DECC

SEVERN TIDAL POWER - SEA TOPIC PAPER

Migratory and Estuarine Fish

May 2010

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ABBREVIATIONS

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The following abbreviations are used in this Topic Report:

AFD	Acoustic Fish Deterrent
AONB	Areas of Outstanding Natural Beauty
BTO	British Trust for Ornithology
B & V	Black and Vetch Limited
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CCW	Countryside Council for Wales
CFD	Computational Fluid Dynamics
CHaMP	Coastal Habitat Management Plan
COEUR	Comité Operationnél des élus et Usagers de la Rance
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EDF	Electricité de France
EIA	Environmental Impact Assessment
EC	European Commission
EMP	Eel Management Plan
EU	European Union
EUFG	Estuarine use functional group
GLFC	Great Lakes Fishery Commission
Ha	Hectare(s)
HRA	Habitats Regulations Assessment
ICE	Institution of Civil Engineers
ICES	International Council for the Exploration of the Sea
IUCN	International Union for Conservation of Nature
JNCC	Joint Nature Conservation Committee
MCMC	Markov Chain Monte Carlo
MFA	Marine and Fisheries Agency
MSW	Multi-sea-winter
1SW	1-sea-winter
MW	Megawatt
NAO	North Atlantic Oscillation
NE	Natural England
ODPM	Office of the Deputy Prime Minister
PPP	The Policy; Plan and Programme Review
RBD	River Basin District
RTE	Regulated Tidal Exchange
SAC	Special Area of Conservation
SAD	Stable age structure
SAP	Salmon Action Plan
SAFFA	Salmon and Freshwater Fisheries Act
SD	Standard deviation
SDC	Sustainable Development Commission
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
SWRDA	South West Regional Development Agency
TWh	Terrawatt hours
UK BAP	United Kingdom Biodiversity Action Plan
UKCP	United Kingdom Climate Impacts Programme
UK	United Kingdom

UN	United Nations
USA	United States of America
WAG	Welsh Assembly Government
WFD	Water Framework Directive
WWTW	Waste water treatment works

NON TECHNICAL SUMMARY

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Introduction

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

This document represents the topic paper for migratory and estuarine fish and contains a summary of the SEA STP assessment. This paper is supported by 8 technical annexes covering the detailed technical information required to inform the assessment of alternative option effects. These annexes are intended to be read alongside this paper for the full technical assessment to be presented.

Consultation

The following consultation activities have been undertaken:

- Scoping consultation in January 2009
- Technical Workshops held in June 2009 and November 2009
- Teleconferences in September 2009 and November 2009: discussion with stakeholders and technical experts with regard to turbines, life cycle modelling, fisheries economic assessment and telemetry and tracking technologies.

Assumptions, limitations and uncertainties

There are a number of data and knowledge gaps which have complicated the assessment of STP alternative options with respect to migratory and estuarine fish which should be noted by any reviewer of this topic paper and the technical annexes. The effects of a tidal power project of this scale upon migratory and estuarine fish has not previously been assessed in the UK or Worldwide and as such much of the assessment is unprecedented. Furthermore, there are a number of knowledge gaps regarding the existing baseline of the Estuary including in particular estimates of the size of the fish receptor populations and their behaviour within the Estuary. In addition to the limitations within the assessment of effects, identified prevent/reduce and offsetting measures have not been undertaken on the scale likely to be required for an STP plan alternative before and/or are not established practices/techniques within the hostile environment of the Severn Estuary. These limitations have necessitated an expert judgement / assumptions based approach with associated uncertainty. The assumptions, limitations and uncertainty within this assessment have been identified throughout this topic paper and the technical annexes, alongside suggestions for further investigations to reduce uncertainty where possible.

SEA Objectives

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

- To avoid adverse effects on designated wildlife sites for fish of international and national importance
- To avoid adverse effects on the populations of other protected fish species and habitats

- To avoid adverse effects on national and local biodiversity target features that include fish habitats and species
- To avoid adverse effects on recreational and migratory commercial fishing
- To avoid adverse effects on commercial fish resources
- To minimise the risk of introduction of non-native invasive fish species.

Baseline Environment

Baseline information provides the basis for predicting and monitoring environmental effects, by describing the receptors that may be affected. Due to the long timescales associated with the construction and operation of alternative options, baseline information is considered over three time periods, to reflect the predicted changes in the area when considered without the development of a Severn Tidal Power project. The baseline therefore also describes the Estuary in a 'do-nothing' scenario.

