows:

"Building on the work of the Sustainable Development Commission and earlier studies, the feasibility study will:

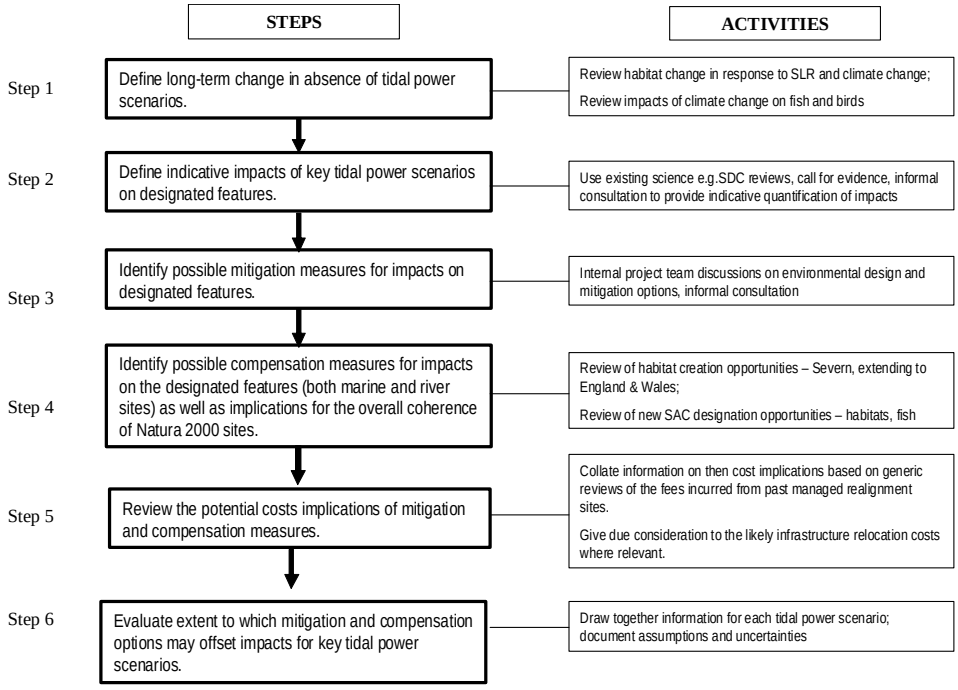
- assess in broad terms the costs, benefits and effect of a project to generate power from the tidal range of the Severn Estuary, including environmental, social, regional, economic, and energy market impacts;
- identify a single preferred tidal range project (which may be a single technology/location or a combination of these) from the number of options that have been proposed;
- consider what measures the Government could put in place to bring forward a project that fulfils regulatory requirements, and the steps that are necessary to achieve this;

- decide, in the context of the Government's energy and climate change goals and the alternative options for achieving these, and after public consultation, whether the Government could support a tidal power project in the Severn Estuary and on what terms."

This Phase 1 study seeks to identify, at a very broad or 'high-level' scale, the possible mitigation and compensation options for key tidal power scenarios that might be required under the Habitats Regulations.

The methodology that has been adopted for this work is based on a series of clear steps and associated activities and these steps are illustrated in Box 1 below. Further details about the work undertaken for each of these steps is presented within the relevant sections of this report and a description of the methodology is provided in Appendix 1.

Box 1 Outline methodology for mitigation and compensation methodology



1.4 Report Structure

The report is structured around the main steps in the methodology as follows:

- Section 1 – background to project and introduction;
- Section 2 – brief review of potential long-term natural changes to features of interest;
- Section 3 – description of potential impacts of short-listed options on features of interest based on current knowledge;
- Section 4 – identification of potential mitigation measures to address possible impacts to specific features and an initial evaluation of their likely effectiveness;
- Section 5 – identification of potential compensatory measures to address possible impacts to specific features and an initial evaluation of their likely effectiveness;
- Section 6 – indicative costing of potential mitigation and compensatory measures;
- Section 7 – evaluation of potential mitigation and compensatory measures in relation to potential impacts;
- Section 8 – conclusions and recommendations.

1.5 Consultation

This report has been prepared by ABPmer with input from Black & Veatch and others.

The study has drawn on existing studies and expertise within the study team (PB, BV, ABPmer), including expertise on birds (BTO) and migratory/estuarine fish (APEM) and on input from statutory agencies and government departments. A consultation meeting/teleconference was held in June 2008 to review the draft methodology with participation from a Working Group comprising Defra, DECC, Natural England, CCW and the Environment Agency.

A Working Group review meeting was held in Cardiff in July 2008, and comments from the Working Group have been reflected in this draft which was circulated to them after the meeting.

SECTION 2

LONG-TERM CHANGE

2 LONG-TERM CHANGE

A brief review of information sources was undertaken to identify natural and major anthropogenic changes in the Severn Estuary system in the absence of any tidal power development and how this may affect interest features within the system.

Key sources of information include:

- Severn Coastal Habitat Management Plan (CHaMP) (ABPmer, 2008) – provides predictions on long-term habitat change within the Severn Estuary for the next 100 years. In the absence of further intervention, coastal squeeze is predicted to result in a net reduction in intertidal area of some 11%. However, in the absence of tidal power development project, it can be assumed that such losses would be compensated for as part of the Severn Estuary Flood Risk Management Strategy in line with Government policy;

- Prater (2007) identified long-term changes in usage of the estuary by waterbirds. The study showed that there had been many changes to species abundance (as has been typical observed for other UK estuaries). The numbers of dunlin and European white-fronted goose in particular have decreased substantially and this was considered to reflect milder winters in recent years. Other species such a ringed plover, grey plover, pochard and tufted duck have also decreased. The reductions in the numbers of the latter two sea duck species were attributed to reductions in nutrient inputs from sewage discharges. Other species of waterfowl have increased considerably in numbers including pintail, shoveler and teal. Also some wader species have increased in abundance including redshank and black-tailed godwit. Overall, there has been a minor reduction in the peak numbers of waders using the estuary of around 4.5% since 1985.

- The number of fish species encountered during surveys of fish entrained at Hinkley Power Station is reported to have increased from 33 in 1982 to 46 in 1988 as a result of changes in the North Atlantic Oscillation (NAO) and increases in sea temperatures (Henderson, 2007, Potter et al, 2001);

- WWF (2001) report a 75% decline in North Atlantic salmon population as a whole between 1983 and 2001 attributed to changes in the NAO and increases in sea temperature.

Although these reports contain predictions about future change, particularly in response to climate change, it must be recognised that such predictions are inevitably subject to considerable uncertainty. Often the assessments focus on potentially deleterious changes to existing features; however, climate change is also likely to provide opportunities for species currently at their northernmost limit.

The issue of long-term change and conservation objectives for the Severn Estuary designated site has been addressed in two main ways:

- The development of the Severn CHaMP has specifically sought to ensure that the site does not deteriorate as a result of seal level rise causing coastal squeeze;

- The conservation objectives for the site have been worded to recognise that there are some natural changes that cannot be controlled, for example, changing bird numbers and distributions linked to climate change.

The Habitats Regulations appropriate assessment will focus on the relevant conservation objectives for affected sites rather than the condition of the affected features at the time of any tidal power development. Information on long-term change is nonetheless of potential interest. In particular, an understanding of such changes can inform views on the likely impact on features at the time development might occur and, in the long-term could also inform revision of the conservation objectives. Such information may also assist in designing compensatory measures to maintain the overall coherence of the Natura 2000 network.

SECTION 3

INDICATIVE IMPACTS OF TIDAL POWER OPTIONS

3 INDICATIVE IMPACTS OF TIDAL POWER OPTIONS

3.1 Introduction

The following internationally designated sites are considered to be those most likely to be affected by tidal power development in the Severn Estuary:

- Severn Estuary SPA
- Severn Estuary cSAC
- Severn Estuary Ramsar Site
- River Usk SAC
- River Wye SAC
- River Tywi SAC

There is a residual risk of sites further away being affected, and this will need to be considered in the formal Appropriate Assessment screening process.

Various studies have been undertaken to investigate the potential environmental impacts of tidal power options in the Severn Estuary. Most of these studies have focused on a Cardiff-Weston Barrage option and were undertaken in the 1970's and early 1980's. Much of this information is consolidated in the SDC review of a Severn Barrage (SDC Research Report 3 (Black & Veatch, 2007)) and for tidal lagoons in SDC Research Report 4 (AEA Energy & Environment, 2007)).

Ahead of detailed hydrodynamic and geomorphological modelling, predicting the impacts of the various tidal power options on the environment, and internationally designated features in particular, is subject to considerable uncertainty. This uncertainty will need to be reflected in any package of mitigation and compensation measures for a preferred option.

Drawing on pre-existing studies, comparative high level indicative information on the potential impacts of four broad tidal power options on the main features within the designated sites potentially affected has been collated for:

- An inner barrage (based primarily on information from existing assessments of the Shoots Barrage (B4))
- A middle barrage (based on information relating to the Cardiff-Weston Barrage (B3))
- An outer barrage (B1/B2)
- The Generic Lagoon Concept (L3)

It is recognised that other options such as a tidal reef or tidal fence may be included on the short-list of options. These options have not been evaluated in this study because there is a lack of information on their potential impacts, although in general terms it might be expected that the impacts on physical processes might be similar to other tidal power options, depending on the extent to which these schemes affected the natural tidal range.

It must be emphasised that none of the potential options has yet been subject to rigorous or detailed environmental assessment using modern assessment tools and methods. While extensive assessment of a possible Cardiff-Weston barrage option was undertaken in the 1970's and 1980's and a more limited evaluation for the Shoots Barrage was carried out in the late 1980's, there are still significant limitations surrounding these studies (not least the basic nature of early computational models). The assessment presented draws on legacy information where appropriate but also takes account of more recent studies and analyses where available. In particular, it draws on early versions of the SEA scoping topic papers. The assessment is intended to provide a precautionary view based on expert judgement, although it should be emphasised that there is currently a high level of uncertainty surrounding such estimates.

Given the large uncertainties surrounding the prediction of impacts at this stage, the evaluation has focused primarily on the implications for the high level features within each site rather than the details of all the sub-features and elements identified in the conservation objectives. However, as part of any formal assessment of a tidal power development proposal under the Habitats Regulations, it will be necessary to evaluate the impacts on the interest features within the designated sites against the conservation objectives for those features and sub-features.

3.2 High Level Evaluation of Potential Impacts

A summary of potential impacts for relevant cSAC, SPA and Ramsar features is presented in Table 1.

Substantial direct losses of cSAC habitats within the Severn Estuary are likely to occur with all four options reviewed, as each is likely to lead to a reduction in tidal range. The lagoon option might also lead to permanent inundation of some areas of former intertidal within the lagoon boundary. While, for all options, the effects on the tidal regime will be greater upstream of the structures, significant downstream effects are also likely to be experienced downstream of the structures as well.

Preliminary estimates of habitat change have been developed as part of the options assessment exercise (Parsons Brinckerhoff and Black & Veatch, in prep.) to enable a fair basis comparison of options for relative comparison of the options:

- Inner (Shoots) Barrage B4 – reduction in intertidal area of around 5,000ha;
- Middle Barrage (Brean Down to Lavernock Point) B3 – reduction in intertidal area of 20,000ha;
- An outer barrage (B1) – reduction in intertidal area of 26,000 to 28,000ha;
- Generic lagoons concept (e.g. Welsh Grounds and Bridgwater Bay) – reduction in intertidal area of approximately 12,000ha.

The estimate of a 20,000ha reduction for the Middle Barrage option compares to a more detailed estimate of around 14,500ha calculated for the SDC review for the Cardiff-Weston Barrage (Black & Veatch, 2007) and the 20,000ha figure is therefore likely to be a significant overestimate created for comparative purposes. Further work is needed to provide a more accurate assessment. It would represent around a 90% reduction compared to the current intertidal area. Such changes would also have significant impacts on many of the associated sub-features, for example, *Zostera* beds.

The uniqueness of the current intertidal invertebrate assemblages (depauperate, stressed and small size of individuals) reflects the extreme physical conditions in the estuary. Changes to this high energy regime will also lead to changes in intertidal benthic assemblages such that they may no longer represent the current extreme range of variation. Such changes would impair the quality of such areas in relation to their conservation objectives.

Further indirect changes may occur over remaining intertidal areas in the Severn Estuary depending on longer-term geomorphological changes. There are currently significantly divergent views on the morphological changes that might be expected to occur following tidal power development. Under a worst-case scenario, the morphological changes may cause ongoing deterioration of the extent and quality of intertidal habitats. Such changes

might also reduce the effectiveness of some of the potential mitigation measures discussed in section 4.

Changes in sediment transport may also affect the quality of subtidal habitats in the Severn Estuary(e.g. subtidal sandbanks, reefs). Middle and outer barrage options could potentially have significant impacts on all the subtidal sandbank features within the designated sites. The current extent of the subtidal sandbank feature has not been quantified, but is likely to be of the order of several thousand hectares. While it is not possible to quantify the extent of potential impact from tidal power development, the current area does at least provide an upper bound for potential impacts.

The main distribution of subtidal *Sabellaria* reef is in the vicinity of the line of a middle barrage and thus might be at significant risk from both middle and outer barrage options. Again, there is no detailed quantification of the resource, but it is known to occur in patches over an area of at least 100km^2.

Pending more detailed studies in Phase 2, it is not currently possible to quantify either the potential direct or indirect changes in estuarine habitats with high confidence although the larger schemes would generally be expected to have the greater impacts.

There is very limited information on the behaviour of migratory fish within the Severn Estuary or tributary estuaries. Available evidence suggests that all barrage options would pose a high risk to migratory fish features in the Severn Estuary cSAC, and the River Usk and Wye SACs. They may also pose a risk to migratory fish using the River Tywi SAC. While the Generic Lagoon concept would not directly cut off access to any of the designated freshwater spawning grounds, it is still considered likely to pose potentially significant risks to migratory fish due to their general movement through the area.

All of the options potentially pose risks to European otter within the Usk and Wye SACs as a result of potential habitat change and food availability within the tidal reaches of these rivers.

For impacts to the SPA features, the key issue is whether changes in extent, quality and availability of habitats under the new tidal regime will reduce the capacity of the SPA to support the bird populations for which it has been designated.

Broad-based predictions made by Goss-Custard and Moser (1988) for a possible Cardiff-Weston Barrage option suggested that post-barrage, the remaining intertidal area may be capable of supporting the existing

populations of many of the bird species occurring on the estuary, with the possible exception of dunlin and shelduck. However, there are significant uncertainties concerning the geomorphological impacts of tidal power projects and the resultant quality of remaining intertidal areas. Furthermore, such estimates are very sensitive to predictions on the extent of remaining intertidal area which is also uncertain. These predictions are therefore considered to be speculative at this stage.

No assessment of the impact of a lagoon option on bird populations has yet been undertaken. The impacts will depend to some extent on the precise location of the lagoons (i.e. do they encroach onto the intertidal) and subsequent morphological change (which could lead to local increases or decreases in intertidal extent). The impacts of an inner barrage on birds would be expected to be less than for a middle barrage option. The impacts of an outer barrage on waterbirds could be greater as it results in a larger change in intertidal area.

Most of the Ramsar site features are also included within the SAC and SPA designations (immense tidal range, estuarine communities, migratory fish, migratory and overwintering birds). However, the Ramsar site designation includes all species of migratory fish. Therefore eel and sea trout require additional consideration in relation to potential impacts to Ramsar features., While no detailed impact assessment is available for these species, in general terms the potential impacts for sea trout are likely to be similar to those for salmon and the potential impacts for eel similar to those for lamprey, although they do use different parts of the estuary and migrate into the tributary rivers at different times of the year depending on life stage.

The Ramsar designation also covers fish populations of estuarine and river systems. There has been no detailed study of potential impacts, although the range of potential impacts expected are likely to be similar to those for migratory fish, particularly where species have a high functional dependence on areas upstream of tidal power development during part or all of their life cycle. However, the magnitude of certain potential impacts (e.g. changes in water quality and habitat availability) on populations of marine/estuarine fish are likely to be less than for migratory fish species (see APEM, in prep).

Table 1 Indicative broad changes to internationally designated features associated with a range of tidal power options[1]

Receptor	Inner Barrage Option	Middle Barrage Option	Outer Barrage Option	Generic Lagoons Concept
<u>Severn Estuary SPA Features</u> • Annex 1 species • Regularly occurring migratory species and internationally important assemblage of waterfowl • Intertidal mudflats & sandflats • Saltmarsh • Intertidal rock and shingle	• No specific assessment available – possible impacts • No specific assessment available; limited impact likely based on existing information on bird distributions • Potential direct loss of c. 5000ha in mid-upper estuary • Unquantified but substantial loss of estimated 133ha resource upstream of inner barrage • Unquantified loss	• No specific assessment available – possible impacts • Species specific assessments generally lacking; geomorphological impacts and thus ecological impacts uncertain • Potential direct loss of c. 20,000ha along length of estuary • Unquantified – approximately 1000ha of total of 1400ha resource is upstream of middle barrage • Unquantified loss	• No specific assessment available – possible impacts • Species specific assessments generally lacking; geomorphological impacts and thus ecological impacts uncertain • Potential direct loss of c. 26,000 to 28,000ha along length of estuary • Unquantified but substantial loss of existing 1400ha resource • Unquantified loss	• No specific assessment available – possible impacts • No specific assessment available; geomorphological impacts and thus ecological impacts uncertain • Potential direct loss of c.12,000ha • Unquantified but likely significant loss • Unquantified loss
<u>Severn Estuary cSAC Features</u> • Atlantic salt meadows/saltmarsh	• Unquantified but substantial loss of estimated 133ha resource upstream of inner barrage	• Unquantified - approximately 1000ha of total of 1400ha is upstream of middle barrage; around 656ha of total resource meets ASM definition	• Unquantified but substantial loss of existing 1400ha resource; likely to include all of ASM resource	• Unquantified but significant loss

[1] At this stage the area change (ha) estimates are provisional and owing to the high-level nature of this assessment may include areas of undesignated habitat. However, the majority of the habitats quoted are within designated sites.

Receptor	Inner Barrage Option	Middle Barrage Option	Outer Barrage Option	Generic Lagoons Concept
• Estuary	• Reduction in tidal range and flows u/s of barrage; small local reduction in tidal range d/s of barrage; changes in sediment supply	• Reduction in tidal range and flows u/s barrage; small local reduction in tidal range d/s of barrage; changes in sediment supply	• Alteration of tidal range and disruption of flows unquantified, but likely to be significant; changes in sediment supply	• Alteration of tidal range and disruption of flows unquantified, but changes likely due to alteration of estuary profile ; changes in sediment supply
• Mudflats and sandflats	• Potential direct loss of up c. 5,000ha in mid-upper estuary	• Potential direct loss of up to c.20,000ha along length of estuary and associated sub-features (e.g. eelgrass)	• Potential direct loss of up to c.26,000 to 28,000ha intertidal area along length of estuary and associated sub-features (e.g. eelgrass)	• Unquantified but likely significant loss
• Reefs (*Sabellaria*)	• Unquantified but minor	• Unquantified, but significant – main reefs are in vicinity of a middle barrage option	• Unquantified, but significant –reefs are upstream of outer barrage option	• Unquantified, but likely significant loss
• Subtidal sandbanks	• Unquantified risk	• Unquantified but possibly significant – majority of feature is upstream of a middle barrage option	• Unquantified but possibly significant –feature is upstream of outer barrage option	• Unquantified risk
• Fish (twaite shad)	• Very high risk of very high mortality. Potential stock eradication.	• Very high risk of very high mortality. Potential stock eradication.	• Very high risk of very high mortality. Potential stock eradication.	• Unquantified risk
• Fish (river and sea lamprey)	• Medium risk of high mortality	• Medium risk of high mortality	• Medium risk of high mortality	• Unquantified risk
<u>River Usk SAC Features</u> • Fish (allis and twaite shad)	• Unquantified risk	• Very high risk of very high mortality. Potential stock	• Very high risk of very high mortality. Potential stock	• Unquantified risk

Receptor	Inner Barrage Option	Middle Barrage Option	Outer Barrage Option	Generic Lagoons Concept
• Fish (river and sea lamprey) • Fish (Atlantic salmon) • European Otter	• Unquantified risk • Unquantified risk • Low risk of impact	eradication • Medium risk of high mortality • High risk of high mortality • Unquantified risk	eradication • Medium risk of high mortality • High risk of high mortality • Unquantified risk	• Unquantified risk • Unquantified risk • Unquantified risk
<u>River Wye SAC Features</u> • Fish (allis and twaite shad) • Fish (river and sea lamprey) • Fish (Atlantic salmon) • European Otter	• Very high risk of high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality • Unquantified risk	• Very high risk of high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality • Unquantified risk	• Very high risk of high mortality. Potential stock eradication • Medium risk of high mortality • High risk of high mortality • Unquantified risk	• Unquantified risk • Unquantified risk • Unquantified risk • Unquantified risk
<u>River Tywi SAC Features</u> • Fish (allis and twaite shad) • Fish (river and sea lamprey) • European Otter	• Low risk of impact • Low risk of impact • Low risk of impact	• Unquantified risk • Unquantified risk • Unquantified risk	• Unquantified risk • Unquantified risk • Unquantified risk	• Low risk of impact • Low risk of impact • Low risk of impact
<u>Severn Estuary Ramsar Site</u> • Tidal range • Unusual estuarine	• Reduction in tidal range and flows u/s of barrage; small local reduction in tidal range d/s of barrage; changes in sediment supply • Changes in salinity and	• Reduction in tidal range and flows u/s barrage; small local reduction in tidal range d/s of barrage; changes in sediment supply • Changes in salinity and	• Alteration of tidal range and disruption of flows unquantified, but likely to be significant; changes in sediment supply • Changes in salinity and	• Alteration of tidal range and disruption of flows unquantified, but changes likely due to alteration of estuary profile; changes in sediment supply • Alterations in flows and

Receptor	Inner Barrage Option	Middle Barrage Option	Outer Barrage Option	Generic Lagoons Concept
communities (reduced diversity and high productivity)	sediment stability u/s of barrage will affect assemblage composition	sediment stability u/s of barrage will affect assemblage composition	sediment stability u/s of barrage will affect assemblage composition	salinity likely to affect assemblage composition outwith lagoons; changes in sediment stability inside lagoons will affect assemblage composition
• Migratory fish	• Medium to very high risk of high mortality depending on species	• Medium to very high risk of high mortality depending on species	• Medium to very high risk of high mortality depending on species	• Unquantified risk but considered likely to be significant
• Bird assemblages of international importance	• No specific assessment available; limited impact likely based on existing information on bird distributions	• Species specific assessments generally lacking[2]; geomorphological impacts and thus ecological impacts are uncertain	• Species specific assessments generally lacking[2]; geomorphological impacts and thus ecological impacts are uncertain	• No specific assessment available; geomorphological impacts and thus ecological impacts uncertain
• Bird species/populations occurring at levels of international importance	• No specific assessment available; limited impact likely based on existing information on bird distributions	• Species specific assessments generally lacking; geomorphological impacts and thus ecological impacts uncertain	• Species specific assessments generally lacking; geomorphological impacts and thus ecological impacts uncertain	• No specific assessment available; geomorphological impacts and thus ecological impacts uncertain
• Fish population of estuarine and river system	• Medium to very high risk of high mortality depending on species	• Medium to very high risk of high mortality depending on species	• Medium to very high risk of high mortality depending on species	• Unquantified risk but considered likely to be significant

SECTION 4

POSSIBLE MITIGATION MEASURES

4 MITIGATION MEASURES

4.1 Introduction

Mitigation measures for the purposes of the Habitats Regulations can be defined as those measures that are implemented as part of the development project with the aim of reducing or avoiding significant adverse effects on conservation features within the designated sites affected. The measures need to be additional to any measures already required to achieve/ maintain favourable condition for designated features and to be targeted towards addressing the specific impacts of the development. Based on advice received from Natural England and CCW, such measures do not necessarily need to be undertaken within the affected designated sites but they do need to be 'felt' within them. Thus, where potential beneficial measures are undertaken within the river SACs that lie upstream of the Seven Estuary SPA/cSAC (and thus benefit migratory fish passing through the Severn Estuary designated site) these could be categorised as mitigation measures. Where equivalent enhancement is taken in other riverine sites to the benefit of migratory species that don't pass through the Severn SPA/cSAC then these are compensatory measures. Other habitat creation or habitat management works within the boundaries of the designated site are also is likely to be classified as mitigation. By contrast, managed realignments to offset habitat losses or bird impacts will almost always be compensatory measures whether they are alongside the Severn or elsewhere. This is because they will involve habitat creation above the high water boundary and outside the designated area.

Based on these established definitions, mitigation measures will therefore include those impact reduction measures that are an integral part of how a power project is designed and implemented within the Seven Estuary SPA/cSAC. Previous studies of tidal power generation options in the Severn Estuary have given relatively little consideration to these issues of environmental design and mitigation. For the purposes of this study a brief desk-based review was undertaken to consider potential mitigation measures and their effectiveness in avoiding or reducing impacts on designated features. An evaluation of the certainty of individual impact reduction measures was also carried out.

It should be noted that the assessment is very much a preliminary one and the key potential mitigation measures will require more detailed study both to evaluate their potential effectiveness and to assess their costs (including indirect costs such as reduced energy yield). The mitigation measures should therefore be seen as broadly illustrative at this stage.

The potential effectiveness and confidence associated with possible mitigation measures are described below. The information is also summarised in a series of tables (Tables 2 to 5). Tables 2 and 3 provide an evaluation of potential mitigation measures and their effectiveness in relation to SAC features (including relevant Ramsar features) for barrage and lagoon development respectively. Tables 4 and 5 provide equivalent information in relation to SPA features (including relevant Ramsar features). Similar mitigation measures would be applicable to other tidal power options.

Table 2 Mitigation measures matrix for barrages - habitats and species

	Annex 1 Habitat types					Annex II species					Additional Ramsar Site Features		
	Estuaries	Subtidal sandbanks	Intertidal Mud and Sandflats	Atlantic Saltmeadow	Reefs (S. alveolata)	Atlantic salmon	River Lamprey	Sea Lamprey	Twaite Shad (and allis shad)	European otter	European Eel	Sea Trout	Estuarine Fish Population
Mitigation Measures	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Usk, Wye SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Usk, Wye Tywi SAC	Severn Estuary Ramsar Site	Severn Estuary Ramsar Site	Severn Estuary Ramsar Site
Barrage design - minimising the impact on tidal range upstream and downstream of a barrage	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×	×	×	×	✓ partial	×	×	×
Barrage design - inclusion of fish passage management options within/near a barrage	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Barrage design - refine barrage wall, sluice and turbine design to enhance safe fish passage	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Operational management of the tidal exposures and exchanges on a day to day or seasonal basis	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×	×	×	×	✓ partial	×	×	✓ partial
Operational management of barrage regime to enhance passage of fish	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Topographic modification upstream and downstream of a barrage	×	✓ partial	✓ partial	✓ partial	✓ partial	×	×	×	×	✓ partial	×	×	✓ partial
Habitat management upstream of a barrage:	×	×	×	✓ partial	×	×	×	×	×	✓ partial	×	×	✓ partial
Transportation/ acoustic herding of fish u/s d/s of barrage	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Habitat management in tributary rivers	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×
Fish stock enhancement in tributary rivers	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×	×

✓ Measure has potential to avoid impact
✓ partial Measure has potential to reduce impact
× Measure does not have potential to reduce impact

Very low confidence in effectiveness of mitigation measure
Low confidence in effectiveness of mitigation measure
Medium confidence in effectiveness of mitigation measure
High confidence in effectiveness of mitigation measure

Table 3 Mitigation measures matrix for lagoons - habitats and species

	Annex 1 Habitat types					Annex II species					Additional Ramsar Site Features		
	Estuaries	Subtidal sandbanks	Intertidal Mud and Sandflats	Atlantic Saltmeadow	Reefs (S. alveolata)	Atlantic salmon	River Lamprey	Sea Lamprey	Twaite Shad (and allis shad)	European otter	European Eel	Sea Trout	Estuarine Fish Population
Mitigation Measures	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Usk, Wye SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Usk, Wye Tywi SAC			
Refine lagoon wall, sluice and turbine design and location to aid fish passage management	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Management of lagoon operational regime to enhance passage of migratory species	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Topographic modification outside of lagoon boundary	×	✓ partial	✓ partial	✓ partial	✓ partial	×	×	×	×	✓ partial	×	×	✓ partial
Habitat management outside of lagoon boundary:	×	×	×	✓ partial	×	×	×	×	×	✓ partial	×	×	✓ partial
Ecological enhancement measures within the lagoon boundary	×	✓ partial	✓ partial	×	✓ partial	×	×	×	×	×	×	×	✓ partial
Habitat management in tributary rivers	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×
Fish stock enhancement in tributary rivers	×	×	×	×	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	×	×

✓ Measure has potential to avoid impact
✓ partial Measure has potential to reduce impact
× Measure does not have potential to reduce impact

Very low confidence in effectiveness of mitigation measure
Low confidence in effectiveness of mitigation measure
Medium confidence in effectiveness of mitigation measure
High confidence in effectiveness of mitigation measure

Table 4 Mitigation measures matrix for barrage options - Severn SPA

Site	Int Imp Annex 1	Internationally Important Migratory Birds				Internationally Important Assemblage of waterfowl including nationally Important individual species										
Types of mitigation measure/Feature	Bewick's swan	Shelduck	Dunlin	Redshank	European White fronted goose	17,502 wildfowl & 50,524 waders	widgeon	teal	pintail	pochard	tufted duck	ringed plover	grey plover	curlew	whimbrel	spotted redshank
Key supporting habitats	Intertidal mud and sandflats and saltmarsh communities for Bewick's swan. Intertidal mud and sandflats and saltmarsh communities, shingle and rocky shore and wet coastal grazing marsh for all other features															
Altering the size and location of a barrage:	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Barrage design - minimise the impact on tidal range upstream of a barrage	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Operational management of tidal exposures and exchanges on a day to day or seasonal basis	✓	✓ partial	✓ partial	✓ partial	✓	✓ partial	✓	✓	✓	✓	✓	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Topographic modification upstream of a barrage and within the site boundary	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Introduction of refuges or bird roosts	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Habitat management upstream of a barrage:	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial

✓ Measure has potential to avoid impact
✓ partial Measure has potential to reduce impact
× Measure does not have potential to reduce impact

Very low confidence in effectiveness of measures
Low confidence in effectiveness of mitigation measure
Medium confidence in effectiveness of mitigation measure
High confidence in effectiveness of mitigation measure

Table 5 Mitigation measure matrix for lagoon option - Severn SPA

Site	Int Imp Annex 1	Internationally Important Migratory Birds				Internationally Important Assemblage of waterfowl including nationally Important individual species										
Types of mitigation measure/Feature	Bewick's swan	Shelduck	Dunlin	Redshank	European White fronted goose	17,502 wildfowl & 50,524 waders	widgeon	teal	pintail	pochard	tufted duck	ringed plover	grey plover	curlew	whimbrel	spotted redshank
Key supporting habitats	Intertidal mud and sandflats and saltmarsh communities for Bewick's swan. Intertidal mud and sandflats and saltmarsh communities, shingle and rocky shore and wet coastal grazing marsh for all other features															
Topographic manipulation outside of lagoon boundary	×	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Introduction of refuges or bird roosts along and outside lagoon margins	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial
Ecological enhancement measures within the lagoonal boundary	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial	✓ partial

✓ Measure has potential to avoid impact
✓ partial Measure has potential to reduce impact
× Measure does not have potential to reduce impact

Very low confidence in effectiveness of mitigation measure
Low confidence in effectiveness of mitigation measure
Medium confidence in effectiveness of mitigation measure
High confidence in effectiveness of mitigation measure

4.2 Possible Mitigation Measures

4.2.1 Tidal Power Structure Design

Minimise Impact on Existing Tidal Regime

There may be scope within the design or siting of tidal power options to minimise the impact on the upstream and downstream tidal regime. This could help to conserve features of interest in situ and provide habitats for dependent species (e.g. birds). For example, increasing high water levels upstream of a middle barrage option by around 1m could potentially preserve significant extents of upper intertidal and saltmarsh. This might be achieved through innate design (increasing the number of sluices, allowing overtopping on spring tides) or enhanced tidal pumping. It should be noted that such measures might have an adverse effect on energy yield. Careful siting of lagoons may also serve to minimise impacts on high water levels. While such mitigation measures might avoid changes to high water levels, the overall reduction in tidal range may affect the geomorphology of the estuary, particularly the balance of sediment supply to intertidal areas. They would therefore generally only have a low level of confidence attached to them.

It is considered unlikely that it would be possible to lower the predicted low water levels upstream of tidal developments without having a very significant impact on net energy yield (i.e. pumping water out of impounded areas at low tide).

Fish Protection Measures

There is scope for the inclusion of a range of measures to seek to protect migratory and estuarine fish, including:

- Screening – physical or behavioural (acoustic deterrents);
- Fish pass/sluice design (and location of sluices in relation to turbines);
- Turbine design (to minimise fish injury and mortality);
- Design of barrage/lagoon wall.

Physical screening technologies although widely used on freshwater hydropower schemes to prevent fish ingress into turbines have not been used on estuarine barrage schemes to date. Such measures are considered unlikely to be practicable because a relatively small mesh size would be needed to prevent ingress of juvenile fish (APEM, in prep). Given the very high flows through the turbines during power generation, continuous cleaning of the screens would be essential. The high flows would also be likely to result in impingement of weak swimming juvenile fish on the screens causing injury and mortality.

Acoustic deterrents can be partially effective in reducing entrainment of hearing sensitive species such as shad. Gibson & Myers (2002) reported a 42% reduction in the passage of shad through the turbines of the Annapolis Royal barrage following installation of an acoustic fish diversion system. However, such systems are relatively ineffective for hearing insensitive species such as lampreys and eel. Furthermore, the scale of the management challenge in seeking to minimise disruption to the passage of migratory and estuarine fish is unprecedented. Based on existing knowledge there is a very low level of confidence that such measures will be effective in mitigating impacts.

Conventional fish passes are not suitable for tidal environments. However, sluices and bypasses could be considered. Two fishways have been installed within the Annapolis Royal barrage (Gibson & Myers, 2002) but their effectiveness is not known.

Given the presence of a large number of sluices within barrage structures, these could be designed to facilitate both upstream and downstream movements of migratory and estuarine fish. There is currently little understanding of how migratory fish use the Severn estuary during migration and other life cycle stages (swimming depth, position relative to shore line etc). Such information will be important in seeking to optimize sluice and turbine location, design and operation from a fish protection perspective, although it should be recognised that physical changes associated with tidal power development may also change the way in which fish use the estuary. Pending further studies of the use of the estuary by migratory and estuarine fish there is a very low level of confidence that such measures will be effective in mitigating impacts.

Research has been undertaken over the last decade to improve turbines for fish passage. Much work has been done by the Advanced Hydro Turbine System programme (AHTS) funded by the US Department of Energy to explore innovative concepts for design of turbines that will have environmental benefits while maintaining efficient electrical generation.

Research undertaken by Alden Research Laboratory Inc./Northern research and Engineering Corporation and Voith Hydro Inc. ARL/NREC has developed a prototype which is currently undergoing trials. Voith have investigated how existing Kaplan turbine designs can be modified to improve efficiency and reduce environmental effects.

Canadian research has sought to develop a vaneless turbine to minimise damage to passage fish. The predicted survival rate for this turbine was estimated at 93.3% based on a five blade runner and 96% for three blades. However, pending the outcome of trials on alternative turbine designs, it is not possible to assign anything other than a very low level of confidence that such measures will be effective in mitigating impacts.

On some smaller scale hydropower schemes, zig-zag wall designs have been used to direct fish towards sluices and away from turbines. It is unclear whether such a design could be used for a large scale estuarine barrage, particularly because the cost implications could be large. Pending further research, the efficacy of such measures is uncertain and thus there is a very low level of confidence that such design measures will be effective.

Bird Roosting Structures

The extent and location of suitable roosts is increasingly recognised as an essential component of coastal habitats for birds. The tidal power structures could provide opportunities to incorporate structures that might be used as high water roosts by some waterbirds. These would have to be elevated well above the MHWS mark and ideally include areas with low vegetation, clear sightlines, low levels of spray and be subject to minimal disturbance. If appropriately located, such features could minimise distances between feeding and roosting sites with attendant benefits in terms of the energy expended by feeding waterbirds. There are many examples of how artificial structures can achieve this but one such example are the limestone 'fish-tail' breakwaters at Morecambe. These were put in place to reduce wave energies and prevent undermining of the sea walls through shoreline topographic change but they have been shown to have value as bird roost especially where they are placed near to prime intertidal feeding areas (ABPmer 2008a).

There is a moderate level of confidence that such mitigation measures would deliver some benefit for some species, although it may be difficult to relate such benefits (better roosting sites) to the potential impacts of tidal power

options (loss of intertidal feeding habitat). Overall therefore the confidence levels have been identified as being either low or very low at this stage.

4.2.2 Management of Operational Regime

Inundation Regime

Management of the tidal exposures and exchanges on a day to day or seasonal basis could be used to seek to maintain saltmarsh and upper intertidal habitats in situ and/or to control mudflat exposure times for wading birds. By applying such measures on an occasional rather than a routine basis (as in 4.2.1), this could minimise economic costs (by reducing impacts on energy yield) while still providing some environmental benefit. For example, maintenance of transitional saltmarsh can be achieved through relatively infrequent inundation of the order of less than 20 inundations per year (see review in ABPmer, 2008b), although more frequent inundation is likely to be required to maintain Atlantic salt meadow saltmarsh communities (low to mid and mid to upper saltmarsh communities). The long-term sustainability of such marshes might also be impaired as a result of reductions in sediment supply.

Manipulation of tidal exposure of intertidal areas upstream of barrage options might also enhance feeding opportunities for wading birds, particularly during harsh winter conditions. As temperatures drop, birds' energetic requirements increase and thus starvation is a major issue in cold weather. Prolonging exposure time by manipulating tidal exposure would increase the amount of feeding time available to birds and reduce the risk of increased mortality.

Because of the uncertainties surrounding the morphological consequences of barrage options, such mitigation measures would generally only be assigned a low level of confidence.

Turbine Operation

Management of turbine operation on a diurnal or seasonal basis could be used to seek to protect some species of migratory fish during periods of passage upstream and downstream of turbine structures. Such measures could be effective for those species for which smolt may migrate downstream relatively rapidly over a short time frame or which migrate predominantly at

night. However, other species migrate downstream over prolonged periods and at different times of year such that timing restrictions on turbine operation would not be cost-effective for all species because of the reduction in energy yield. Given the current relative lack of understanding of migratory fish movements in the estuary, any mitigation measures would generally be assigned very low confidence at this stage, pending further study.

4.2.3 Topographic Manipulation

Tidal power developments are likely to alter the tidal regime upstream so that the low water levels will be higher than the existing regime and the high water levels will be lower. To offset the resulting reduction in intertidal area one possible solution might be to alter the topography to create new areas of intertidal. For example, raising the level of an area such as the Welsh Grounds by 4 to 5m under a middle or outer barrage option could create a very large area of new intertidal habitat. There may also be scope to manipulate the topography in the vicinity of tidal lagoons to create additional intertidal habitat. However, it should be noted that some uncertainty remains concerning the acceptability of this measure as mitigation.

Such topographic manipulation could be achieved through the placement of structures (resulting in accretion in the lee) or through direct placement of material, for example, dredged material arising from barrage construction. This might reduce intertidal habitat losses although the character of the habitats may be different because the duration and periodicity of tidal inundations is unlikely to be the same as it is under baseline conditions and the material types might differ. Heavily engineered solutions may be contentious because they would not be consistent with a 'dynamic coasts' philosophy. Given the uncertainties about long-term morphological change in response to tidal power development, such interventions may only be temporary. The confidence associated with such measures would therefore only be low.

4.2.4 Habitat Management

<u>Estuarine Habitats</u>

Alongside topographic changes, other approaches to intertidal habitat creation could involve Regulated Tidal Exchange (RTE) or artificial irrigation of areas using saline waters to maintain or create estuarine habitats. To date a small number of small-scale RTE projects have been undertaken in the UK

(approximately 11 in total, creating some 80ha of intertidal). Larger scale projects have, however, been implemented overseas including in the Netherlands, Germany and the United States. Many of these have involved the creation of the full range of intertidal habitats from mudflats to transitional habitats. For example, the 853ha Beltrinharder Koog scheme in Germany, which formed part of a compensation package, created a 378ha saline lagoon, 166ha of mud flats, 214ha of saltmarsh and 95ha of transitional habitat (ABPmer, 2008). In the UK, the 6ha Goosemoor scheme on the Clyst, led to the creation of approximately 4.25ha of saltmarsh, 0.75ha of mud flats and a 0.75ha saline lagoon. In 2006, two years post implementation, of the 4.25ha of saltmarsh, 2ha were upper saltmarsh, and approximately 1ha mid-level saltmarsh (Lyons & Ausden, 2007). Very few RTEs have led to the exclusive creation of upper saltmarsh communities. The recently implemented 14ha Treraven Meadows scheme on the Camel Estuary is one such example, as it is only flooded on spring tides (which is the only time the stretch of the estuary that the scheme is on is reached by the tides) (ABPmer, 2008).

RTE sites could be created at various elevations within a post-tidal power development tidal range to produce areas where tidal flows are manipulated and intertidal inundation/exposure further managed. This could include RTEs that are topped up with water on bigger tides but allowed to drain solely over smaller tides thus creating saline lagoon habitat. Further topographic manipulation within these sites could be undertaken to enhance the ecological value and biodiversity of these habitats (e.g. the creation of island features or location with different substrata that could have value for different species (e.g. shellfish species).

An alternative approach might involve the installation of pumps that discharge water over large areas of such habitat. This kind of technique has been used with success in the Margrethe Kog in Denmark where saline water is intermittently pumped over a large area through a 60cm diameter pipe at about 400l/s (10-15,000m^3/day when operational) (see ABPmer, 2008b). Even through the pump is relatively small and the site is subject to high levels of stress from temperature, inundation and salinity variations, a relatively large area (220ha) of valuable habitat has been created.

Small scale management of estuarine habitats may also be undertaken to create additional roosting and nesting areas for waterbirds.

While such measures can successfully be applied to create intertidal habitats, there is greater uncertainty concerning the quality and functioning of such habitats and thus the extent to which like-for-like habitat may be created.

There is therefore only a low level of confidence that such measures can be effective in creating Atlantic salt meadow. The prevailing topography is likely to be a constraint in seeking to create intertidal mudflat because of the high elevation relative to the high water mark post tidal power development.

River Habitats

Improvements to the spawning and nursery habitats in designated catchment rivers of migratory fish affected by tidal power development could contribute to an overall package of mitigation measures. These are distinct from equivalent measures that might be undertaken in other rivers and for other migratory populations that would unaffected by the power generation work which would be seen as compensatory measure. The mitigation measures could include installation of fish passes, removal of weirs, gravel cleaning, gravel replacement and/or measures to reduce sediment inputs to rivers (e.g. buffer strips, improved land management). Any such measures would necessarily have to be in addition to those required to achieve site conservation objectives.

Habitat measures have been demonstrated to be effective for some species of migratory fish in a variety of different situations. However, unless the potential impacts associated with passage through tidal power structures in the estuary can be addressed, such measures on their own are likely to be of limited effect. Pending further research, these measures have therefore been assigned a low level of confidence for salmonids and eel but a very low level of confidence for lamprey and shad that are less well understood.

4.2.5 Fish Transportation/Acoustic Herding

Transportation of migratory fish has been undertaken in the US and Europe to facilitate passage across major dams and barrages. However, the use of such techniques to assist downstream migration through an estuarine barrage is relatively novel. A considerable issue to consider within estuaries is the osmoregulatory requirements of fish (physiological requirements of fish to adjust to changing salinity) and, without further study, confidence in such measures would be low.

Acoustic herding techniques could be used for hearing sensitive species such as shad to encourage rapid movements past barrage or lagoon structures. Such techniques are used for commercial fishing.

Pending further research, there is a very low level of confidence that such measures will be effective in mitigating impacts.

4.2.6 Fish Stock Enhancement

Various measures to improve stocks of migratory fish within the designated river tributaries might be included within an overall package of mitigation measures. These could include the establishment of artificial hatcheries to boost production of fry, predator control or reductions in commercial fishing activity (by paying commercial fishermen not to fish) within the designated rivers.

For example, hatcheries have been successfully used internationally to enhance stocks of salmon, lamprey and shad. However, the establishment of artificial hatcheries can be a contentious option because of the distorting effects on the natural gene pool. Confidence in the effectiveness of such measures in mitigating in a like-for-like manner is therefore assessed as very low for species such as shad and lamprey where information is limited and low for salmon and eel where there is a greater understanding.

SECTION 5

OPTIONS FOR COMPENSATORY MEASURES

5 OPTIONS FOR COMPENSATORY MEASURES

5.1 Introduction

This section explores potential options for providing compensatory measures under the Habitats Directive on the assumption that significant effects will remain following application of mitigation measures.

A range of guidance is available at national and European level in relation to the requirements for compensatory measures under the Habitats and Birds Directives and Ramsar Convention. The key documents include the following:

- Planning Policy Statement 9 (PPS9): Biodiversity and Geological Conservation containing policies for England. Equivalent policies for Wales are contained in TAN 5: Nature Conservation and Planning.
- ODPM Circular 06/2005: Biodiversity and Geological Conservation – Statutory Obligations and their Impact within the Planning System
- Managing Natura 2000 Sites (MN2000) – The Provisions of Article 6 of the 'Habitats Directive' 92/43/EEC (guidance prepared by the European Commission, 2000)
- Assessment of plans and projects significantly affecting Natura 2000 sites: Methodological guidance on the provisions of Article 6(3) and (4) of the Habitats Directive 92/43/EEC (guidance prepared by the European Commission, 2001)
- Guidance document on Article 6(4) of the Habitats Directive: Clarification of the concepts of: Alternative Solutions, Imperative Reasons of Over-riding Public Interest, Compensatory Measures, Overall Coherence, Opinion of the Commission, January 2007.