Over 100 fish species have been recorded within the Severn Estuary. All of these species represent the fish receptors included within the migratory and estuarine fish topic. The receptors include internationally designated species under the European Habitats Directive, priority UK BAP species and non-protected species. The STP assessment has been undertaken following an ecological guild approach with the following categories; diadromous species (split into the following species; Atlantic salmon (*Salmo salar*), sea trout (*Salmo trutta*), allis shad (*Alosa alosa*), twaite shad (*Alosa fallax*), river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromyzon marinus*), eel (*Anguilla anguilla*) and sturgeon (*Acipenser sturio*)), marine migrants, marine stragglers, estuarine residents and freshwater stragglers.

In light of the absence of estimates of population of the fish receptors within the Severn Estuary and its tributaries, life cycle modelling was undertaken for key migratory fish species as part of this study to estimate baseline scenarios and inform the assessment of effects. Due to the number of species under consideration and a general paucity of information, model development was restricted to the internationally protected species; Atlantic salmon, twaite shad, river lamprey, sea lamprey and eel. The life cycle models developed are novel and represent in the majority of cases the first attempts of their kind. The life cycle models developed have focused upon three baseline scenarios, current (up to 2009), directive case (2014- 2020) which considers improvements which could be expected within the populations as a result of directive targets and management plans and a climate change case (2020 – 2140) which incorporates potential population changes which may be experienced as a result of changing climate. Model outputs have been presented for each of the studied fish receptors. For those species for which life cycle modelling has not been undertaken, a qualitative assessment of baseline has been given.

Baseline environment up to 2009

Existing evidence suggests that the stocks of the internationally protected migratory species of Atlantic salmon, allis shad, twaite shad, river lamprey, sea lamprey and eel within the study area are typically in unfavourable condition. Salmon stocks are believed to be 50% down on the ten-year average. Spawning populations of allis shad and twaite shad are restricted in the UK with spawning populations of twaite shad now limited to only four rivers, all of which could potentially be affected by an STP development. During recent condition assessments of the UK populations, river lamprey were classed as in favourable condition only in the River Usk while sea lamprey were in favourable condition only in the River Wye. European eel is believed to be beyond safe biological limits throughout Europe, and the upper reaches of the Severn and Avon catchments are believed to be below carrying capacity. Sea trout are less abundant than salmon in the Severn Estuary tributaries and since 1965 catches of the species have been low. While there are no formal UK records of sturgeon breeding in UK waters, there are historical records of individuals in the Severn Estuary and tributaries. With regard to the guilds of marine migrants, marine stragglers, estuarine species and freshwater stragglers, current baseline conditions are largely unknown.

Future baseline during construction: 2014-2020

Receptor A: Atlantic salmon. A continued minor reduction over the next five years is predicted in the River Wye salmon stocks. The Conservation Limit for the River Usk has been achieved during the last 10 years. The River Severn has achieved its Conservation Limit in 6 of the last 10 years. At base case conditions the egg depositions for the Severn, Wye, Usk and Taff/Ely were 16.1, 24.5, 19.5 and 0.9 million eggs respectively. Under Directive conditions the egg depositions rose to 16.6, 39.6, 19.5 and 3.4 million eggs respectively. Stocks of migratory fish in the South Wales coalfield rivers (Ely, Ebbw, Taff and Rhymney) are currently small in comparison to the other Severn Estuary tributaries. Stocks have however, begun to recover over the last 30 years and are likely to improve further into the future.

Receptor B: shad. The predicted twaite shad population is in the region of 184,000 adult individuals split between the Rivers Severn, Wye, Usk and Tywi, although the population size in a given year may range between 112,000 and 596,000 adult individuals. The model suggests that the River supporting the greatest proportion of the population is the Wye (~92,000 adult individuals) followed by the Usk and Severn (~37,000 adult individuals per river) and then the Tywi (~18,000 adult individuals). It was not possible to develop a Directive case model for twaite shad due to a paucity of robust empirical data.

Receptor C: river and sea lamprey. The base case model for river lamprey has predicted population estimates for the River Usk of approximately 22 million ammocoetes, 3.5 million transformers and 28,000 adults whereas for the Wye estimates are approximately 71 million ammocoetes, 11 million transformers and 88,000 adults. The estimated sea lamprey population are smaller on both Rivers with approximately 14 million ammocoetes, 2 million transformers and 3,000 adults on the Usk and 57 million ammocoetes, 9 million transformers and 12,000 adults on the Wye. Based upon the ammocoete densities used in the baseline model it is considered that both river and sea lamprey populations are currently in favourable condition under the Habitats Directive, no Directive case modelling has therefore been undertaken.