There is also some further experience through case law and case examples, although these have not been explored within this high level study. However, it should be noted that the available guidance has been developed to address procedures for projects and plans of a scale that generally only affect a small part of a designated site. There are therefore some difficulties in seeking to interpret and apply such guidance to some of the larger development options being contemplated within the Severn Tidal Power Study.

Under the Habitats Directive, where a project or plan cannot demonstrate with sufficient certainty that it will not have an adverse effect on the integrity of a Natura 2000 site and in the absence of alternative solutions and where the competent authority determines that a project should proceed on the grounds

of imperative reasons of overriding public interest (IROPI), compensatory measures must be taken to ensure the overall coherence of Natura 2000 is protected (Regulation 53 of Habitats Regulations). Such measures might typically involve the creation of new or the enhancement of existing habitats to replace the functions that are affected by a particular development.

In relation to Ramsar sites, paragraph 31 of ODPM Circular 06/2005 states that:

'Article 4(2) of the Ramsar Convention requires Contracting Parties that delete sites or restrict site boundaries to provide compensatory measures for the loss of conservation interests. The convention refers to creating additional nature reserves for waterfowl and for the protection, either in the same area or elsewhere, of an adequate portion of the original type of habitat. Compensatory measures should provide, as a minimum, no net loss to the overall value of the national Ramsar site series either by way of quality or area'.

EC (2007) defines compensatory measures as being *'independent of the project (including any associated mitigation measures). They are intended to offset the negative effects of the plan or project so that the overall ecological coherence of the Natura 2000 Network is maintained'.*

5.1.1 Requirements for Compensatory Measures

Coherence of Natura 2000 Network

With respect to managing Natura 2000 site EC guidance (EC, 2000) states that:

'In order to ensure the overall coherence of Natura 2000, the compensatory measures proposed for a project should address, in comparable proportions, the habitats and species negatively affected; concern the same biogeographical region in the same Member State; and provide functions comparable to those which had justified the selection criteria of the original site'.

MN2000 (Section 5.4.2) indicates that compensatory measures *sensu stricto* have to ensure the maintenance of the contribution of a site to the conservation at favourable status of one or several natural habitats *'within the biogeographical region concerned'*. It indicates that appropriate measures could include new habitat creation or *'work to improve the biological value of an area (to be designated) or of an SPA (designated) so that the carrying capacity or the food potential are increased by a quantity corresponding to the loss on the site affected by the project'*. It further indicates that in terms of the Habitats Directive, the

compensation could similarly consist of the re-creation of a comparable habitat, the biological improvement of a substandard habitat or even the addition to Natura 2000 of an existing site the proposal of which under the directive had not been deemed essential at the time of drawing up the biogeographical list.

EC (2007) generally confirms these requirements but also expands on some aspects, for example by providing guidance on the criteria for designing compensatory measures. The guidance states (Section 1.5.1):

'Compensatory measures under the Habitats Directive must be established according to reference conditions that are defined after the characterisation of the biological integrity of the site likely to be lost or deteriorated, and according to the likely significant negative effects that would remain after mitigation. Biological integrity can be defined as all those factors that contribute to the maintenance of the ecosystem including structural and functional assets. In the framework of the Habitats Directive, the biological integrity of a site is linked to the conservation objectives for which the site was designated as part of the Natura 2000 network.'

This guidance thus makes a strong link to the site's conservation objectives and aspects of structure and function affecting biological integrity.

Section 1.5.5 of the 2007 guidance includes a further requirement that the area selected for compensation *'must have - or must be able to develop the specific features attached to the ecological structure and functions, and required by the habitats and species populations. This relates to qualitative aspects like the uniqueness of the assets impaired and demands the consideration of local ecological conditions'.*

However, section 1.5.3 of EC (2007) recognises:

'According to current knowledge, it is highly unlikely that the ecological structure and function as well as the related habitats and species populations can be reinstated up to the status they had before the damage by a plan or project. To overcome the intrinsic difficulties standing in the way of full success for the reinstatement of ecological conditions, compensatory measures must be designed:

- *Following scientific criteria and evaluation in accordance with best scientific knowledge;*
- *and taking into account specific requirements of the ecological features to be reinstated (e.g. soil, humidity, exposure, genetic pool, existing threats and other conditions critical to the success of reinstatement).*

- *The critical aspects to technical feasibility will determine the suitability of the location of compensatory measures (spatial feasibility), the appropriate timing and their required extent'.*

Amount of Compensation

On compensation ratios the EC (2007) guidance indicates that:

The extent required for the compensatory measures to be effective has a direct relationship to the quantitative and qualitative aspects inherent to the elements of integrity (i.e. including structure and functionality and their role in the overall coherence of the Natura 2000 network) likely to be impaired and to the estimated effectiveness of the measures. Consequently, compensation ratios are best set on a case-by-case basis and must be initially determined in the light of the information managed during Article 6(3) assessment and ensuring the minimum requirements to meet ecological functionality. The ratios may then be redefined according to the results observed when monitoring the effectiveness, and the final decision on the proportion of compensation must be justified.'

The guidance further states:

'There is wide acknowledgement that ratios should be generally well above 1:1. Thus, compensation ratios of 1:1 or below should only be considered when it is demonstrated that with such an extent, the measures will be 100% effective in reinstating structure and functionality within a short period of time (e.g. without compromising the preservation of the habitats or the populations of key species likely to be affected by the plan or project).'

Timing of Compensatory Measures

With respect to the timing of compensatory measures, Paragraph 30 of ODPM Circular 06/2005 states that:

'..where new habitats are created as compensatory measures, the newly created habitats should be in place in time to provide fully the ecological functions that they are intended to compensate for'.

EC (2007) establishes as a general principle that '*a site should not be irreversibly affected by a project before the compensation is in place'.* However, it recognises that there may be situations where it will not be possible to fulfil this condition. It recommends that 'best efforts' should be made to assure compensation is in place beforehand. Where this isn't achievable, the

competent authorities should consider extra compensation for the interim losses that would occur in the meantime.

Section 1.5.6 of EC (2007) provides further specific guidance on the timing of compensatory measures. In particular it highlights the importance of *'the continuity of the ecological processes essential for maintaining the biological structure and functions that contribute to the overall coherence of the Natura 2000 network'*. It further requires *'a tight coordination between the implementation of the plan or project and the implementation of the measures, and relies on issues such as the time required for habitats to develop and/or for species populations to recover or establish in a given area'*. In addition, the guidance identifies that other factors and processes must also be considered:

- A site must not be irreversibly affected before compensation is in place;
- The result of compensation should be effective at the time the damage occurs on the site concerned. Under certain circumstances where this can not be fully achieved, overcompensation would be required for the interim losses;
- Time lags might only be admissible when it is ascertained that they would not compromise the objective of 'no net losses' to the overall coherence of the Natura 2000 network;
- Time lags must not be permitted, for example, if they lead to population losses for any species protected in the site under Annex II of Directive 92/43/EEC or Annex I of Directive 79/409/EEC, requiring particularly attention when it entails priority species;
- It may be possible to scale down in time compensatory measures according to whether the significant negative effects would presumably arise in the short, medium or long term.

The guidance emphasises that *'all necessary provisions, technical, legal or financial, necessary to implement the compensatory measures must be completed before the plan or project implementation starts, so as to prevent any unforeseen delays that may hinder the effectiveness of the measures'*.

Location of Compensatory Measures

The Managing Natura 2000 document (EC, 2000) states that the compensatory measures proposed for a project should *'concern the same biogeographical region in the same Member State'*. EC (2001) further indicates that the compensatory provision should *'be in as close proximity as possible to the habitat that has been adversely affected by the project or plan'*.

The 2007 guidance repeats the requirements for compensation measures to be within the same biogeographic region (for Habitat Directive sites) or within the same range, migration route or wintering area for bird species (site designated under the Birds Directive) in the Member State concerned.

In addition, there is general agreement that the local conditions necessary to reinstate the ecological assets at stake are found *'as close as possible to the area affected by the plan or project'*. Therefore, locating compensation near to the Natura 2000 site concerned in a location showing suitable conditions for the measures to be successful seems the most preferred option. However, this is not always possible and it is necessary to set a range of priorities to be applied when searching locations that meet the requirements of the Habitats Directive. EC guidance states the priorities as:

- Compensation within the Natura 2000 site provided the necessary elements to ensure ecological coherence and network functionality exist within the site.

- Compensation outside the Natura 2000 site concerned, but within a common topographical or landscape unit, provided the same contribution to the ecological structure and/or network function is feasible. The new location can be another site designated as Natura 2000 or a non-designated location. In the latter case, the area must be designated as Natura 2000 site itself in due course and be subject to all the requirements of the 'nature' directives.

- Compensation outside the Natura 2000 site, in a different topographical or landscape unit. The new location can be another site designated as Natura 2000. If compensation takes place on a non-designated location, the area must be designated as Natura 2000 site itself in due course and be subject to all the requirements of the 'nature' directives.

5.2 Approach to the Identification of Potential Compensatory Measures

The available guidance has been used to establish a set of principles to inform the approach to the identification of potential compensatory measures:

- The measures seek to address, in comparable proportions, the habitats and species negatively affected and to provide comparable functions to those affected by development. In practical terms at this stage of the study, the assessment has focused on identifying the potential extent of habitats or species replacement that might be achievable.

- The initial area of search has focused on the vicinity of the Severn Estuary and then extended to England and Wales.

- For planning purposes compensation ratios of 1:1 and 3:1 have been considered, although the requirement will need to be refined once residual impacts (after mitigation measures) and effectiveness of compensatory measures are defined. It should be noted that this does not make any assumptions about an appropriate ratio to apply to the Severn Estuary and that some compensation ratios have exceeded a 3:1 ratio.

EC guidance states '*ratios should be generally well above 1:1. Thus, ratios of 1:1 or below should only be considered when it is demonstrated that with such an extent, the measures will be 100% effective in reinstating structure and functionality within a short period of time, without compromising the preservation of the habitats or populations of key species likely to be affected by the plan or project'*.

Where existing habitat is newly designated to compensate for losses due to the project to the extent where this habitat already provides functionality of the Natura 2000 network, then it is possible that a ratio of 1:1 only need be applied.

The following types of compensatory measures have been explored as part of this review:

- **Assessment of Managed Realignment Opportunities** - New habitat creation through managed realignment of low lying areas behind existing flood defences with the presumption that such areas are subsequently designated as SACs, Ramsar sites and/or SPAs. This would be intended as habitat compensation and also a measure to address impacts to birds.
- **Scoping the potential for new SAC site designations**[2] **(or Ramsar sites)** [3] – European guidance indicates that it may be possible to compensate for impacts to designated features through the inclusion of additional sites within the overall SAC list, although it should be noted that there is currently no formal process by which this might be progressed. These would comprise areas that are currently not designated as SAC but support

[2] It is important to note that these provisions only apply in relation to SAC habitats and species. Under the Birds Directive Member States are required to classify all suitable territories as SPAs and thus there will not be any additional suitable sites that might be classified. The only exception to this would be where habitat creation or management undertaken as compensatory measures improved the quality of an area for birds such that it then met the qualifying criteria for classification as an SPA.

[3] There is no policy guidance on the scope for designating additional Ramsar sites as a mechanism for compensating for impacts to Ramsar site features. For the purposes of this study it is assumed that this would be possible for non-avian impacts.

one or more of the following features and which merit inclusion in the SAC list:

- Estuarine habitats (estuary, intertidal mudflats and sandflats, subtidal sandbanks, atlantic saltmeadow, reefs);
- Migratory and estuarine fish species (allis shad, twaite shad, river lamprey, sea lamprey, Atlantic salmon; Ramsar site series only: eel, sea trout, estuarine fish).

- **Assessment of Enhancement Opportunities** - Enhancement measures within other designated areas (SACs or SPAs) that are additional to any measures required to support achievement of conservation objectives:
  - Improvements to estuarine habitats (estuary, intertidal mudflats and sandflats, subtidal sandbanks, atlantic saltmeadow, reefs);
  - Fish stock enhancement, fish spawning habitat enhancement, predator control;
  - Fish stock translocation (transferring fish from potentially affected sites to other sites).

The methodologies applied for these elements of the study are briefly described below.

5.2.1 Assessment of Managed Realignment Opportunities

The scope for managed realignment of low lying areas behind existing flood defences has been evaluated for England and Wales based on the Environment Agency's 1:100 year tidal flood plain and using a search area of up to 5km inland from the existing coastline. Urban areas and internationally designated sites (SPA, SAC and Ramsar) have been excluded from the search area. The area of search has been limited to England and Wales because there is readily available and consistent information available for this area, although in theory it may be possible to provide compensatory habitat anywhere within the Atlantic biogeographical region. If information for Scotland and Northern Ireland was included, it is considered unlikely that it would affect the overall conclusions of the study.

The resulting potential realignment areas were then validated against a number of existing regional scale studies which have used additional criteria to more accurately define potential realignment sites. Based on this validation exercise a scaling factor has been derived that can be applied for England and Wales as a whole. Separate consideration has been given to possible habitat creation opportunities for sites >500ha identified through the screening process. A more detailed description of the evaluation methodology is provided in Appendix 2.

5.2.2 Identification of Additional Sites for Inclusion in SAC List

An initial scoping exercise has been undertaken to identify a list of estuaries and coastal waters supporting significant intertidal habitats and which are not currently designated as SACs, based on the comprehensive list of transitional waterbodies in England and Wales (prepared under the auspices of the Water Framework Directive) and with reference to JNCC's Designated Sites database. A total 82 locations were identified of which 63 were transitional (estuarine) and 19 were coastal. The list was further filtered by selecting sites with intertidal areas greater than 200ha. Additional information on the nature and extent of broad intertidal habitat types was collated from a literature search. It should be noted that the presence of a broad habitat type (e.g. saltmarsh) does not necessarily indicate the presence of SAC qualifying feature such as Atlantic salt meadow, nor that such a feature, if present is suitable for inclusion in the SAC list.

A similar scoping exercise has been undertaken to identify non-SAC estuaries and non-SAC rivers supporting migratory fish (allis shad, twaite shad, river and sea lamprey and Atlantic salmon), based on records held in the National Biodiversity Network (NBN) database.

While these broad areas of search provide a starting point for consideration of the merits of inclusion of additional sites, detailed evaluation would need to be undertaken in accordance with the criteria set out in the Habitats Directive (Article 4 and Annex III).

5.2.3 Assessment of Enhancement Opportunities

A further type of compensatory mechanism involves the enhancement of existing habitats and populations in areas that are not affected by any power project (including other designated and potentially 'designatable' sites). It is recognised though that where such enhancements are proposed for the Severn and its upstream tributaries to the benefit of migratory fish passing through it (as reviewed in Section 4) such enhancements would be mitigation measures with the benefits being 'felt' within the site(s) affected. Therefore, this section and Section 5.5 can apply to both compensation and mitigation aspects depending on whether the benefit is felt inside or outside the affected designated sites. Inevitably then, there is overlap between this aspect and the preceding review of mitigation options (in Section 4). However, the thinking process and practical requirements are the same and only locations are different.

Opportunities for enhancement measures will be site specific and it was beyond the scope of this project to explore them in detail. The study has therefore sought to identify the potential types of enhancement measures that might be of benefit focusing on:

- Enhancement of estuarine habitats;
- Enhancement of migratory fish spawning and nursery habitats in rivers;
- Migratory fish stock enhancement (e.g. artificial hatcheries; predator control);
- Fish stock translocation.
- It should be noted that enhancement measures must be additional to any measures that might already be required to support achievement of existing site conservation objectives.

5.3 Findings from Managed Realignment Opportunities Review

Table 6 summarises the outputs from the high-level screening exercise undertaken for England and Wales.

Table 6 Summary of the possible compensation area extent based on high-level screening

Description of areas	
Area within tidal floodplain within 5km of existing coast	460,000ha
Urban area within tidal floodplain within 5km of existing coast	41,000ha
Designated area within tidal flood plain within 5km of existing coast	104,000ha
Potential managed realignment area	310,000ha
Scaling factor based on detailed regional studies	36%
'Realistic' managed realignment area	111,600ha
Number of potential sites >500ha	58

While there are approximately 500,000ha of land within the tidal flood plain for England and Wales within 5km of the coast, only a proportion of this area is likely to be suitable for managed realignment. When urban areas and internationally designated sites are excluded the available area is reduced to some 310,000ha. A range of additional constraints will serve to further limit suitable areas for managed realignment.

The potentially suitable areas identified in this study have been compared to the findings from a number of more detailed regional habitat creation studies, including the Severn (ABPmer, 2007), Thames (ABPmer, 2008c) and Essex

(ABPmer 2004a and b). This comparison indicated that the more detailed studies were identifying only around 29-44% (unweighted average 36%) of the total area identified in this study. These differences are accounted for by the more detailed criteria applied in the regional studies. In particular, the regional studies generally had more detailed information on land elevations behind existing flood defences and also took account of a wider range of constraints (roads, railways, existing land use etc).

Applying this scaling factor to the broad search data gives a plausible realignment area of around 112,000ha. Around 50% of the potentially available area is in east England. While the regional studies have taken account of a greater range of constraints, it should be emphasised that it is not necessarily the case that the full extent of potential realignment in these areas could be realised. Nor should it be assumed that intertidal habitats would be created over the full extent of the potential areas.

For the Severn Estuary, based on studies for the Severn CHaMP, approximately 11,500ha of potentially suitable realignment area have been identified in the Severn Estuary area (ABPmer, 2007), although much of this is designated as SSSI. A further evaluation of these sites for this study suggests that around 8,000ha of this total has reasonable potential for managed realignment.

The overall figure for England and Wales compares with an estimate of around 33,000ha for Great Britain (Pilcher et al., 2002) that was based on significantly more stringent search criteria, in particular:

- An absence of infrastructure
- No increase in the length of flood defence as a result of the realignment

Some further analysis of the high level assessment has identified 58 sites greater than 500ha in size that are devoid of major infrastructure (motorways, A roads, railways etc). These sites amount to an area of around 106,000ha. This is comparable to the figure obtained using the scaling factor. Around 60% of the potential area is located in east England. Given the distribution of potentially suitable land, larger scale managed realignment programmes would necessarily have to rely on a major contribution from east coast sites.

At this stage of the analysis a number of important caveats must be applied to the figures presented. The study has only identified the broad scale of potential suitability area for managed realignment. More detailed studies of potential locations would be necessary at a later stage to assess:

- Engineering feasibility – is it possible to provide an appropriate level of long-term and sustainable flood protection to the rear of the site?
- Environmental design –can potential areas create like-for-like (or other) functional intertidal habitats that might provide suitable compensatory measures for impacts to affected sites (for example, to what extent might compensatory measures replace the functions and range of variation provided by the features in the Severn Estuary)?
- Morphological development – will the habitats created be sustainable in the long-term, for example, is there sufficient sediment supply to fill and maintain intertidal areas?

There are also broader issues relating to the scale of potential managed realignment that might be required, how it might be delivered, the time scales over which delivery might be required and the consequences in terms of land use change. However, it should also be recognised that existing policy recognises that 'holding the line' everywhere is not sustainable.

Many potentially suitable areas, for example, grazing marsh, wetlands etc, are also likely to have high existing nature conservation value, even though they may not be subject to international designation. In taking forward specific schemes it is also likely to be necessary to offset these impacts where possible. Where schemes have impacts on internationally designated sites, it would be an essential pre-requisite of any approval that such impacts were fully compensated for. The scale of managed realignment required might also give rise to concerns about the availability of suitable areas to provide compensation for other types of development activity (compensatory measures for flood defence and port development).

Large scale managed realignment might also contribute to compensatory measures for birds if it was required. Experiences from early managed realignment sites are that while it is relatively easy to create mudflat and/or saltmarsh, the newly created areas may not always support the bird species contained in the habitats that have been lost. The reasons for this are twofold. First, realignment sites tend to be high in the tidal frame, whereas the lost habitats tend to be lower and are used by different species. Second, realignment sites tend to be small and enclosed and not used by a number of species that prefer open estuaries. However, after over 15 years of undertaking managed realignments in the UK, there is now a greater understanding of the functional requirements for creating larger and more successful managed realignments for birds, for example, ensuring topographic variation across sites, good drainage and an adequate sediment supply. This knowledge should assist in ensuring that the functional value of

managed realignment sites for birds is enhanced (Atkinson et al., 2001, 2003 and 2004).

In addition to uncertainties relating to the feasibility of habitat creation, the nature of habitats to be created and their sustainability, other factors such as location within the biogeographic region, proximity to flyways and the ability to replace the functions lost to tidal power development in the Severn Estuary (for example, preferred feeding area during cold winters, feeding area for passage birds etc) will also be important in determining the acceptability of compensatory measures for birds.

5.4 Scoping the Potential for New SAC Designations

5.4.1 Estuary and Coastal Habitats

The scoping exercise for estuaries and coastal locations, has identified a total of 25 sites that support intertidal habitats (intertidal mudflats and sandflats and saltmarsh) greater than 200ha which are currently not wholly or partially designated as SACs (Table 7). In total the non-SAC intertidal area is over 34,500ha. However, around 30,000ha of this area is already designated as SPA. Where features are already protected within SPA designations, additional designation as SAC features would not provide any additional protection and would therefore not make any contribution to the protection of the Natura 2000 network. Areas of search for new SAC site designations would therefore need to focus on sites supporting potentially qualifying features that are not already classified as SPAs or on features within existing SPAs that were not already protected by the SPA designation.

Comparable summary information for subtidal habitats (subtidal sandbanks and inshore reefs) is not available. Many of the major estuaries (e.g. Thames, Mersey, Ribble) support extensive subtidal habitats including subtidal sandbanks and reefs, although further evaluation is required against the SAC site selection criteria.

It is possible that some of the intertidal and/or subtidal areas may be suitable for inclusion as new sites within the SAC list. However, considerable further evaluation would be needed to assess their suitability.

Table 7 Estuaries that are not SACs and have more than 200ha of intertidal area (presented in order of intertidal extent)

Waterbody Name	Waterbody Category	Intertidal Area / Ha	Tidal Spring Range/m	Comments
Mersey	Transitional	5976	8.4	Designated as an **SPA** which extends over 5,023ha (predominantly intertidal) of which the habitat proportions are: - 89% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **4470ha** 11% cover of saltmarshes = **552ha** (NB there is a discontinuity between the WFD water body and SPA boundaries and as a result there is likely to be more intertidal than quoted)
Ribble	Transitional	4205	8.8	Designated as an **SPA** (alongside the Alt Estuary) across both estuaries the site extends over 12,412ha of all habitat (the WFD water body extent appears to exclude saltmarsh and all of Alt Estuary and coastal areas between hence comparatively much larger extent in designated site). Also area overlaps with Sefton Coast SAC. Area calculations are necessarily approximate but Assuming 82% of the undesignated 42505ha waterbody are mudflat, sandflat estuary, estuary, lagoons tidal rivers etc = **3448ha** 17% cover of saltmarshes =**2110ha**
Thames TW2	Transitional	670 (approx. 3000 to 4000 with TW1 included)	6.2	Outer Thames (TW1) has been excluded because the waterbody overlaps with an SAC. However, the Thames Estuary and Marshes **SPA** (4,839ha of outer estuary transitional habitat) and Benfleet & Southend SPA (2,251ha of coastal habitat) are not SAC and are worth considering here. Taking just the habitats within the Thames Estuary and Marshes SPA the habitat proportions are: - 57% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **2758ha** 1.5% cover of saltmarshes = **73ha**
Medway	Transitional	2950	5.2	Designated as an **SPA** which extends over 4,684ha (predominantly intertidal) of which the habitat proportions are: - 67% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **3138ha**

Waterbody Name	Waterbody Category	Intertidal Area / Ha	Tidal Spring Range/m	Comments
				15% cover of saltmarshes = **702ha**
Poole Harbour	Transitional	2140	1.6	Designated as an **SPA** which extends over 2,271ha of which the habitat proportions are: - 59% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = 1340ha 23% cover of saltmarshes = 522ha
Orwell & Stour	Transitional	1 – 555 2 - 1536 Both - 2091	3.9	Designated as an **SPA** which extends over 3,677ha (predominantly intertidal) of which the habitat proportions are: - 88% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **3236ha** 5% cover of saltmarshes = **184ha**
The Swale	Transitional	2017	3.7	Designated as an **SPA** which extends over 6,514ha (including large area of terrestrial habitat) of which the intertidal habitat proportions are: - 39% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **2540ha** 5% cover of saltmarshes = **325ha**
Sussex	Coastal	1871	5.5	Not designated – **Coastal Habitat**
Whitstable Bay	Coastal	1360	3.7	Not designated but partially overlapped by Swale SPA – **Coastal Habitat**
Exe	Transitional	1157	3.2	Designated as an **SPA** which extends over 2,345ha (predominantly intertidal) of which the habitat proportions are: - 80% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **1876ha** 5% cover of saltmarshes = **117ha**
Portsmouth Harbour	Coastal	994	3.9	Designated as an **SPA** which extends over 1,249ha (predominantly intertidal) of which the habitat proportions are: - 85% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **1062ha** 5% cover of saltmarshes & 'salt steppes' = **175ha**
Hamford Water	Transitional	891	3.8	Designated as an **SPA** which extends over 2,187ha (predominantly intertidal) of which the habitat proportions are: - 70% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **1531ha** 25% cover of saltmarshes = **547ha**

Waterbody Name	Waterbody Category	Intertidal Area / Ha	Tidal Spring Range/m	Comments
Camel	Transitional	696	6.5	Not designated – **Transitional habitat**
Thames Coastal South	Coastal	571	3.7	Not designated – **Coastal Habitat**
Tees	Transitional	568	4.6	Designated as an **SPA** (Teesmouth and Cleveland Coast) which extends over 1247ha (predominantly intertidal) of which the habitat proportions are: - 54% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **674ha** 7% cover of saltmarshes = **87ha**
Wyre	Transitional	549	8	Lies within the Morecambe Bay **SPA**.
Holyhead strait	Coastal	505	4.9	Not designated – **Coastal Habitat**
Deben	Transitional	476	2.7	Designated as an **SPA** which extends over 979ha (predominantly intertidal) of which the habitat proportions are: - 80% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **783ha** 18% cover of saltmarshes = **176ha**
Tyne	Transitional	366	3.9	Not designated – **Transitional habitat**
Holyhead Bay	Coastal	329	4.9	Not designated – **Coastal Habitat**
Dart	Transitional	309	4.3	Not designated – **Transitional habitat**
Salcombe Harbour	Transitional	305	4.6	Not designated – **Transitional habitat** (NB there are two water bodies here one transitional and one coastal. The latter overlaps with the South Devon Dock Shore SAC.
Harwich Approaches	Coastal	238	3.6	Not designated – **Coastal Habitat**
Pagham Harbour	Coastal	219	5.1	Designated as an **SPA** which extends over 637ha (including large area of terrestrial habitat) of which the habitat proportions are: - 39% mudflat, sandflat estuary, estuary, lagoons tidal rivers etc. = **229ha** 5% cover of saltmarshes = **32ha**
Teign	Transitional	218	3.9	Not designated – **Transitional habitat**

5.4.2 Migratory Fish

Tables 8 and 9 provide extracted National Biodiversity Network (NBN) records for migratory fish in non-SAC rivers and estuaries respectively. It should be noted that the records are incomplete and that there are other non-SAC locations at which migratory fish are present but which are not recorded in the database. Furthermore, while the records indicate that the relevant species were present, they do not indicate whether the records relate to an established population or to stray individuals.

It should be emphasised that the presence of populations of particular migratory species does not imply that the sites may be suitable for SAC designation and all potential sites would require detailed assessment against the SAC site selection criteria to ascertain their suitability.

Allis Shad

Information on the distribution of allis shad (*Alosa alosa*) in the UK and the location of SACs in which it is identified as a feature or sub-feature is presented in Figure 5. Allis shad are rare in the UK. Although formerly known to spawn in several British river systems, the only recently-confirmed spawning site is in the Tamar. There is possibly also a spawning population in the Solway Firth area but rivers in the Severn catchment may no longer support viable breeding populations (APEM in prep.).

Based on current information, there are few if any opportunities to compensate for impacts to allis shad through the inclusion of additional sites UK within the SAC list, with the River Tamar possibly representing the only opportunity.

Twaite Shad

Information on the distribution of twaite shad (*Alosa fallax*) in the UK and the location of SACs in which it is identified as a feature or sub-feature is presented in Figure 6. There are no records of twaite shad spawning in rivers other than the four that are already designated as SACs (Severn[4], Wye, Usk

[4] Only the Severn Estuary is a designated site while much of River Severn itself , where shad would spawn, is undesignated as SAC or SSSI

and Tywi) and historically in the Thames. The records for twaite shad in estuaries in southern and south-west England are considered to represent strays either from known UK sites or from France.

Based on current information, there are few if any opportunities to compensate for impacts to twaite shad through the inclusion of additional sites within the SAC list.

River Lamprey

Information on the distribution of river lamprey (*Lampetra fluviatilis*) in the UK and the location of SACs in which it is identified as a feature or sub-feature is presented in Figure 7. The river lamprey is widespread in the UK, occurring in many rivers from the Great Glen in Scotland southwards (JNCC website). However, the latest condition assessment for England and Wales in 2007 suggests that all but the River Usk population were deemed to be in unfavourable condition. Nonetheless, based on the relatively widespread distribution of this species, there may be opportunities to include additional sites supporting this species within the SAC list. This could be accompanied by other measures to achieve favourable condition as defined by the CSM guidance such as improvement in water quality and flow as well as stocking and potentially habitat enhancements (APEM, in prep). To fully understand requirements to improve the status of river lamprey, however, further study is recommended.

Sea Lamprey

Information on the distribution of sea lamprey (*Petromyzon marinus*) in the UK and the location of SACs in which it is identified as a feature or sub-feature is presented in Figure 8. The sea lamprey is reasonably widespread in UK rivers. In some places it is still common, but it has declined in parts of its range and has become extinct in a number of rivers. Indeed during the most recent condition assessment for England and Wales in 2007, only the River Wye was deemed to be in favourable condition. Nonetheless, based on the relatively widespread distribution of this species, there may be opportunities to include additional sites supporting this species within the SAC list.

Atlantic Salmon

Information on the distribution of Atlantic salmon (*Salmo salar*) in the UK and the location of SACs in which it is identified as a feature or sub-feature is presented in Figure 9. The Atlantic salmon is a widespread species in the UK and is found in several hundred rivers, many of which have adult runs in excess of 1000. The latest estimates of the UK spawning population size (ICES, 2000) are, however, about 50% down on the ten-year average. Based on the widespread distribution of this species, there may be opportunities to include additional sites supporting this species within the SAC list.

Sea Trout

No summary information on the distribution of sea trout is readily available. However, they are generally accepted as having a distribution similar to that of Atlantic salmon. Based on the widespread distribution of this species, there may be opportunities to include additional sites supporting this species within the Ramsar site series.

European Eel

The Severn is the principal river for eel in the UK although they are distributed widely throughout all other river systems. Based on the widespread distribution of this species, there may be opportunities to include additional sites supporting this species within the Ramsar site series.

Estuarine Fish

The estuarine fish assemblage includes all of the key migratory species identified above, plus a wide range of other fish species including freshwater species, estuarine species, marine migrants and marine stragglers. Marine stragglers comprise the greatest number of species within the estuary followed by marine migrants. There are relatively few truly estuarine species recorded (APEM, in prep).

It may be possible to designate new Ramsar sites to protect estuarine fish or to extend one or more existing Ramsar designations to include estuarine fish.

Table 8 List of non-designated rivers that have records of key migratory species

River	Twaite Shad	Allis Shad	River Lamprey	Sea Lamprey	Atlantic Salmon
Tamar	-	2000		-	Many - all years
Rother	-	-	1997, 1998, 1999	-	-
Frome	-	-	1956, 1996	-	Many - all years
Watchet	-	-	1992, 1994, 1997, 1999	-	-
Doniford	-	-	1992, 1994, 1997, 2000	-	-
Taw	-	-	1971, 1972	1972	Many – all years
Ely	-	-	1980	-	-
Dyfi	-	-	1972	-	-
Conwy	-	-	-	1958, 1971, 1972	Many - all years
Great Stour, Kent	-	-	-	-	1972, 1989
Torridge	-	-	-	-	Many - all years
Parrett (upper)	-	-	-	-	Many - all years
Ogmore	-	-	-	-	Many - all years
Llynfi	-	-	-	-	Many - all years
Taf	-	-	-	-	1995, 1997

Table 9 List of non-designated estuaries that have records of key migratory species

River	Twaite Shad	Allis Shad	River Lamprey	Sea Lamprey
Medway	1971, 1972	-	-	-
Swale TW	1971, 1972	-	-	-
Sussex	1965, 1972, 2000	-	-	-
Orwell & stour2	-	-	-	1972
Exe	2000	1979, 1995, 2000	1967, 1972	-
Hamford water	-	-	-	1972
Camel	-	1907	upper (1984)	-
Thames TW2	2005	-	1967, 1972	2000
Tees	-	-	1995	1995, 1996, 1997, 1998
Orwell & Stour	-	-	-	1972
Deben	1932, 1972	-	-	1972
Tyne	-	-	1972	1972, 1995
Dart	1995	-	-	1972
Harwich approaches	-	-	-	1972
Pagham harbour	1965, 1972, 2000	-	-	-
Teign	-	-	-	1972
Penzance	-	1877, 1909, 1969, 1983, 1997, 1999	-	-
Fowey	-	1998, 2000	-	1902
Avon	-	-	-	-
Wear	-	-	1972	1972
Erme	-	(upper) 1965	-	-
Neath	-	-	1980	-
Alaw	-	-	(upper) 1977	-
Adur	-	-	(upper) 1998	-
Looe	-	1900	1882, 1972, 1979	-
Clywd	-	-	1969, 1972, 1977	1972
Axe	-	-	-	1972
Blue lagoon	1984	-	-	-
Ouse	1965, 1972	-	-	-
Wootton creek	2000	-	-	-
Derwent	-	-	1996	-
Tawe	1972	-	1972	1972
Esk (e)	-	-	1960, 1972	1972
Pagham lagoon	1965, 1972, 2000	-	-	--

5.5 Enhancement Opportunities

5.5.1 Estuarine Habitats

Within individual designated SACs there are likely to be opportunities to enhance the extent and/or quality of habitats. Such enhancement initiatives could potentially contribute to a package of compensatory measures where those actions were not already required to support achievement of the conservation objectives. As discussed previously, where such measures would benefit features inside the Severn Estuary SPA/cSAC or any other affected site they would become part of any mitigation measures package rather than compensation. Examples might include the removal of redundant structures that are affecting the quality of designated features. Such opportunities would need to be reviewed on a local basis. A comparable exercise is currently being undertaken for the purposes of the Water Framework Directive for water bodies that have been identified as heavily modified for which there is a requirement to consider the scope for achieving an objective of Good Ecological Potential. While it is possible that such a review may identify some opportunities, based on initial exploration of opportunities the scale of possible benefit is unlikely to be very large, particularly in comparison to the potential scale of impacts.

There may also be opportunities to undertake habitat enhancement within existing SPAs on a similar basis, although again, the scale of potential benefit is considered to be relatively small.

5.5.2 Migratory Fish Spawning and Nursery Habitats

Improvements to the spawning and nursery habitats of migratory fish affected by tidal power development could contribute to an overall package of mitigation (where they benefit species using the affected designated sites) and compensation (where they benefit remote and unaffected sites that are either designated or not). The measures could include installation of fish passes, removal of weirs, gravel cleaning, gravel replacement and/or measures to reduce sediment inputs to rivers (e.g. buffer strips, improved land management). They could be applied both to designated sites upstream of tidal power development in the Severn (where they may be considered as mitigation measures) or in other rivers supporting relevant migratory fish species (where they might be considered as compensatory measures). Any such measures would necessarily have to be additional to measures already required to support achievement of site conservation objectives.

5.5.3 Migratory Fish Stock Enhancement

Various measures to improve stocks of migratory fish in other rivers might be included within an overall package of compensatory measures. These could include the establishment of artificial hatcheries to boost production of fry, predator control or reductions in commercial fishing activity (paying commercial fishermen not to fish) within the affected rivers or translocation of fish to other river systems.

For example, hatcheries have been successfully used internationally to enhance stocks of salmon. However, the establishment of artificial hatcheries can be contentious option because of the distorting effects on the natural gene pool.

5.5.4 Fish Translocation

Translocation of migratory fish has been undertaken on a widespread basis. For instance shad have been successfully translocated within North America. In addition Atlantic salmon and eel have successfully been moved between catchments within Europe (APEM in prep.).

5.6 Summary of Compensatory Measures

Table 10 presents a summary of the potential effectiveness of the compensatory measures in contributing to the maintenance of the Natura 2000 network and the confidence attaching to individual measures.

The study has identified significant scope for managed realignment around England and Wales, particularly along parts of the east coast. For smaller tidal power development schemes further upstream in the estuary, there are also significant potential areas for realignment within the Severn Estuary (i.e. on adjoining land above the high water mark rather than in the designated site). While there is increasing experience of managed realignment schemes in the UK, confidence in the effectiveness of such measures in compensating for tidal power development impacts in the Severn on a like-for like basis is low. This is because there are currently significant uncertainties concerning the nature, quality and sustainability of habitats that might be created through managed realignment and the difficulties associated with seeking to replace the functioning and extreme range of variation of features that will potentially be affected in the Severn Estuary.

It is assumed that an extensive programme of managed realignment could also provide suitable replacement habitat for waterbirds. However, there is an uncertainty surrounding this assumption because it is currently unclear what habitats might be created and whether the resulting biogeographical distribution of such habitats would be appropriate in relation to the requirements of the affected birds. Experiences from early managed realignment work indicate that while it is relatively easy to create the habitats, the newly created areas may not always contain the bird species that had been present in the habitats that were originally lost. However, after over 15 years of undertaking managed realignments in the UK, there is now a much greater understanding of the requirements for creating larger and more successful managed realignments for bird. Notwithstanding these developments, the potential difficulties of creating like-for-like habitats in this case means that confidence in the ability of these habitats to act as compensation for birds must be the same as for habitats (i.e. low) pending further analysis.

Habitat creation may also provide benefits to marine and estuarine fish.

It is of note that the only practicable compensatory measure for subtidal sandbanks and reefs is likely to be the inclusion of additional sites within the SAC list because it is generally not possible to re-create these features. The presence of *Sabellaria alveolata* reefs subtidally in an estuarine environment is a unique feature of the Severn Estuary and any compensation package would only be able to replace these features with other types of reef feature (possibly through the designation of additional *Sabellaria spinulosa* reef habitat). Given the difficulties in replacing the functioning and range of variation represented by these features in the Severn Estuary, confidence in the effectiveness of additional designations as a like-for-like compensatory measure for *Sabellaria alveolata* is assessed as very low and for subtidal sandbank is assessed as low.

For species such as allis and twaite shad the only potential compensatory measures available are likely to comprise measures to improve spawning and nursery areas in unaffected river catchments and/or corresponding stock enhancement measures. However, confidence in the effectiveness of these measures in providing like-for-like compensation is very low. Improvements to spawning and nursery habitats for other migratory fish (salmon, trout and eel) could potentially provide benefits, although the scale of such benefits will depend on site specific factors. Any such measures would need to be additional to those already required to support achievement of conservation objectives. Stock enhancement measures may also make a contribution to an overall compensation package especially for these species.

Equivalent measures in the Severn catchment for those migratory fish that would be affected by the proposal (which would be mitigation not compensation) would be particularly limited by the fact that the populations would also remain exposed to the risk of impact from turbines.

For migratory fish species other than allis and twaite shad, it may be possible to identify additional sites for inclusion with the SAC list that, in conjunction with additional management measures at these sites, contribute to maintaining the overall coherence of the network, although the extent to which such measures may provide like-for-like compensation are uncertain.

The scope for enhancement of estuarine habitats within existing designated sites (outside of the sites affected by the proposal) is considered to be limited and such measures are unlikely to make a major contribution to an overall package of compensatory measures for estuarine habitats or waterbirds. Any such measures would need to be additional to those already required to support achievement of conservation objectives.

Confidence in the effectiveness of the option of relocating migratory fish populations to a completely new estuary/river system is generally considered to be low although for some species such as eel it has been conducted successfully within Europe. For other species such as lamprey and shad for which little information is available the effectiveness of this measure is considered to be very low (APEM, in prep.).

Table 10 Compensation measures matrix - habitats and species

	Annex 1 Habitat types					Annex II species					Additional Ramsar Site Features			SPA Features
	Estuaries	Subtidal sandbanks	Intertidal Mud and Sandflats	Atlantic Saltmeadow	Reefs (S. alveolata)	Atlantic salmon	River Lamprey	Sea Lamprey	Twaite Shad (and allis shad)	European otter	European eel	Sea trout	Estuarine fish community	Migratory species, , internationally important assemblage
Types of compensation measure/feature	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Severn cSAC	Usk, Wye SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Severn cSAC, Usk, Wye Tywi SAC	Usk, Wye Tywi SAC	Severn Estuary Ramsar Site	Severn Estuary Ramsar Site	Severn Estuary Ramsar Site	Severn SPA
Managed Realignment	✓	×	✓	✓	×	×	×	×	×	✓	×	×	×	✓
Inclusion of additional sites in SAC List - habitats	✓	✓	✓	✓	?	×	×	×	×	✓	×	×	×	×
Inclusion of additional sites in SAC List/Ramsar Site series – migratory and estuarine fish	×	×	×	×	×	✓	✓	✓	×	×	✓	✓	✓	×
Enhancement Measures – estuarine habitats	×	×	✓	✓	×	×	×	×	×	✓	×	×	×	✓
Enhancement Measures – migratory fish spawning and nursery habitats	×	×	×	×	×	✓	✓	✓	✓	×	✓	✓	×	×
Enhancement measures – artificial hatchery; stocking, , predator control	×	×	×	×	×	✓	✓	✓	✓	×	✓	✓	×	×
Enhancement measures – fish translocation	×	×	×	×	×	✓	✓	✓	✓	×	✓	✓	×	×

✓ Measure has potential to contribute to compensation package for impacts to feature
× Measure does not have potential to compensate for impacts to feature
? Potential uncertain

Very low confidence in effectiveness of measure
Low confidence in effectiveness of measure
Medium confidence in effectiveness of measure
High confidence in effectiveness of measure

SECTION 6

REVIEW OF COSTS OF MITIGATION AND COMPENSATION OPTIONS

6 REVIEW OF COSTS OF MITIGATION AND COMPENSATION OPTIONS

To inform judgements about the feasibility and cost effectiveness of mitigation and compensation measures, information on the scale of costs of measures has been collated based on information readily available to the project. The data are summarised in Table 11.

It must be recognised that there is a high level of uncertainty about many of the potential costs. This is particularly so for costs relating to design modifications of tidal power development options where both the capital costs both of the modifications themselves and the implications on energy yield (and thus reduced revenues) need to be taken into account. Based on an initial consideration it is likely to be possible to provide some level of mitigation through modifications to scheme design and the operational regime but these possibilities require further evaluation as a key part of Phase 2 studies, assuming these proceed, to assess their overall costs and effectiveness.

Costs associated with modifications to the operational regime, for example to seek to maintain upstream high water levels or to protect passage of some species of migratory fish through or past tidal power development structures are also likely to be medium to high because of the likely impacts on energy yield. Further evaluation is required to establish the potential effectiveness and cost effectiveness of such measures.

The costs of topographic modification measures will depend on the scale and location of potential measures. Generally costs might be expected to be relatively high, although there could be scope for beneficial use of dredged material from the excavation works required for the construction of the foundations for tidal power development structures or from other major development projects. The costs of habitat enhancement measures would also be specific to the potential measure and the scale at which it was applied. Schemes involving saline inundation could be relatively inexpensive although concerns remain concerning the extent to which these measures might create like-for-like habitat.

The provision of additional bird roosting structures is relatively inexpensive, although the effectiveness of such measures in offsetting potential impacts (such as loss of feeding area) is questionable.

The costs associated with undertaking managed realignment on a large scale are likely to be very significant both in absolute terms and in relation to the overall costs of tidal power development in the Severn Estuary. For example, based on applying compensation ratios of 1:1 and 3:1 for a middle barrage option and assuming a loss of 20,000ha of intertidal habitat and a total replacement cost of £65k per hectare would indicate a potential compensation cost of £1.3 to £3.9bn. Equivalent figures for an outer barrage would be in the range £1.7 to £5.1bn. Delivery of compensatory measures on this scale would also impose a major cost on Government and its agencies through the regulatory approvals process.

Information on the costs of SAC site selection indicate that these costs are relatively small. The costs associated with site management would depend on the nature and extent of management measures that might be required to support achievement of conservation objectives. These costs could be high, particularly where major restoration initiatives are required.

The potential costs associated with migratory fisheries measures are particularly tentative because of the unprecedented scale of mitigation and compensation that might be required and uncertainty concerning the effectiveness of measures (and thus how much of a measure might be required). Costs associated with design modifications to tidal power structures to provide benefits to migratory fish could potentially be large. Similarly modifications to the operational regime could be large even where such measures can be effectively targeted to key migration periods.

Costs associated with migratory fish spawning and nursery habitat enhancement in rivers will largely be site specific. Indicative figures suggest costs could be of the order of £5m per river.

There is limited information available on the costs of stock enhancement measures. For example, the cost to set up a salmon/sea trout hatchery is of the order of £1m to £2m with annual running costs of around £400k. Similar orders of cost may apply to other migratory species. Transportation and translocation costs are generally estimated to between £300-£700k per species per year. The costs of acoustic herding for shad are estimated to around £4m p.a. Overall, costs related to stock enhancement could be of the order of £10m per river with annual operating costs of up to £1m per species or £5m p.a. for shad if acoustic herding was deployed.

Based on the indicative costs available, the total costs for those measures that have been quantified could be of the order of £15m per river plus annual operating costs of at least £1m p.a. per river. These measures might be

required as mitigation in each of the three river SACs. They might also be required as compensatory measures in a number of other rivers.