Receptor D: eel. The silver eel biomass for the River Severn River Basin District has been estimated as approximately 57,000 Kg which equates to a yellow eel population of approximately 609,000 and silver eel population of in the region of 157,000 individuals. The River Severn is predicted to support the largest proportion of the population, followed by the Wye.

Receptor E: sea trout. Life cycle modelling was not possible to sea trout owing to the complexities and variability of their life cycle therefore predictions of the baseline during the construction period were not possible.

Receptor F: sturgeon. Although reintroductions of sturgeon are occurring within Europe no plan to introduce the species is currently in existence within the UK.

Receptors G to J: marine migrants, marine stragglers, estuarine residents and freshwater stragglers. Due to the vast number of species within these ecological guilds in the Severn Estuary and a general paucity of information regarding their stocks it was not possible to predict any changes to the baseline conditions which may occur during the 6 year construction period.

Future baseline during operation 2020-2140, decommissioning and longer term trends

Where possible issues regarding the potential effects of climate change upon the individual species model parameters and the overall populations have been incorporated into the life cycle models to aid estimates of the future baseline.

Receptor A: Atlantic salmon. Current knowledge of salmon population responses suggests that the effects of climate change are likely to result in an overall decrease of river carrying capacity and smolt production. Modelling indicated that should marine & freshwater survival decrease by 25%,

reproductive capacity would remain present only in the River Usk. Under the 4 modelled scenarios populations were predicted to reduce to between 7.37 and 0.05 million eggs on the Severn, 14.01 and 0.01 million on the Wye, 12.04 and 4.13 million on the Usk and 0.71 to 0 million on the Taff/Ely.

Receptor B: shad. Under modelled temperature increases of both 1 and 2°C shad were predicted to persist with increasing redundancy within the population as temperature increases. The stock replacement under the temperature increase scenarios suggests a surplus of between approximately 3.3 and 6.75 million eggs, corresponding to ~75,000 and 153,000 adult individuals.

Receptor C: river and sea lamprey. A paucity of available data predicting the potential effects of climate change on life history parameters prevents a meaningful modification of the lamprey models to simulate the effects of climate change upon the river and sea lamprey populations. The only feasible option was therefore identified as altering the amount of available nursery habitat within the rivers which effectively results in a halving or doubling of the populations.

Receptor D: eel. Climate change was simulated within the eel models by manipulating the rate of growth in eel based on predictions that rising temperatures would result in increasing growth rates. Under this scenario the silver eel biomass within the Severn River Basin District is predicted to increase to approximately 198,000 Kg.

Receptor E: sea trout. Trout are predicted to show increasingly poor growth rates under all climate change scenarios. Later maturity due to adverse freshwater conditions may aid the marine migration, although the feeding and growth opportunities in the marine environment may require tradeoffs in terms of lifetime fitness.

Receptor F: sturgeon. There is no current plan to reintroduce this species to the UK.

Receptor G: marine migrants. Increasing water temperature could adversely affect some species (e.g. sea snail) at the limit of their warm water tolerances. In contrast both bass and sole could benefit from an increase in water temperature which is linked with enhanced recruitment. Increases in inshore water temperature in combination with a decrease in salinity have been linked with increases in fish species richness.

Receptor H: marine stragglers. Increases in water temperature could affect the distribution of small-eyed ray, which is close to its northern limit in the Severn Estuary, and Norway pout and dab which are close to their southern limit. Any species at its northern limit in the Severn Estuary should benefit from climate change with positive effects predicted. In addition, species usually found at locations further south may be able to penetrate northwards. Dab growth decreases with increasing water temperature and therefore increasing water temperature could lead to a decrease in this species, while other species such as conger eel and red mullet could extend their range.

Receptor I: estuarine species. Increased rainfall could lead to decreased salinity which could affect the distribution of these species, particularly the less euryhaline species which may move seaward if salinity penetration decreases to maintain an isotonic state.

Receptor J: freshwater stragglers. Decreased salinity could aid penetration of these species seawards. Changes in growth and distribution would be expected as a result of increased water temperature and decreased salinity.

Key Environmental Issues and Problems

A number of protected species are currently failing to meet conservation objectives as described in numerous policies and plans such as Salmon Action Plans and Core Management Plans. For Atlantic salmon stocks in the Rivers Severn, Usk and Wye this is reportedly due to various factors (including poor water quality, barriers to migration, habitat degradation). Furthermore, a number of issues (such

as abstraction, barriers to migration, entrainment and poor water quality) are thought to be affecting designated features of the River Wye/ Afon Gwy SAC and River Usk/ Afon Wysg SAC, including Atlantic salmon, shad and lamprey. Eel habitat is believed to have been lost throughout the Severn catchment, primarily through barriers to migration. Incorporation of Directive target compliance into baseline scenarios may be unrealistic for some of the migratory fish species as they may not reflect feasible future baselines if legislative requirements are not met in the near future.