At this level, the costs associated with many of the fish measures might be considered relatively modest compared to the costs for managed realignment. However, it should be emphasised that not all potential costs have been quantified at this stage and it remains unclear whether the fisheries measures at this scale could be effective.

The information on costs has been used in section 7 as part of the overall evaluation of mitigation and compensation options for tidal power development in the Severn Estuary.

Table 11 Information on the potential costs of mitigation and compensation measures

	Measure	Cost	Source	Comments
Mitigation Measures	Modification of barrage design to minimise impacts on tidal regime: • Increase number of sluices • Provide for overtopping of embankment on spring tides • Tidal pumping	Probably High		Costs of additional sluices likely to be high. Implications for energy yield considered to be minor; Costs to provide for overtopping probably minor, but some reduction in energy yield; Costs of tidal pumping unknown but unlikely to have negative effect on energy yield.
	Modifications to tidal power development structures to minimise impacts on migratory fish	Probably High		Cost of additional sluices, turbine modifications, wall design likely to be high. Impacts on energy yield could also be significant
	Management of operational regime of barrage to reduce impacts on tidal regime/promote safe fish passage	Medium to High		Assuming inundation of upstream saltmarsh was undertaken on the 20 largest spring tides, this may affect energy generation by around 5%. The cost impact would be proportionally greater because the larger spring tides provide the greatest opportunities for energy generation. Conversely, turning off some turbines for a prolonged period to protect migratory fish is likely to have a proportionally smaller impact on energy yield.
	Topographic modification • Sediment recharge • Enhanced sedimentation through placement of structures	 £2.50 per m^3 Low to High	ABPmer, 2004c	For a sediment recharge and assuming a depth of recharge of 5m, cost of raising elevation over 100ha could be of the order of £12.5m. Costs for structures not known – likely to be a function of deployment depth.
	Habitat management in estuary	Probably Low		Costs will depend on requirements for land purchase (if any). Capital and operating costs for saline irrigation schemes likely to be relatively modest.
	Provision of additional roosting structures	Low		Incorporation of roosting structures into engineering design can normally be accommodated at relatively low cost.
	Fish transportation • Acoustic herding of shad • Transportation costs	 £4m p.a. £300k to £700k p.a.	 APEM pers comm..	
	Enhancement opportunities – river SAC habitats • Fish pass addition • Weir removal • Gravel cleaning, habitat enhancement, silt reduction, buffer strips etc	 £500k to £1.5m £500k £5m per river	 APEM, pers comm.	Costs of hatchery are per species. Separate hatcheries might be required for a number of fish species on each river.
	Stock enhancement • Establishing and maintaining an artificial hatchery • Predator control	 £1m to £2m set up, £400k to	 APEM, pers comm.	Costs of hatchery are per species. Separate hatcheries might be required for a number of fish species on each river.

	Measure	Cost	Source	Comments
	• Paying commercial fishermen not to fish	£700k p.a. Low Low		
Compensation Measures	Managed realignment	£65k per ha	Postle & Vernon, 2001, Rupp-Armstrong et al, 2008	Postle & Vernon figure uprated for inflation; Armstrong et al at 2007 prices – considered to represent mid-range cost for managed realignment requiring counter walls or provided as compensatory habitat. Additional economic costs would be incurred through, for example, loss of farming revenues
	Designation and management of new estuarine SACs (for habitats): • Site selection • Site management	 £200k per site £42k p.a. per site	RPA et al, 2006 based on English Nature costs associated with European Marine Sites	Site selection includes surveying, management of site selection, consultation and preparation of management scheme. Ongoing management includes plan implementation, monitoring and enforcement. Additional costs may subsequently be incurred in implementing measures to improve the condition of these sites.
	Designation and management of new river SACs (for migratory fish): • Site selection • Site management	 Low Probably Low		May be similar costs to those for designation of sites for estuarine habitats
	Enhancement opportunities – estuary SAC habitats	?		Costs will be site specific. Options requiring decommissioning and removal of infrastructure likely to be expensive.
	Enhancement opportunities – river SAC habitats • Fish pass addition • Weir removal • Gravel cleaning, habitat enhancement, silt reduction, buffer strips etc	 £500k to £1.5m £500k to £1m £5m per river	APEM, pers comm.	
	Stock enhancement • Establishing and maintaining an artificial hatchery • Predator control • Paying commercial fishermen not to fish	 £1m to £2m set up, £400k to £700k p.a. Low Low	APEM, pers comm.	Costs of hatchery are per species. Separate hatcheries might be required for a number of fish species on each river.
	Fish translocation • Acoustic herding of shad • Transportation costs	 £4m £300k to £700k	APEM pers comm..	Assumes one-off cost for transfer

SECTION 7

EVALUATION OF MITIGATION AND COMPENSATION OPTIONS

7 EVALUATION OF MITIGATION AND COMPENSATION OPTIONS

7.1 Introduction

This section draws together information from the previous sections on the nature and scale of potential impacts on designated features, the scope for possible mitigation measures to avoid or reduce these potential impacts and the opportunities for compensatory measures.

As highlighted previously there are currently major uncertainties surrounding the potential impacts and the effectiveness of possible mitigation measures. Similarly, the exploration of potential compensatory measures is at an initial stage and it would therefore be inappropriate to draw firm conclusions about the extent to which any of the tidal power options considered may or may not be able to comply with the requirements of the Habitats Regulations.

A key uncertainty surrounding potential impacts relates to the geomorphological consequences of tidal power development. There are currently divergent views on this issue. One view suggests that tidal power development could create an erosive tendency on intertidal areas which would lead to a long-term deterioration in the quality and extent of intertidal habitats in addition to the direct impacts as a result of changes to tidal range. Such a scenario would have significant implications both for the quantity of mitigation and/or compensation required and for the effectiveness of any mitigation measures. Further research to address the current uncertainties must therefore be seen as a high priority for the study.

It must also be emphasised that the uniqueness of the ecology of the Severn Estuary is a function of the extreme physical regime. Significant changes in the physical regime will inevitably lead to changes in ecological structure and function. This has important implications for the delivery of any compensatory measures for habitats because strict like-for-like replacement will require a similarly extreme physical regime.

In contemplating possible compensation options, it is recognised that the study makes important assumptions about the need for the project, alternative solutions and IROPI. However, this exploration of possible measures is not intended to bypass these requirements but simply to look at what might be possible, should these other tests be satisfied.

Given the current uncertainties surrounding impacts, the evaluation only covers the potentially affected features at a high level. It is recognised that more detailed evaluation will be required as part of any formal assessment should a preferred option be progressed.

7.2 SAC Habitats

All the tidal power options evaluated are likely to have very significant adverse effects on some or all of the habitat features within the Severn cSAC. In addition to direct impacts associated with changes in water levels, long–term geomorphological changes may cause chronic deterioration to the habitat features. Investigation into the long-term morphological changes arising from tidal power development will be important in clarifying the potential rate and direction of future morphological change and thus the likely long-term impacts for habitat features. Pending the outcome of such studies, a precautionary approach needs to be adopted in predicting impacts. For the middle and outer barrage options, it is therefore possible that the habitat features will be adversely affected across the majority of their existing extent within the Severn cSAC. While the habitat impacts of the other options considered are likely to be smaller, they are still likely to be of major significance in relation to the Severn cSAC.

There are a range of mitigation measures that might be implemented to avoid or reduce impacts to habitat features, including:

- Measures to reduce impacts on tidal range;
- Management of tidal exposure and exchanges on a daily/seasonal basis;
- Topographic modification within the designated site;
- Habitat management within the designated site.

While these measures have some potential to partially offset potential impacts to habitat features, none of the measures is likely to be able to fully offset impacts in a like-for-like manner because the changes in the physical regime will inevitably affect the ecological sub-features associated with the broad habitat types. Given the uncertainties surrounding the future geomorphological functioning of the estuary and the ability for such measures to avoid or reduce changes in important sub-features, the level of confidence associated with such measures is assessed as low. A more rigorous evaluation of potential mitigation measures should be undertaken as part of Phase 2 studies to identify their potential effectiveness and cost effectiveness, assuming the study is progressed beyond Phase 1.

The costs of possible mitigation measures that might involve modifications to barrage operating regimes are currently uncertain. Additional costs would relate not only to the barrage modifications themselves but also to consequent reductions in energy yield. The potential cost effectiveness of such measures will need to be explored as part of Phase 2 studies, if progressed. Initial consideration suggests that the costs associated with reduced energy yield could be high.

Capital costs associated with topographic modification could be of the order of £12.5m for the creation of 100ha of intertidal area, based on a large scale sediment recharge, although less costly solutions may be available. While heavily engineered solutions would not be consistent with a 'dynamic coasts' philosophy, estuary processes are likely to be considerably changed by tidal power development and the potential benefits of engineered solutions would need to be considered in this context. The long term morphological development of any modified areas is currently uncertain and such interventions may not create like-for-like habitat because of the overall changes in physical regime. Further evaluation of potential opportunities should be undertaken as part of Phase 2 studies, if progressed.

The costs associated with habitat management will depend on the nature of the management activity. Maintenance of high level saltmarsh could be achieved through spray irrigation using saline water. RTE schemes could be implemented to successfully create a wider range of habitats including mudflat and a range of saltmarsh types, although the nature of the intervention would mean that functional aspects of the habitat could be affected, for example, impairment of sediment supply. The costs of RTE schemes is likely to be similar to those for managed realignment, particularly where land purchase is required.

There are a number of possible options to provide compensatory habitat:

- Managed realignment at locations adjacent and close to the Severn Estuary, extending further afield to the rest of England and Wales;
- Inclusion of additional sites within the SAC list to replace features affected by tidal power development within the Severn cSAC;
- Enhancement of relevant habitat features within existing designated sites (where such actions are not already required to support the achievement of conservation objectives).

The initial broad scale review of managed realignment opportunities has identified a total area greater than 100,000ha for England and Wales that is potentially suitable and subject to lower levels of constraint from existing

development. Around 8,000ha of the total area is within the Severn Estuary and Bristol Channel. The total area includes 58 potential sites greater than 500ha. Larger programmes of managed realignment will necessarily require a number of schemes in the east of England.

At this stage, it is not possible to define the types of habitats that might be created through realignment of these areas (i.e. the extent to which features and sub-features within the Severn Estuary might be replaced), the sustainability of habitats created, the range of variation that such habitats might represent (e.g. salinity variation, physical conditions) nor the extent to which such schemes might contribute to an overall package of compensatory measures. Further evaluation of potential areas could be undertaken relatively easily through an evaluation of local topographic information to provide more detailed information on the nature and extent of initial habitats that might be created. However, significant uncertainties would remain concerning the extent to which such areas might support the specific features and sub-features associated with the Severn Estuary cSAC and the quality of those features.

Given the unique physical conditions within the Severn Estuary, it will not be possible to compensate for the impacts to cSAC habitats on a strict like-for-like basis. Functional mudflat and saltmarsh habitats can be created, but the physical conditions in the areas where such habitats might develop will not be fully representative of those in the Severn Estuary. Clarification is required on whether this would lead to an overall loss of coherence of the Natura 2000 network. It should also be noted that there is limited experience in the UK of replacing some sub-features, for example, *Zostera*, although there have been a number of successful restoration projects in the United States (see for example, Fonseca et al, 1998)

It is unlikely that any of the possible realignment sites would be suitable for recreating subtidal sandbank or reef habitats and the main focus would be on compensating for intertidal mudflats and sandflats and saltmarsh habitats.

There are also a number of major challenges in contemplating managed realignment on a very broad scale, not least issues of public acceptability, economic, social and environmental impacts, project costs and delivery in a time scale that would satisfy the requirements of the Habitats Regulations. The scale of compensation that might be required for a large tidal power development in the Severn is unprecedented and managed realignment opportunities would need to be pursued at a strategic level by Government. Such a major initiative could also contribute to climate change mitigation efforts to deliver long term sustainable flood defences.

Based on applying compensation ratios of 1:1 and 3:1 for a middle barrage option and assuming a loss of 20,000ha of intertidal habitat would indicate a potential compensation cost of £1.3 to £3.9bn. Equivalent figures for an outer barrage would be in the range £1.7 to £5.1bn.

Large scale realignment is likely to be necessary. Reliance on smaller scale schemes could result in an unacceptably large number of schemes. Furthermore, smaller scale schemes would be likely to require relatively longer lengths of flood protection and thus prove to be considerably more expensive both in terms of capital and future maintenance costs.

A wide range of further research studies would be required in particular to explore the geomorphological implications of large managed realignments, for example, changes to sediment supply on local and regional levels and to examine the engineering feasibility and costs of realignment on this scale. Additional assessment of the economic, social and environmental impacts of large scale managed realignment would also be necessary.

The review of sites which support extensive (>200ha) intertidal habitats has identified some 25 estuaries and coastal locations that are not currently designated as SACs. The total area of intertidal habitat exceeds 34,500ha. However over 30,000ha of this area is already designated as SPA for migratory and overwintering waterfowl and the associated habitats. Where features are already protected within SPA designations, additional designation as SAC features would not provide any additional protection and would therefore not make any contribution to the protection of the Natura 2000 network. Areas of search for new SAC site designations would therefore need to focus on sites supporting potentially qualifying features that are not already classified as SPAs or on features within existing SPAs that were not already protected by the SPA designation.

Possible candidate sites will need to be evaluated against the criteria for site selection laid down in the Habitats Directive and also evaluated in terms of the relevant habitat features that such sites could contribute to an overall package of compensatory measures recognising that precise replacement of function and range of variation will not be possible. An impact assessment would need to accompany any proposal for extending the list of SACs. It is noted that there is currently no clear process for designating additional SACs and this would need to be addressed as part of the wider feasibility study.

The designation of new areas as SAC is likely to be the only feasible mechanism for compensating for impacts to subtidal sandbank or reef

features. There is currently little summarised information on the distribution of such features in inshore areas. Given the distribution of the features within the Severn Estuary, the potential compensation requirements for middle and outer barrage options, could be large (for example, the current area of subtidal sandbank probably exceeds several thousand hectares). If it was assumed that an additional ten sites were to be designated to provide compensatory habitat for subtidal sandbanks and reef features, based on the unit costs presented in section 6, this could generate a one-off cost of approximately £2.0m and annual running costs of £420k. The initial costs associated with designating new SACs for estuarine habitats would be very low compared to the costs of new habitat creation through managed realignment. However, following designation of new sites, it is likely that additional expenditure would be required to improve the quality of designated features as part of an overall compensation package. These costs could be large, particularly where major restoration actions were required.

There may be scope within other existing SACs to undertake enhancement measures which are not already required to maintain/achieve favourable condition for designated features. However, such measures would be site specific and are unlikely to deliver the kind of large scale benefit that might be necessary to make a significant contribution to a package of compensatory measures. It is not possible to quantify the costs of potential measures at this stage although if they involve extensive decommissioning and removal of infrastructure such costs could be very large relative to the benefit delivered.

7.3 SAC Species

All tidal power options are likely to affect migratory fish and otter features associated with the Severn Estuary cSAC, and the Usk and Wye River SACs to varying extents. The risks to features in the River Tywi SAC are likely to be lower than for the other sites because of its location well to the west of potential development areas. However, there is currently a high level of uncertainty concerning the movements of some species of migratory fish (e.g. shad, lamprey) within the Severn Estuary and Bristol Channel and it is possible that individual fish from the Tywi could encounter tidal power development structures prior to entering, or following downstream migration from, their natal river.

The Severn Estuary cSAC and the three river SACs are the only four known locations within the UK that definitively support breeding populations of twaite shad and each population is genetically unique. Shad are particularly sensitive to impacts associated with tidal power development and there is

therefore considered to be a high risk of high mortality, particularly should such fish pass through standard turbines. Impacts to populations of other species of migratory fish affected are also considered likely to be large.

While a number of potential mitigation measures exist, there is generally a low confidence in their effectiveness, for example, based on experiences with deploying similar measures in the vicinity of power station cooling water intakes. Measures such as fish passes, while applicable for migratory fish traversing rivers, are generally considered unlikely to be effective in the Severn Estuary. Ongoing research into alternative turbine technologies may lead to the development of less damaging designs for migratory fish. However, there is currently little certainty that such research will lead to designs that reduce fish injury and mortality to acceptable levels.

Significant additional research is required in seeking to identify potentially suitable mitigation measures for migratory fish. This needs to include a much better understanding of how migratory fish use the Severn Estuary during upstream and downstream migration, for example, proximity to shore, swimming depth, residence times etc. Such information could be of value in developing effective mitigation strategies, although it is noted that the behaviour of fish may change as a result of changes to the physical regime of the estuary that would occur as a result of tidal power development..

In relation to otters, the main risks relate to modification of habitats within the tidal stretches of the rivers which could affect movement corridors in these areas. Many of the mitigation measures proposed for habitats could possibly contribute to reducing these risks. Where appropriate it might be possible to undertake specific mitigation activities to improve connectivity within tidal areas of the tributary rivers to offset potential impacts.

The costs associated with design modifications to tidal power development structures (including turbine design) to benefit migratory fish are not known but are likely to be large. The design modifications might also result in loss of energy yield.

The costs associated with switching off a small number of turbines during important migration periods could be of the order of 1.5% of energy yield assuming 10% of turbines were switched off for 3 months. However as different fish species migrate at different times of year and for differing periods of time, switching turbines off is only likely to be feasible for a specific target species (e.g. if cessation of operation was conducted over the specific migratory period for a particular species lifestage). Turbines could potentially be switched off over night and this has the potential to be

beneficial as several migratory species can migrate during the night. Overall, however, it is considered to be unlikely that such a measure could be used to protect all migratory fish or the wider estuarine fish population.

Various options for compensatory measures have been reviewed including:

- Designation of additional rivers supporting the relevant migratory fish species or otters;
- Enhancement measures either within the affected rivers or in other designated rivers where such measures are additional to those required to support achievement of conservation objectives.

The very limited distribution of allis and twaite shad in England and Wales means that there are effectively no other locations that could be considered for designation.

For the other species of migratory fish (river and sea lamprey, Atlantic salmon) there are other rivers supporting breeding populations of these species. While it would not be possible to replace the genetically unique populations affected within the Severn Estuary cSAC and river SACs, it may be possible to identify some currently undesignated sites that could contribute to a package of compensatory measures, subject to more detailed evaluation against SAC site selection criteria. As noted previously, a process for designating new SACs would need to be developed as part of the wider feasibility study.

Similarly there may be opportunities to designate additional rivers for otters, although this has not been explored as part of this study.

There may also be opportunities to implement stock enhancement measures for migratory fish either within the affected rivers or at other locations where the relevant species occur. The scope for such measures would need to be assessed on a site specific basis. As noted previously, the benefits of stock enhancement are likely to be very limited unless the direct impacts of tidal power options on the migratory fish populations can be effectively mitigated. As a last resort fish translocation could be contemplated whereby an entire population of migratory fish was transferred to another river system. While this approach has been applied in the US, the long-term effectiveness of such a measure in the UK is unproven.

The costs associated with designating additional river SACs are not known, but may be similar to the costs for designation estuary SACs (around £200k per site and running costs of around £40k p.a.). While these initial costs may

be low, significant additional expenditure may subsequently be required to improve the condition of the newly designated sites.

The costs of habitat and stock enhancement measures could be of the order of £15m per river with ongoing costs of £1m p.a. or more. While these costs appear relatively cheap in comparison to the potential costs for managed realignment options, it should be emphasised that there is currently a high level of uncertainty about whether such measures would be sufficiently effective and a number of potential costs remain unquantified.

7.4 SPA Features

The SPA features include both the waterbirds for which the site has been classified as an SPA and the intertidal habitats on which the birds depend. The intertidal habitats are essentially the same as those identified in the Severn Estuary cSAC and similar impacts apply.

The impacts to bird features – both the Annex 1 species (Bewick's swan) and the migratory and overwintering assemblage of waterfowl are likely to be significantly affected by tidal power development in the Severn Estuary. Greater impacts are likely to be associated with larger scale tidal power development. A critical issue in refining impact predictions relates to the changes in intertidal extent, the quality (in terms of feeding resource) of those areas and how that quality might change over time. These issues will need to be a key focus for the Phase 2 studies, assuming the project progresses beyond Phase 1.

The main opportunities for mitigation measures, relate to measures to maintain existing habitats in situ or to recreate intertidal habitats within the boundary of the SPA. There is relatively low confidence in the effectiveness of such measures at this stage because of the large uncertainties about the geomorphological response of the estuary to tidal power development. Provision of additional roosting sites associated with tidal power development structures is only likely to make a minor contribution to reducing impacts.

The costs of habitat mitigation would be similar to those described under section 7.2. Costs associated with provision of additional roosting structures would be relatively small.

The scope for compensatory measures will primarily be limited to the creation of new intertidal habitats through managed realignment or other habitat creation techniques such as regulated tidal exchange. While a significant area for potential habitat creation opportunities has been identified, the extent to which such measures may contribute to an acceptable compensation package for waterbirds is currently unclear. In addition to uncertainties relating to the feasibility of habitat creation, the nature of habitats to be created and their sustainability, other factors such as location within the biogeographic region, proximity to flyways and the ability to replace the functions lost to tidal power development in the Severn Estuary (for example, preferred feeding area during cold winters, feeding area for passage birds etc) will also be important. It is difficult to make an evaluation of these issues pending more detailed assessment of potential impacts. The costs associated with such measures are likely to be large but are already effectively accounted for in the figures for habitat creation to offset impacts to cSAC features.

There may also be scope for enhancement measures to contribute to a compensation package, through measures to improve existing SPAs that are not required to support achievement of conservation objectives. However, the scale of such opportunities is not considered to be significant in relation to the potential compensation requirements. The costs of enhancement measures could be large if they involve extensive decommissioning and removal of infrastructure.

7.5 Ramsar Features

Most of the Ramsar features are similar to those for the Severn Estuary SPA and cSAC. One exception is that the Ramsar designation includes all species of migratory fish and not just those identified under Annex 2 to the Habitats Directive. The main additional migratory species of fish afforded protection under the Ramsar designation are eel and sea trout. The evaluations of impact to these features are similar to those for lamprey and salmon respectively. Similar mitigation and compensatory measures might apply for sea trout. However, because eel do not breed in UK rivers, most of the mitigation measures proposed for migratory fish in rivers would not apply, although an important mitigation measure might relate to a reduction in the collection of glass eel from the Severn for translocation to other river systems.

The Ramsar designation also covers fish populations of estuarine and river systems. There has been no detailed studies of potential impacts, although the

potential impacts are likely to be similar to those for migratory fish, particularly where species have a high functional dependence on areas upstream of tidal power development during part or all of their life cycle. Mitigation measures that are applied for migratory fish will also provide benefit to some extent for estuarine fish. However, for estuarine fish that are present in the estuary for significant periods of time and/or which move up and down the estuary in response to tidal or other periodic factors, the effectiveness of such measures may be reduced. It may be possible to designate new Ramsar sites for the protection of estuarine fish communities (or to add such features to existing Ramsar sites) although the policy basis for this is unclear and may need to be developed further as part of the feasibility study.

Some additional costs might be incurred if additional sites were included within the Ramsar site series specifically for eel, sea trout or the wider estuarine fish community. Such costs are likely to be similar in scale to those identified for SAC migratory fish.

SECTION 8

CONCLUSIONS AND RECOMMENDATIONS

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This high-level evaluation has considered the potential impacts of generic tidal power development options on designated features associated with the internationally designated sites. A preliminary evaluation of possible mitigation measures has been undertaken to seek to avoid or reduce potential impacts together with a confidence assessment in the effectiveness of these possible measures. Options for compensatory measures to fulfil the requirements of the Habitats Regulations and their likely effectiveness have also been explored at a strategic level.

At this early stage in the development and consideration of tidal power options, the magnitude of many of the potential impacts remains uncertain. Nevertheless it is clear that all of the tidal power options considered are likely to have very significant effects on some or all of the features associated with the internationally designated sites. Some of the key uncertainties surrounding impact predictions relate to:

- The potential impacts on the Estuary hydrodynamics, particularly its tidal range. These changes are fundamental in informing an evaluation of changes in the extent of intertidal habitat;
- The current limited understanding of the impacts of tidal power development on long-term geomorphology. This is important because the geomorphology strongly influences the distribution, quality and functional aspects of ecological features and would also influence the effectiveness of potential mitigation measures;
- Aspects of the use of the Severn Estuary by some migratory fish species (e.g. shad, lamprey) and thus the potential risk posed by tidal power development in specific locations.

Assuming Phase 2 studies are progressed, the above issues should be an important focus for further research.

There are a range of potential mitigation measures that could be applied to seek to avoid or reduce specific impacts to designated features. However, confidence in the effectiveness of such measures is currently low. For habitat mitigation measures much of this uncertainty relates to the lack of understanding of long-term morphological change as a result of tidal power

development which could limit the effectiveness of possible measures. For migratory fish, previous experiences of mitigation measures for power station cooling water intakes has highlighted the difficulties in finding effective measures for estuaries and coastal waters. The scale of development associated with most of the options is unprecedented. Currently, there is therefore a very low level of confidence in the effectiveness of such measures for large scale tidal power development, although a number of promising avenues for further research have been identified. However, it should also be recognised that further research could either increase or decrease confidence in the certainty of individual measures.

If progressed, the Phase 2 study should place a strong emphasis on exploring possible mitigation measures, particularly in relation to reducing impacts on the level of high water during spring tides and in relation to migratory fish. Such an exploration is important for the following reasons:

- there is a strong presumption in guidance under the Habitats Directive that developments will seek to minimise their impacts on designated sites before recourse to compensatory measures;
- confidence in the effectiveness of compensatory measures is in most cases low (see below); and
- the costs of compensatory measures are likely to be very high and it is therefore in the interests of any tidal power development project to adopt effective mitigation measures where practicable.

Further exploration of the potential costs of mitigation measures is also needed, including impacts on energy yield. It is possible that the costs of mitigation measures could be significant both in absolute terms and in relation to the overall costs of tidal power development as a whole.

Three potential approaches to compensatory measures have been identified:

- managed realignment to create new intertidal habitats and to provide new feeding and roosting areas for waterbirds;
- designation of new SACs for intertidal and subtidal habitats and for migratory fish and for designation of new Ramsar sites in respect of eel, sea trout and estuarine fish; and
- enhancement measures for estuarine and river habitats and migratory fish stocks.

The scale of managed realignment that might be required is unprecedented. Delivery is only likely to be achieved through a major strategic initiative by Government. Such an initiative could be linked to large scale climate change

adaptation. Particularly for the larger tidal power schemes, a series of major realignment schemes would need to be undertaken. Large sites would almost certainly be required both for practical reasons to limit the overall number of managed realignment schemes required and to minimise the length of replacement flood defences. Given the geographical distribution of potential managed realignment areas, larger tidal power development projects would require an increasing proportion to be delivered in eastern England. Only for tidal development schemes with the smallest impacts might it be possible to deliver a significant proportion of the potential managed realignment requirement in the west of England and Wales.

Managed realignment on this scale poses significant challenges in terms of public acceptability and deliverability. Taking forward such proposals would represent a very major project in its own right with substantial economic, social and environmental impacts as well as potential benefits. Managed realignment on this scale could also have wider benefits in relation to the provision of ecosystem goods and services (carbon sequestration, fisheries, flood defence benefits etc.).

There are also important technical and scientific issues associated with engineering design and geomorphology. Further evaluation of large scale managed realignment should be undertaken to address some of these issues. Questions also remain about the acceptability of managed realignment as a compensatory measure for the impacts of tidal power development on the Severn Estuary both in relation to habitats but also in terms of function for waterbirds. In particular, the ecology of the Severn Estuary is unique and intimately associated with its hyper tidal and extremely dynamic physical regime. This makes like-for-like replacement exceedingly difficult.

A number of possible opportunities exist for the designation of new SACs for intertidal and subtidal habitats to replace those affected by tidal power development. These opportunities need to be evaluated against SAC site selection criteria and in the light of potential compensatory requirements for tidal power development in the Severn Estuary to inform discussions on their potential acceptability as part of a package of compensatory measures. A policy approach for designating new SACs would need to be developed.

Similar opportunities for new SAC designations exist for some species of migratory fish (river and sea lamprey, Atlantic salmon). Opportunities are also likely to exist for new Ramsar designations in relation to eel, sea trout and other estuarine fish. These opportunities need to be reviewed and prioritised to inform discussions on their potential acceptability as part of a package of compensatory measures. The Severn Estuary cSAC and associated

river SACs support the only known breeding populations of twaite shad. These populations are genetically unique and could not readily be compensated for.

The scope for enhancement opportunities for estuary habitats is anticipated to be limited, based on comparable initial work in relation to Water Framework Directive (WFD) measures, although where schemes are identified they should be considered for inclusion within an overall package of compensatory measures. For river habitats, there is scope for improving spawning and nursery habitats for species of migratory fish and such measures could be relatively inexpensive, although the overall effectiveness of such measures remains uncertain. There is also scope for stock enhancement measures in the river SACs and other river systems but the effectiveness of these measures is likely to be limited unless the main impacts of tidal power options associated with the passage of migratory fish can be effectively mitigated. Further research on habitat and stock enhancement opportunities for migratory fish should be commissioned.

It is possible that the overall costs of compensation measures could be significant both in absolute terms and in relation to the overall costs of tidal power development as a whole. For example, the cost of delivering large scale managed realignment for a major tidal power scheme such as an outer or middle barrage could be between £1.3 and £5.1bn. Costs for a smaller scheme would be significantly lower.

This study has documented the many significant uncertainties concerning the scale of potential impacts associated with tidal power development in the Severn Estuary and identified many challenges in developing and delivering the mitigation and compensation measures that would potentially be required. The potential scale of measures required is likely to be unprecedented and in a number of areas there is currently a low level of confidence in their effectiveness. While it will not be possible to compensate for impacts on a strict like-for-like basis, it remains unclear, the extent to which possible measures might contribute to protecting the overall coherence of the Natura 2000 network. Pending further evaluation of both the potential impacts and the mitigation and compensation opportunities it is not possible at this stage to categorically determine whether any of the tidal power options could or could not comply with the requirements of the Habitats and Birds Directives.

8.2 Recommendations

Recommendations for progressing a possible package of mitigation and compensation measures are discussed below. In particular, the Severn Tidal Power (STP) Project will need to determine how best to take forward the issues to explore in more detail some of the areas of greatest uncertainty. While a number of the uncertainties relating to potential impacts will be addressed through Phase 2 studies for the SEA, many of the issues concerning compensatory measures will need separate consideration.

It is recognised that significant new research is required to fully explore risks and issues associated with tidal power development in the Severn Estuary. As part of the STP project, it is necessary to prioritise these studies to meet project time scales and available budgets. This research will be focused on informing the options appraisal and assessment process. Should any preferred option subsequently be progressed through the planning system, considerable additional research is likely to be required to refine detailed assessment of impacts and targeting of mitigation and compensation measures.

8.2.1 Refinement of Impact Predictions

Phase 2 studies should, *inter alia*, focus on addressing the following key uncertainties:

- effect of tidal power options on physical processes, long-term geomorphological change and the implications for the structure and function of ecological receptors; and

- usage of the estuary by migratory fish during upstream and downstream migration (position relative to shore, swimming depth, longitudinal movement, residence times) and how this might change following tidal power development.

The assessment of effects on physical process will require a substantive programme of modelling and assessment. In the case of effects on migratory fish, technical challenges mean that it will probably be not practicable to execute fish-related fieldwork within Phase 2. Assessments of impacts upon fish within Phase 2 will therefore most likely need to be based upon desk-study.

8.2.2 Evaluation of Mitigation Measures

There is some scope for incorporating mitigation measures within the overall design of a possible preferred tidal power option. Phase 2 studies should focus on:

- evaluation of the costs and effectiveness of measures to minimise impacts to the existing tidal range and in particular existing high water levels. This should take account of potential reductions in energy yield; and

- exploration of a package of measures to minimise impacts to migratory fish building on the findings of desk-study research into their use of the estuary during upstream and downstream migration.

8.2.3 Consideration of Compensation Options

This initial study has identified the high-level potential for managed realignment around England and Wales. Some further exploration of key issues would be helpful, in particular:

- a viability study for large scale managed realignment – this should explore issues of engineering feasibility/cost, social and economic impacts and the geomorphological implications of such large interventions;

- desk-based evaluation of likely habitats that could be created – evaluation of a proportion of the 56 sites >500ha to predict likely habitats based on elevation data (LiDAR) and knowledge of physical processes. The evaluation should also explore possible requirements to mitigate for impacts to habitats/species affected by the managed realignment schemes;

- evaluation of the effectiveness of possible managed realignment options in compensating for impacts to waterbirds; and

- evaluation of other suitable compensatory measures that have not yet been identified.

Further evaluation and prioritisation of potential sites for inclusion in the SAC list/Ramsar site series should be undertaken (new SAC designations for intertidal and subtidal habitats and migratory fish) (and/or new Ramsar designations (eel, sea trout and estuarine fish)).

Additional work could be undertaken on potential enhancement opportunities for estuarine habitats, although this is not considered to be a

high priority. However, further exploration of options for enhancing river habitats for migratory fish spawning and nursery areas in the three River SACs would be worthwhile. Additional consideration should also be given to stock enhancement measures.

The nature of studies on compensation options, their priority, and potential for their inclusion within the Phase 2 package of work, is currently under consideration.

8.2.4 Other Activities

As this Phase 1 desk-based assessment anticipates the formal Screening or Appropriate Assessment process, in making these recommendations it is assumed that other aspects of the Habitats Regulations requirements will be progressed separately, in order to ensure complete compliance with the EU Habitats and Birds Directives. These will include the following:

- consideration of far-field effects on designated features not explicitly discussed in this report;
- consideration of issues of the need for the project, alternatives and imperative reasons of overriding public interest;
- clarification of the compensation requirements to protect the 'overall coherence' of the Natura 2000 network; and
- consideration of the potential for developing a policy approach to designating new SACs or Ramsar sites.

SECTION 9

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9 REFERENCES

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APPENDIX 1 – OUTLINE METHODOLOGY

APPENDIX 1. MITIGATION AND COMPENSATION STUDY – OUTLINE METHODOLOGY

1. INTRODUCTION

A Cross-Government Project Team has commissioned a programme of work to support the Severn Tidal Power Feasibility Study, including a Strategic Environmental Assessment (SEA). The SEA study as a whole includes engineering, technical and environmental assessments of options, and is divided into two phases. Phase 1 covers the first six months of the study (from May to October 2008) and has six objectives:

- To identify, review and rank all potential tidal range power generation schemes in the Severn Estuary in an impartial and evidence-based way;
- To confirm a shortlist of tidal range power projects that should be consulted upon and evaluated as part of the Strategic Environmental Assessment process;
- To review and update construction and operational costs, modes of operation and associated energy yields;
- To assess, at a high level, the extent, availability and viability of potential habitat compensation;
- To produce an SEA Scoping Report that can be issued for public consultation following ministerial approval to proceed to Phase 2;
- To identify and quantify major engineering and/or environmental risks to assist Ministers in determining whether to proceed with the second phase of the Feasibility Study.

Phase 2 extends from November 2008 to April 2010 and covers the preparation of the SEA itself and the associated Environmental Report.

This note sets out the proposed method to assess, at a high level, the extent, availability and viability of potential habitat compensation within Phase 1. The method is intended to support the Ministerial decision on whether to proceed with Phase 2; and does not constitute a formal part of the Habitats Regulations Assessment process. It is anticipated that further assessment of the feasibility of mitigation and compensation measures will therefore form an integral part of Phase 2.

2. WORK TO DATE

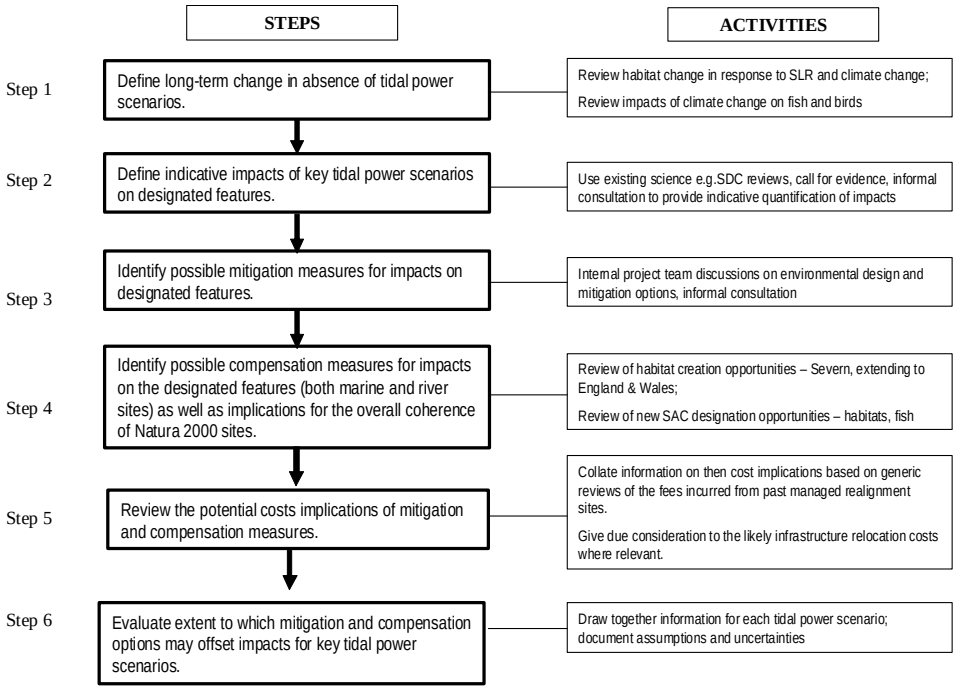
The Sustainable Development Commission's report 'Tidal Power in the UK' recommended that further consideration should be given to the feasibility of providing compensatory measures to offset the possible impacts of tidal power development in the Severn Estuary and in any other designated sites that could be affected. This mitigation and compensation

study therefore seeks to identify, at a very broad or 'high-level' scale, the possible mitigation and compensation options for key tidal power scenarios. In so doing it seeks to inform reviews of the feasibility of the project and, in particular, contribute to the internal review.

3. PROPOSED METHOD

The methodology is illustrated in Box A below, based on a series of clear steps and associated activities.

Box A. Outline Methodology



In contemplating possible compensation options, it is recognised that the method makes important assumptions about project need, alternative solutions and IROPI. Also, this high-level initial assessment does not constitute part of a formal Screening or Appropriate Assessment process at this stage. Instead, this study anticipates, rather than replaces, the work required for a formal Habitats Regulations Appropriate Assessment. This is needed for the purposes of informing the Ministerial decisions regarding Phase 2.

4. STEP 1 LONG-TERM CHANGE

Information on predicted long-term change in broad habitat types (subtidal, intertidal, saltmarsh) in response to relative sea level rise and associated geomorphological change is available from the Severn CHaMP. A review of long-term changes in waterbird populations has been prepared by Prater (2007)5 Some information on trends in migratory fish populations is also available (e.g. WWF, 2001)6.

The information will be useful in identifying natural change in the absence of any tidal power development and how this may affect interest features within the Severn Estuary system. It will however be assumed that anthropogenic impacts such as coastal squeeze impacts as a result of flood defence structures would be compensated for in terms of impact extent and, where feasible, on a like-for-like basis. It should also be emphasised that the aim of this element of the work is not to allow for a future 'Netting Off' of the impacts from potential tidal power generation initiatives against habitat losses and species declines that are expected to occur in the future via other processes. Instead the intention is to simply enhance the baseline description by better understanding both the existing and potential future status of the key habitats and species.

5. STEP 2 INDICATIVE IMPACTS OF TIDAL POWER OPTIONS

A wide range of studies have been undertaken to investigate the potential environmental impacts of various tidal power options in the Severn Estuary. This information is consolidated in the various SDC reviews. However, it is recognised that considerable uncertainty remains concerning the likely impacts on conservation features.

The indicative impacts identified in the SDC reviews will be used to indicate the potential extent of habitat and species impacts and to identify key uncertainties. The review will encompass not only the Severn Estuary European Marine Site (cSAC and SPA) but also those adjacent sites such as the River Usk, River Wye and River Tywi SACs (which will be most obviously impacted where the passage of migratory fish to and from these sites is affected).

The Conservation Objectives (COs) for the relevant Natura 2000 sites will be used as the basis to further evaluate the features and sub-features/attributes of the European site that will potentially be affected (the COs for the Severn cSAC were issued on 16 June 2008). It is however recognised that it will be difficult to assess many of the potential impacts at this

[5] Prater, T. 2007. Ecological aspects of the Severn Barrage. Royal Society for the Protection of Birds.
[6] WWF, 2001. The Status of Wild Atlantic Salmon: A River by River Assessment

level, and a coarser review at the broad habitats level (marine, inter-tidal, sub-tidal etc.) may only be achievable.

A 'potential impact' table will be prepared that identifies for key tidal power options, the extent to which those options will affect features and sub-features/attributes and providing indicative quantification where possible. Decisions about adverse impacts will, as required under the Habitats Regulations, be assessed in relation to the COs. An indication of the confidence or certainty that can be placed on the impacts will be included albeit that the high-level nature of this initial assessment must be recognised at all times.

6. STEP 3 POSSIBLE MITIGATION MEASURES

Previous studies have given relatively little consideration to the environmental design aspects of tidal power options. In the short timescales for this study, it will not be possible to evaluate possible mitigation measures in detail. Nonetheless initial discussions will be held within the project consortium to identify potential aspects of design that could generate environmental benefits and the features and sub-features/attributes for which such mitigation might be partially or wholly effective.

A matrix will be developed identifying generic types of mitigation measures and the impacts upon features that these can address, e.g. fish passes mitigating impacts on migratory fish.

7. STEP 4 POSSIBLE COMPENSATION OPTIONS

Information on the potential impacts of key tidal power options will be used as a starting point to identify possible compensation requirements. The objective of compensation will be the maintenance of the overall coherence of the Natura 2000 network by implementing compensatory measures that seek to offset the predicted impacts (after the within-site mitigation measures are considered).

A matrix identifying the extent to which types of compensation options might be able to offset impacts to specific features and sub-features will be prepared. The compensation measures will be initially categorised by type (e.g. managed realignment, river restoration, re-stocking programmes etc.) and, if sufficient information exists, specific locations. It is however quite possible at this stage that only generic types of consultation measures will be identified without progressing to identifying specific sites. In any case, to avoid risk of 'blight', any reporting during Phase 1 will collate and present available compensation measures on a regional basis. This will ensure that specific potential sites cannot be identified.

Options for providing compensation will be explored as follows:

- Opportunities for creating compensatory habitats (in Severn and wider England & Wales)
  - Using information from previous regional and national scale studies (e.g. EA regional habitat creation studies and CHaMPS)
  - Expert desk study on opportunities for large scale managed realignment in smaller number of locations (e.g. undoing major reclamations in large estuaries)
- Scope for selecting additional undesignated sites to replace features affected by key tidal power options (e.g. designation of new SACs for specific habitats or species) – this will draw on available information from conservation agencies on the rationale for selection of the original marine SAC series and from the moderation exercise
- Opportunities for enhancing habitats within designated sites where such measures are not already required to support achievement of conservation objectives.

The limitations of compensation methods as ways of creating 'like-for-like' habitat or addressing failures of COs for individual species (e.g. Twaite Shad) will be noted although the detailed debate on these issues will be addressed separately and do not form part of this review.

8. STEP 5 EVALUATE POTENTIAL COSTS OF MITIGATION AND COMPENSATION MEASURES

An initial evaluation of the potential costs of mitigation and compensation measures will be undertaken. In keeping with the context of the whole project, the valuations will be necessarily approximate and based on generic reviews of the costs incurred from past managed realignments. This review will need to consider whether major infrastructure relocation costs and CPOs are likely to be relevant.

9. STEP 6 EVALUATE POTENTIAL TO OFFSET IMPACTS

Information from the above steps will be collated and evaluated to determine the extent to which potential impacts to features and sub-features/attributes might be offset by mitigation and compensation measures for the different key tidal power options. Key assumptions and uncertainties will be documented.

10. CONSULTATION

The study will draw on expertise within the study team (PB, BV, ABPmer), including expertise on birds (BTO) and migratory fish (APEM). A consultation meeting/telecon was held on 13 June 2008 to review the draft methodology with CCW and the Agency.

A more formal meeting to review the study's tentative findings on impacts and possible mitigation/ compensation measures is being convened for 9th July. This will be with the Statutory Agencies only, with the approach to engagement with NGOs and wider conservation interests currently being under review by DECC.

Additional technical meetings with certain specialists within the Statutory Agencies may be needed after the 9th July meeting, but prior to completion of the draft report in late July 2008.

Regular communication will be maintained by email.

APPENDIX 2 –METHODOLOGY FOR HIGH LEVEL SCREENING OF POTENTIAL MANAGED REALIGNMENT OPPORTUNITIES

APPENDIX 2: METHODOLOGY FOR HIGH LEVEL SCREENING OF POTENTIAL MANAGED REALIGNMENT OPPORTUNITIES

Analysis was performed using both ESRI ArcGIS V9.2, and Mapinfo Professional V9.0.1 Geographical Information Systems (GIS) Software. The Tidal Flood Zone 3 data from the Environment Agency was used as the basis for this analysis which represents the area which would be flooded by the sea once in every 200 years. From this data layer GIS analysis was used to exclude layers in succession and areas calculated at each stage creating a cumulative Potential Habitat Creation Site data layer. The initial process could be automated in the GIS and is summarised in the steps below:

1. Cut the Tidal Flood zone 3 data to 5km of the coastline of England and Wales. (The 5km distance criteria was chosen so to provide a more realistic estimate of suitable areas for habitat creation).
2. Exclude areas classed as 'Urban' in the Ordnance Survey's Strategic data from the potential habitat creation site layer.
3. Exclude designation data including: Natura 2000 (Special Areas of Conservation, Special Protection Areas), and Ramsar Sites from the potential habitat creation site layer.
4. Use GIS analysis to ensure that all potential sites within the PHCS were non-continuous with other sites i.e. separate entities, single process units.