Key assumptions, limitations and uncertainty in the development of baseline scenarios include uncertainties surrounding the life history parameters for the models used to predict future baseline values for salmon, shad, lamprey and eel. It was considered that data was so scarce, and life histories so poorly understood or that there were too many species within each of the ecological guilds that modelling was not an appropriate or feasible approach for sea trout or marine and estuarine species. Limited understanding of climate change upon species populations prevents confidence in the assessment of long-term baseline scenarios.

Evaluation of Plan Alternatives

Assessment Methodology

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

The topic specialist studies and methods used to assess options' effects were as follows:

- Desk-based research/literature reviews of potential effects.
- Stochastic numerical models of potential turbine passage individual mechanistic effects.
- Numerical modelling of potential compound mortality rates from turbine passage.
- HR Wallingford fish movement model to assist with the prediction of the risk of multiple passes through turbines.
- Qualitative expert judgement based assessments.

Alternative Options

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

Alternative	Location	Length (approx)	Operating mode	Turbine type	No. turbines	Annual energy output	Caissons	Locks
B3: Brean Down to Lavernock Point Barrage	Lavernock Point to Brean Down	16km	Ebb only	Bulb-Kapeller	216 (40MW)	15.1 to 17.0 TWh/year	129	2
B4: Shoots Barrage	West Pill to Severn Beach	7km	Ebb only	Bulb-Kapeller	30 (35MW)	2.7 to 2.9 TWh/year	46	1
B5: Beachley Barrage	Beachley to land directly to the east	2km	Ebb only	Straflo	50 (12.5MW)	1.4 to 1.6 TWh/year	31	1

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

Assessment of Likely Significant Effects on the Environment

Six effect pathways have been considered with regard to the fish receptors in relation to the likely significant effects of each alternative option; alterations to migratory cues, disruption to route of passage including turbine passage, habitat change and/or loss, changes to water quality and anthropogenic noise disruption. All significant effects would be considered likely to occur in the short and medium term during construction and decommissioning and in the long-term during operation.

Disruption to route of passage as a result of turbine passage was considered likely to result in a significant negative effect on all the fish receptors for all of the alternative options. Of all the effect pathways considered, it was only possible to quantify the effects associated with turbine passage. Incorporating these into life history models was possible for Atlantic salmon, twaite shad, sea lamprey, river lamprey, and eel (primarily due to a lack of data regarding the other species/fish guilds). This resulted in an estimate of likely minimum compound effects upon the populations of these species in the Rivers Severn, Wye and Usk.

It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

- Sea trout - It is considered that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.
- Allis shad - It is considered that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.
- Marine migrants - It is considered that there is potential risk of reductions in population size.
- Marine stragglers – It is considered that there is potential risk of reductions in population size.
- Estuarine residents - It is considered that there is potential risk of reductions in population size.
- Freshwater stragglers - It is considered that there is potential risk of reductions in population size.

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

- Atlantic salmon - It is considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.

- Twaite shad - It is considered that there is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify farfield effects there is potential for effects to be seen within the remaining UK population within the River Tywi. Were B3 to result in significant population reductions within this river as well as those encompassed by this plan alternative there is potential for whole UK stock extinction.
- Sea lamprey – The B3 plan alternative has the potential to result in reductions in the population size of sea lamprey within the Rivers Usk and Wye and the European stock.
- River lamprey – The B3 plan alternative has the potential to result in reductions in the population size of river lamprey within the Rivers Usk and Wye and the UK stock.
- Eel - There is potential for reductions in the outputs of silver eel from these rivers which could make compliance with the EU Eel Regulations and associated escapement targets a significant challenge.