The potential habitat creation site layer was validated against regional habitat creation opportunities information from various sources including:

- Site search information from the Severn CHaMP (ABPmer, 2007) for the area of the Severn Estuary and parts of the Bristol Channel
- Site search information from the Thames CHaMP (ABPmer, 2008c) for the Greater Thames Natural Area
- Site search information from the Thames and Essex areas stemming from studies to identify potential compensation land for Lappel Bank and Fagbury Flats (ABPmer, 2004a, b)

These studies used more detailed criteria than were applied in this initial screening exercise for the STP study and were used to develop a scaling factor to generate a more 'realistic' potential managed realignment area for England and Wales.

Following the comparison study the sites within the potential habitat creation site layer were further refined by manually visiting each site >500ha within

the GIS and amending their boundaries based on the following additional criteria:

- Where an A-Road, B-Road, railway or motorway cut through a site the landward side of the site was excluded.
- Where urban areas from the OS Strategic data of >30 ha were present these were excluded and boundaries amended to accommodate these areas so that they were not isolated by road (A,B) or by railway.
- Site boundaries were amended to ensure they were realistic in their shape so sites that were continuous but appeared to be fragmented were excluded.

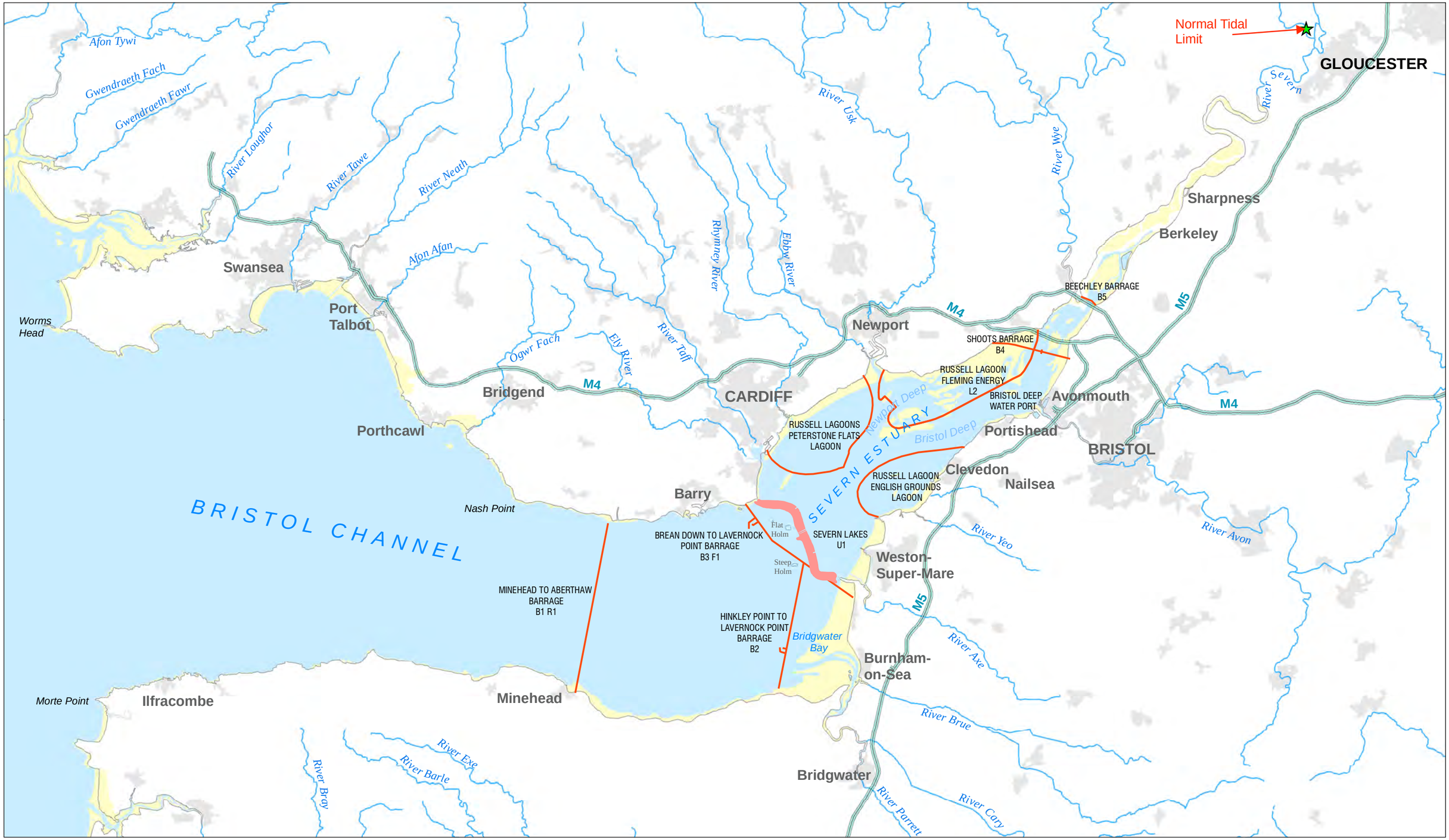
GIS analysis was used to cut the derived data layer to approximate boundaries to generate a revised layer comprising potential sites >500ha.

It should be noted that the following features were not taken into account for this screening study:

- Energy Infrastructure (cables, power lines);
- Leisure and Recreation;
- Other transport links;
- Historical Sites;
- Public Rights of Way;
- National and locally designated nature conservation sites;
- Details of site elevation, slope and aspect.

These features may or may not pose significant additional constraints for individual sites. Further evaluation of constraints will be necessary to validate potential habitat creation opportunities.

FIGURES



Rev	Date	Description	By	Chkd	Appd
1	14/08/08	Changes to river names	JAK	UB	TM
2	30/10/08	Updated client logo	JAK	UB	TM

The options shown on this map are illustrative and may differ from the final set of options presented elsewhere. This does not affect the conclusions of the study which uses generic options as the basis for its conclusions.

THIS DRAWING WAS PRODUCED USING ARCGIS AND SHOULD ON NO ACCOUNT BE AMENDED BY HAND

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CLIENT/PROJECT
Department of Energy and Climate Change
SEVERN ESTUARY TIDAL POWER

TITLE
Figure 1: Location Plan

DATE	30/10/08	DRAWN BY	JAK
SCALE	NTS	PRODUCED BY	JAK
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		APPROVED BY	TM

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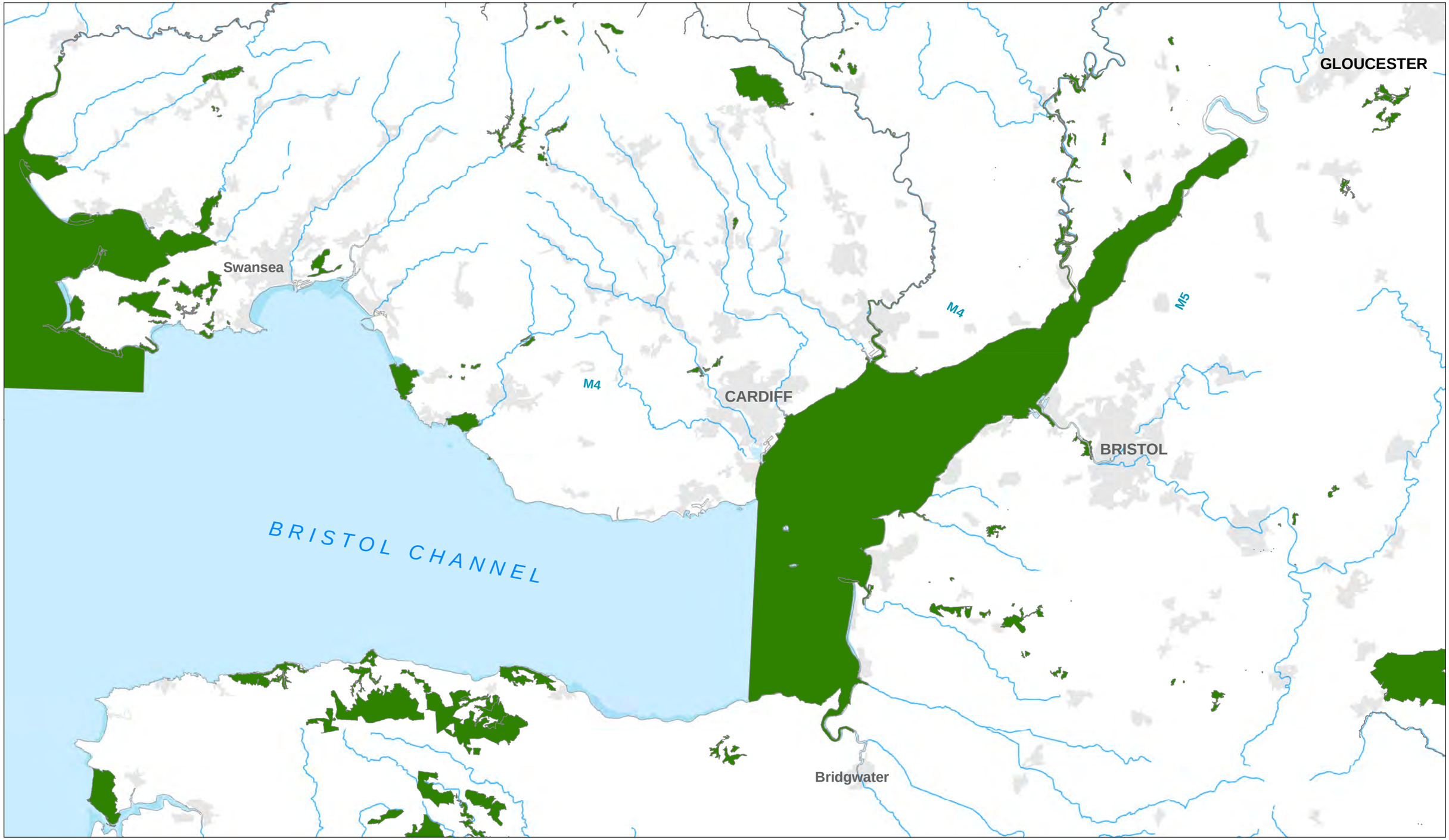

Rev	Date	Description	By	Chkd	Appd
1	20/10/08	Change to client logo	JAK	TC	TM

Legend

Special Areas of Conservation

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CLIENT/PROJECT

Department of Energy and Climate Change

Severn Estuary Tidal Power

TITLE

Figure 2: Special Areas of Conservation and Candidate Special Areas of Conservation

DATE	29/10/2008	DRAWN BY	ROS
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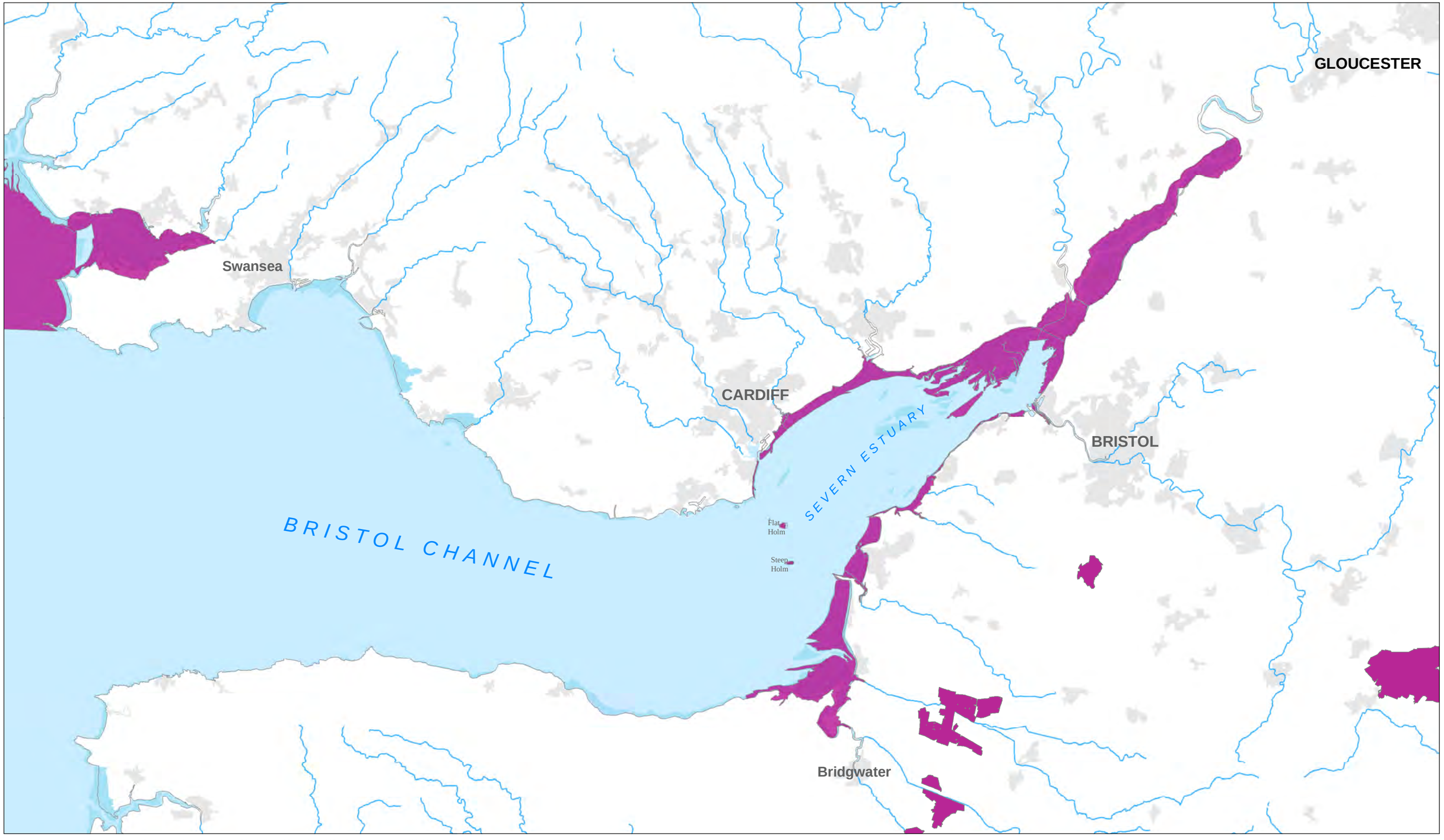
GIS REF		CHECKED BY	JAK
		APPROVED BY	TM

DRAWING NUMBER

121320-PDF-0020



Rev	Date	Description	By	Chkd	Appd
1	06/10/08	Minor edits to SPA coverage	JAK	TC	TM
2	20/10/08	Change to client logo	JAK	TC	TM

Legend

Special Protection Areas (SPA)

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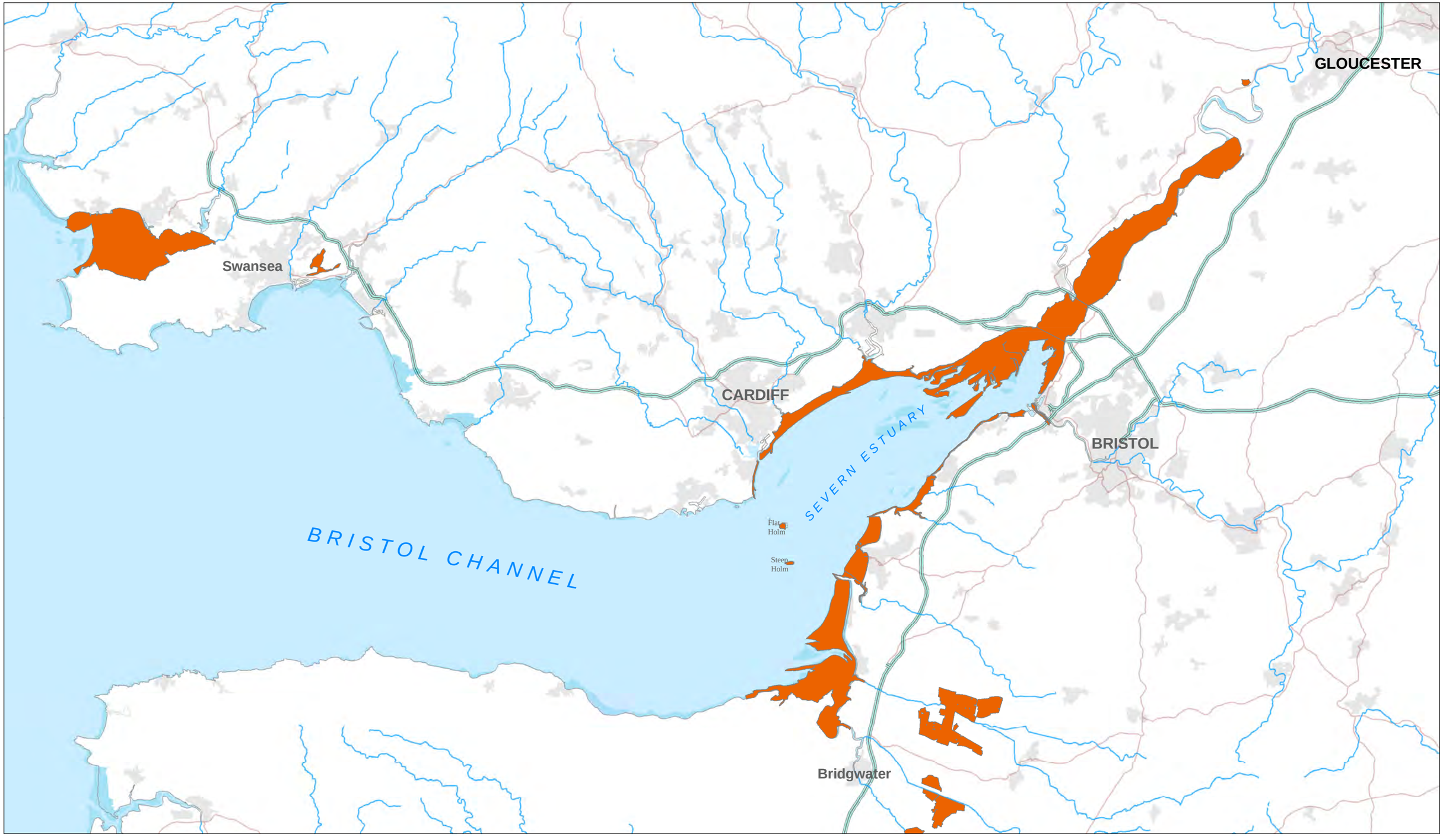
CLIENT/PROJECT
Department of Energy and Climate Change
Severn Estuary Tidal Power

TITLE
Figure 3: Special Protection Areas

DATE	28/10/2008	DRAWN BY	ROS
SCALE	NTS	PRODUCED BY	JAK
GIS REF		CHECKED BY	JAK
		APPROVED BY	TM

DRAWING NUMBER
121320-PDF-0021



Rev	Date	Description	By	Chkd	Appd
1	20/10/08	Change to client logo	JAK	TC	TM

Legend

Ramsar Sites

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CLIENT/PROJECT

Department of Energy and Climate Change

Severn Estuary Tidal Power

TITLE

Figure 4: Ramsar Sites

DATE	28/10/2008	DRAWN BY	ROS
SCALE	NTS	PRODUCED BY	JAK
GIS REF		CHECKED BY	UB
		APPROVED BY	TM

DRAWING NUMBER

121320-PDF-0022

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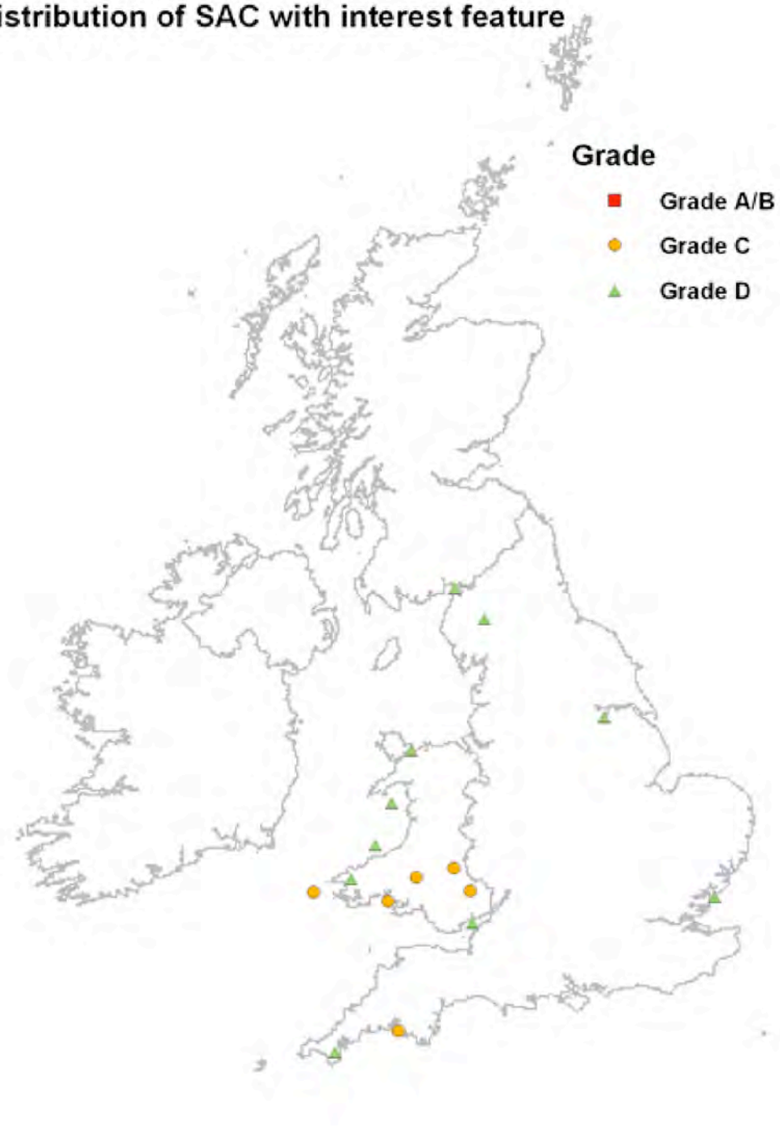
UK Distribution

(based on NBN records)

Distribution of SAC with interest feature



Explanation of grades

A Outstanding examples of the feature in a European context.

B Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

C Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

D Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Distribution of SACs/SCIs/cSACs containing species 1102 Alosa alosa

Rev	Date	Description	By	Chkd	Appd

Data Sources:
Joint Nature Conservation Committee (JNCC)

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CLIENT/PROJECT

Department of Energy and Climate Change

SEVERN ESTUARY TIDAL POWER

TITLE

Distribution of Allis Shad in UK rivers and SACs supporting the feature

DATE	15/08/08	DRAWN BY	PAR
SCALE	Scale @ A3	PRODUCED BY	JAK
		CHECKED BY	JAK
GIS REF	Fig_ABPmer_Allis_Shad	APPROVED BY	TM

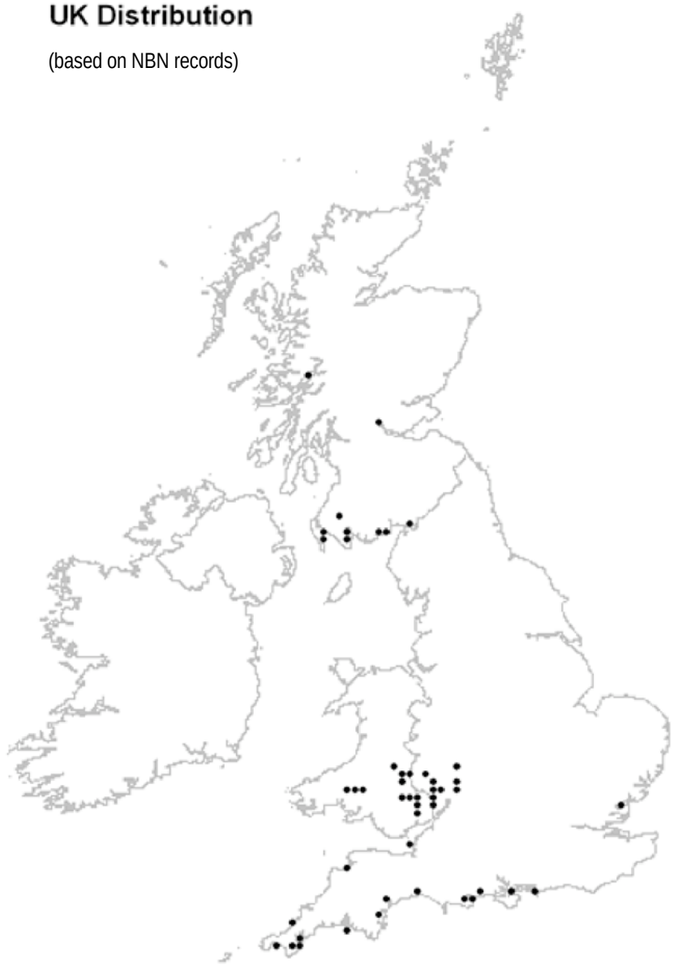
DRAWING NUMBER

121320-PDF-0017

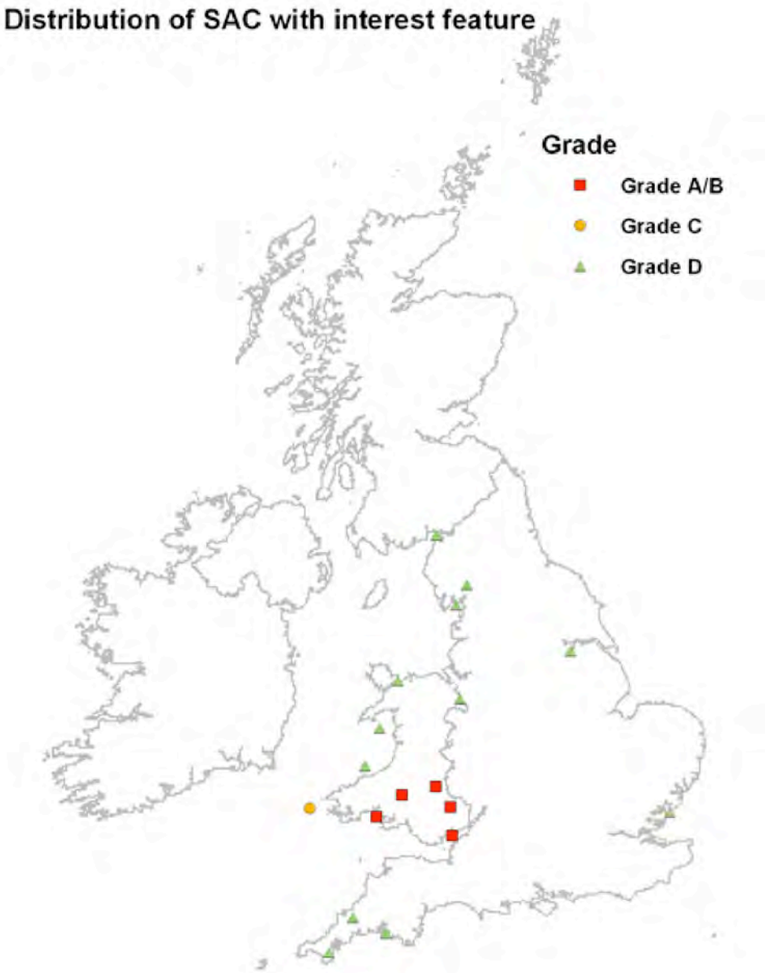
Figure 5

UK Distribution

(based on NBN records)



Distribution of SAC with interest feature



Distribution of SACs/SCIs/cSACs containing species 1103 Alosa fallax.

Explanation of grades
A Outstanding examples of the feature in a European context.

B Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

C Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

D Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Rev	Date	Description	By	Chkd	Appd

Data Sources:
Joint Nature Conservation Committee (JNCC)

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CLIENT/PROJECT
Department of Energy and Climate Change
SEVERN ESTUARY TIDAL POWER

TITLE
Distribution of Twaite Shad in UK rivers and SACs supporting the feature

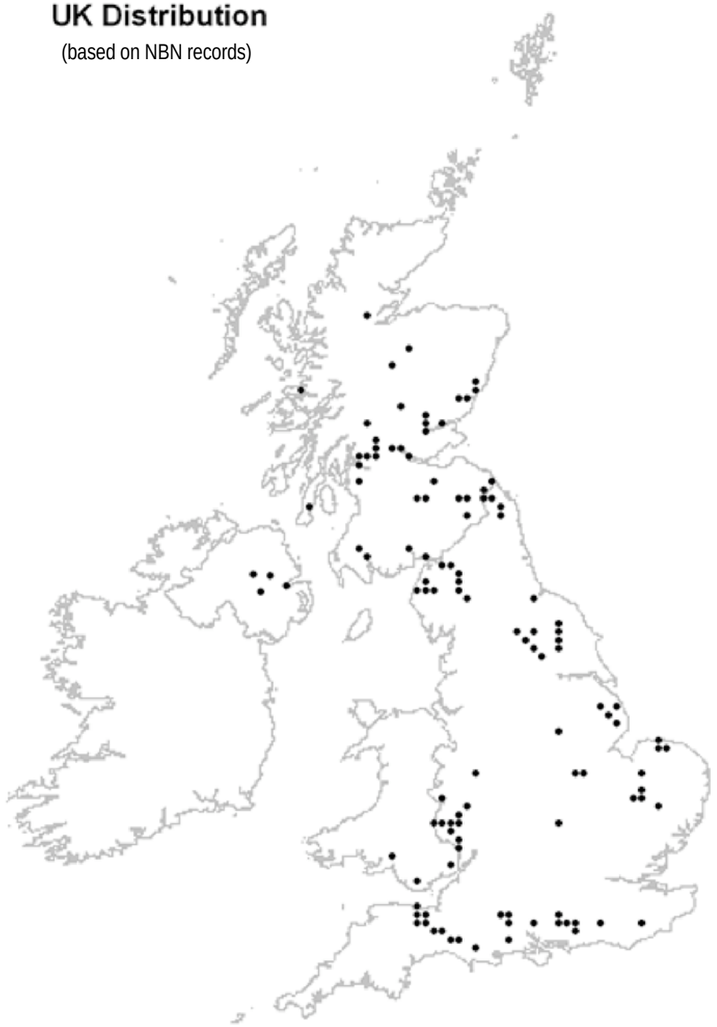
DATE	15/08/08	DRAWN BY	PAR
SCALE	Scale @ A3	PRODUCED BY	JAK
		CHECKED BY	JAK
GIS REF	ABPmer_Twaite_Shad	APPROVED BY	TM

DRAWING NUMBER
121320-PDF-0026

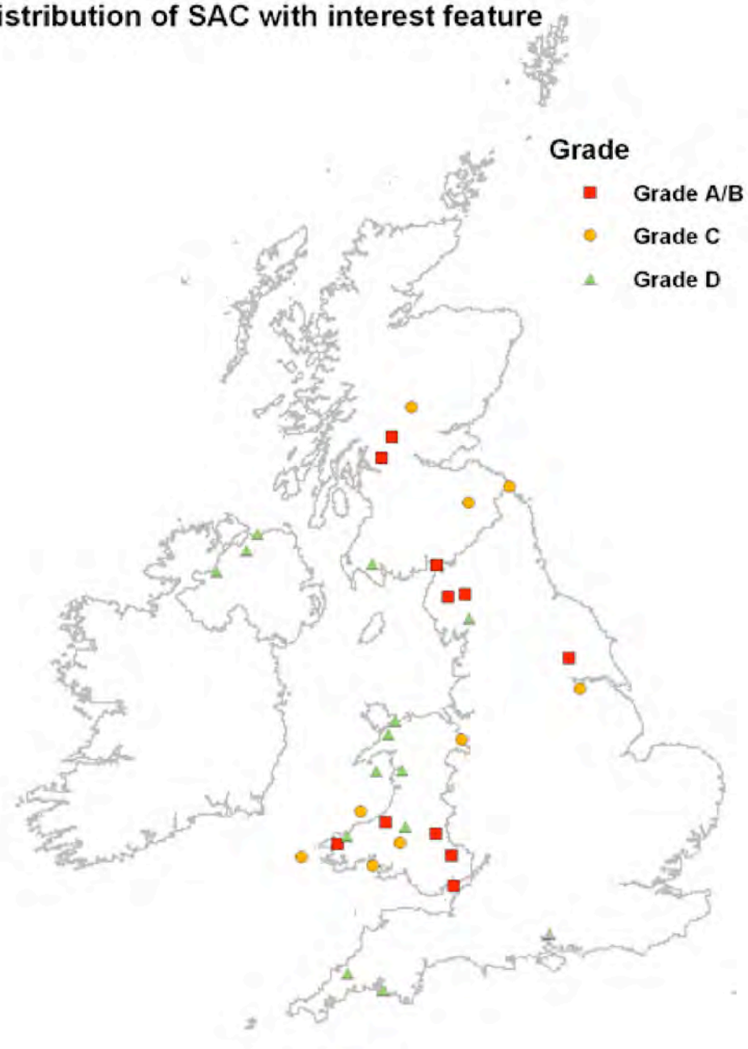
Figure 6

UK Distribution

(based on NBN records)



Distribution of SAC with interest feature



Distribution of SACs/SCIs/cSACs containing species 1099 Lampetra fluviatilis

Explanation of grades

A Outstanding examples of the feature in a European context.

B Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

C Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

D Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Rev	Date	Description	By	Chkd	Appd

Data Sources:
Joint Nature Conservation Committee (JNCC)

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CLIENT/PROJECT

Department of Energy and Climate Change

SEVERN ESTUARY TIDAL POWER

TITLE

Distribution of River Lamprey in UK rivers and SACs upporting the feature

DATE	15/08/08	DRAWN BY	PAR
SCALE	Scale @ A3	PRODUCED BY	JAK
		CHECKED BY	JAK
GIS REF	ABPmer_River_Lamprey	APPROVED BY	TM

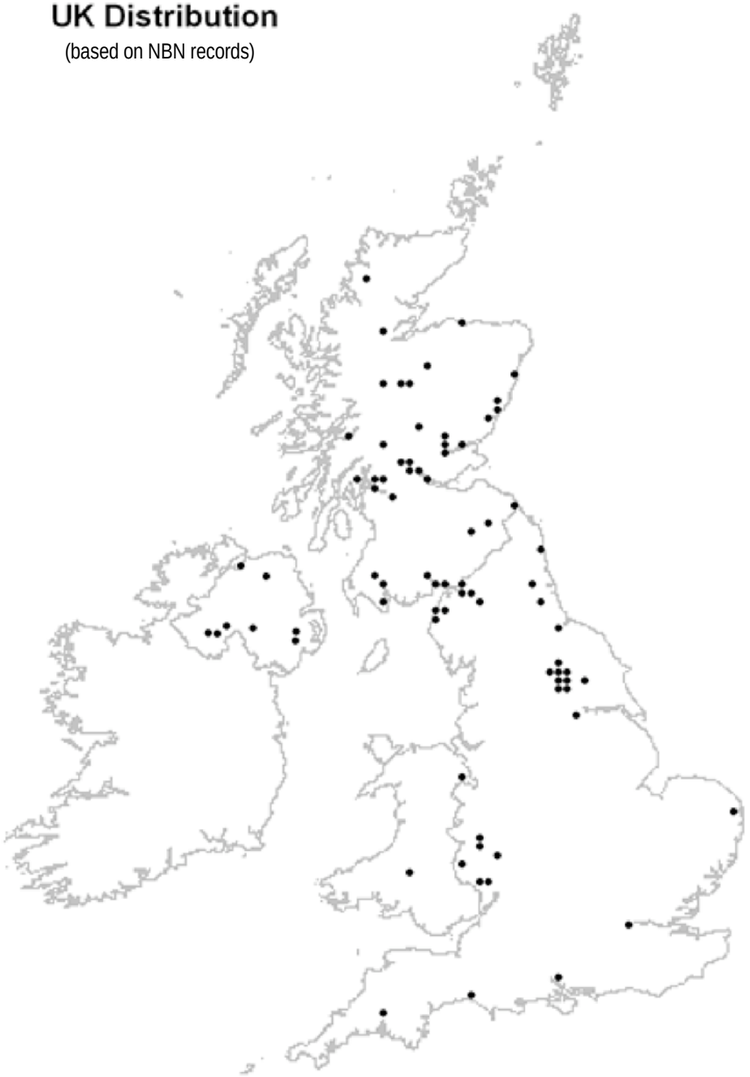
DRAWING NUMBER

121320-PDF-0015

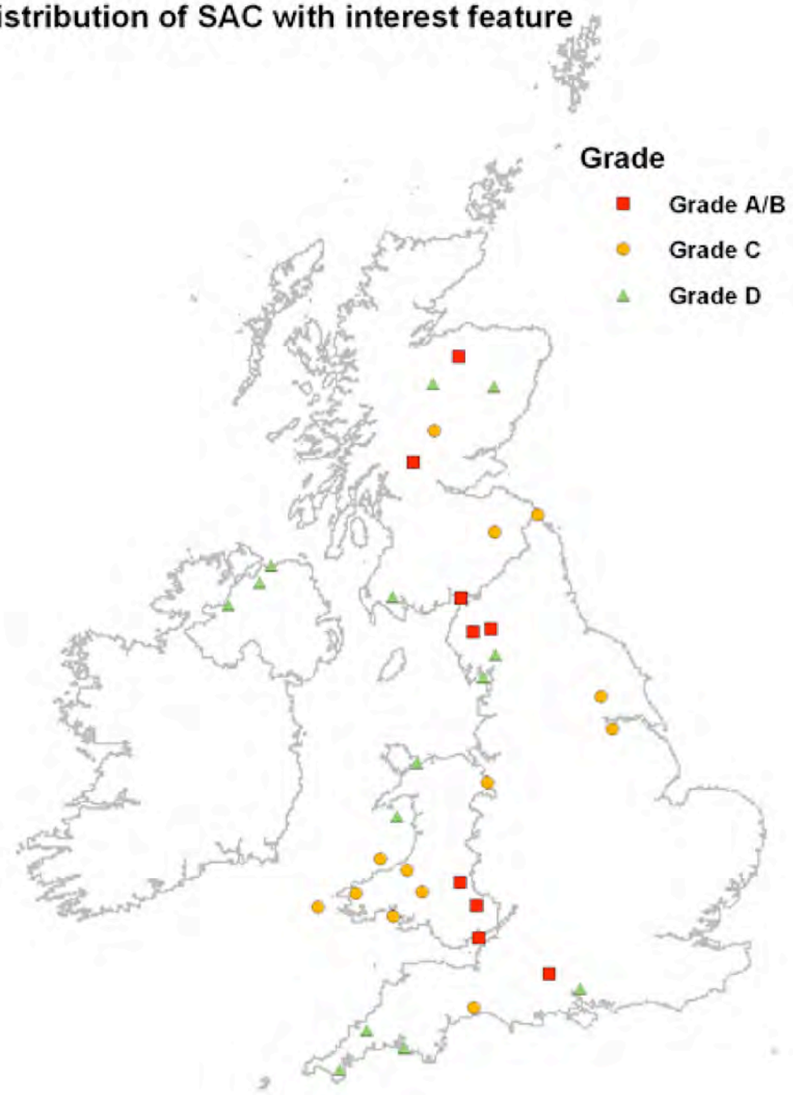
Figure 7

UK Distribution

(based on NBN records)



Distribution of SAC with interest feature



Distribution of SACs/SCIs/cSACs containing species 1095 Petromyzon marinus

Explanation of grades
A Outstanding examples of the feature in a European context.

B Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

C Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

D Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Rev	Date	Description	By	Chkd	Appd

Data Sources:
Joint Nature Conservation Committee (JNCC)

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CLIENT/PROJECT

Department of Energy and Climate Change

SEVERN ESTUARY TIDAL POWER

TITLE

Distribution of Sea Lamprey in UK rivers and SACs supporting the feature

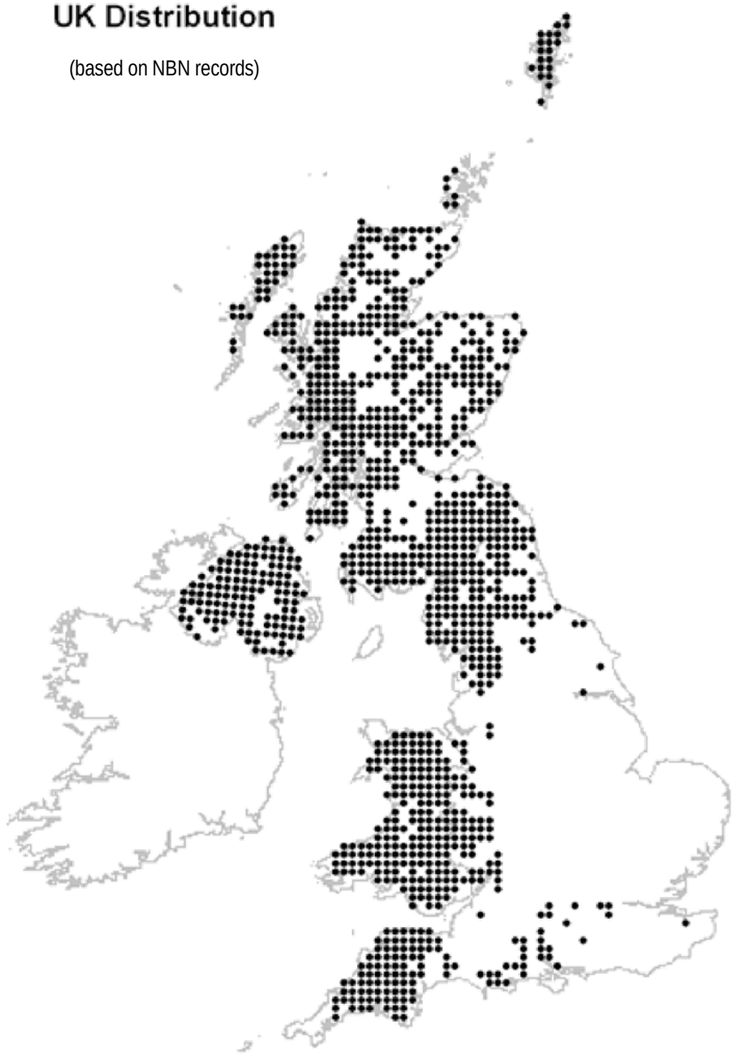
DATE	15/08/08	DRAWN BY	PAR
SCALE	Scale @ A3	PRODUCED BY	JAK
		CHECKED BY	JAK
GIS REF	ABPmer_Sea_Lamprey	APPROVED BY	TM

DRAWING NUMBER
121320-PDF-0018

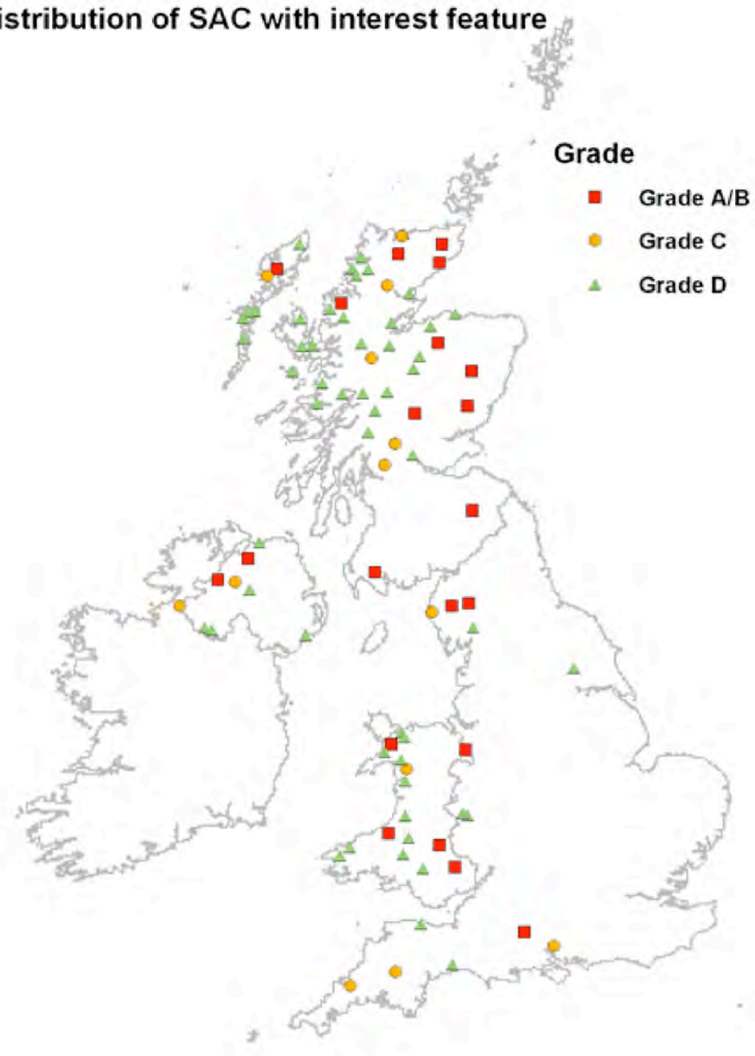
Figure 8

UK Distribution

(based on NBN records)



Distribution of SAC with interest feature



Distribution of SACs/SCIs/cSACs containing species 1106 Salmo salar

Explanation of grades
A Outstanding examples of the feature in a European context.

B Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

C Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

D Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

Rev	Date	Description	By	Chkd	Appd

Data Sources:
Joint Nature Conservation Committee (JNCC)

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CLIENT/PROJECT
Department of Energy and Climate Change
SEVERN ESTUARY TIDAL POWER

TITLE
Distribution of Atlantic Salmon in UK rivers and SACs supporting the feature

DATE	15/08/08	DRAWN BY	PAR
SCALE	Scale @ A3	PRODUCED BY	JAK
		CHECKED BY	JAK
GIS REF	ABPmer_Atlantic_Salmon	APPROVED BY	TM

DRAWING NUMBER
121320-PDF-0019

Figure 9