Alternative Option B4: Shoots Barrage

- Atlantic salmon - It is considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.
- Twaite shad - It is predicted that there is potential for the extinction of the River Severn and Wye twaite shad populations with the B4 plan alternative. Furthermore, there is potential for reductions in the population size of the Rivers Usk and Tywi (from farfield effects) stocks. It is considered however, that on the basis of the predicted model outputs that populations although reduced in size would likely be retained within the Rivers Usk and Tywi.
- Sea lamprey – Predicted losses would represent a significant reduction in population size which with inclusion of additional effects for which it has not currently been possible to quantify could result in population collapse in particular on the River Wye and could reduce European stock size.
- River lamprey – Predicted losses represent a significant reduction in population size which with incorporation of all compound effects could potentially put the population at risk of collapse and reduce the UK stock size.
- Eel - It is considered that predicted reduced outputs for the Rivers Severn and Wye could represent population reductions and place compliance of the EU Eel Regulations at significant risk. Effects upon the outputs of the River Usk however, are considered unlikely to result in significant reductions in population size.

Alternative Option B5: Beachley Barrage

- Atlantic salmon - It is considered that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye, Severn and Usk.
- Twaite shad - The predicted effects associated with the B5 STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.
- Sea lamprey – It is considered that there is potential for population collapse of the sea lamprey populations of the Rivers Wye and Usk and reductions in the European stock size.
- River lamprey – There is the potential for collapse of the river lamprey population on the Rivers Wye and Usk for the B5 STP plan alternative and reductions in the UK stock size.
- Eel - It is considered that predicted reduced outputs for the Rivers Severn and Wye could represent population reductions and place compliance of the EU Eel Regulations at risk. It

is not predicted that output from the River Usk would be reduced and as such there would be no non-compliance risk for this stock.

Alternative Option L2: Welsh Grounds Lagoon

- Atlantic salmon - It is considered that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye, Severn and Usk.
- Twaite shad - The predicted effects associated with the L2 STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.
- Sea lamprey – It is considered that there is potential for collapse of the sea lamprey population on the River Usk, a significant reduction in population size on the Wye for the B5 STP plan alternative and reductions in European stock size.
- River lamprey – The losses predicted from the river lamprey population would represent a significant reduction in the River Usk and Wye population size and a reduction in the UK stock size.
- Eel - It is considered that predicted reduced outputs for the Rivers Severn Wye and Usk could represent population reductions and place compliance of the EU Eel Regulations at risk.

Alternative Option L3d: Bridgwater Bay Lagoon

- Atlantic salmon - It is considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye and Severn and to a lesser extent the Usk.
- Twaite shad - The predicted effects associated with the L3d STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.
- Sea lamprey – It is considered that these losses would represent reductions in sea lamprey population size for both the Rivers Wye and Usk and the European population.
- River lamprey – It is considered that these losses would represent reductions in river lamprey population size for both the River Wye and Usk and the UK population.
- Eel - Although representing a reduction to the population size of this species with potential implications for compliance of the EU Eel Regulations for the Severn RBD it is considered very unlikely that the effects associated with the L3d plan alternative would affect the status of the European eel stock.

Assumptions, Limitations and Uncertainty

Detailed discussions of the assumptions, limitations and uncertainty associated with the assessment of effects have been provided throughout this paper. It has been assumed that the Rivers Brue, Cary and Parrett are not significant rivers for the designated migratory species, with the exception of eel. It has been assumed that there is also potential for effects upon the stocks of the coalfield rivers which are likely to be similar to the effects predicted for the River Usk. There is limited information available regarding: the behaviour of fish within the Estuary; effects to fish populations following turbine passage; habitat utilisation by both fish species and their key prey species; the effects of key water quality parameters on fish populations; synergistic and/or cumulative effects of contaminants on fish or prey species; or data on peak hearing frequencies and hearing ranges for many fish species. The

assessment has been undertaken without specific knowledge of construction methods, and without baseline ambient noise data for the likely development sites.

Mitigation & Offsetting for Adverse Effects

Mitigation measures within this SEA are those measures that prevent or reduce as fully as possible any significant adverse effects. The mitigation measures identified to address likely significant effects within this topic are described below. Each of the identified measures may, in isolation, not be sufficient to fully prevent or reduce a given effect, however it is the cumulative effect of these measures (and potentially in combination with offsetting measures) which is important when assessing their potential to prevent or reduce any negative effects of the proposed development. It is considered likely however, that even in combination that prevent/reduce measures would not be fully effective and that residual effects could remain.

It should be noted that the unprecedented scale of measures likely to be required for an STP plan alternative and the fact that many of them are novel is likely to result in the uncertainty of their success being high in a number of cases. Due to a paucity of detail, scientific knowledge and precedent on the scale likely to be required, a number of expert judgement assumptions have been necessary during this assessment. There is however, no inference that such assumptions would represent the actual circumstance and it is strongly recommended that the investigations identified throughout this paper be undertaken to improve the confidence in efficacy estimates.

During option optimisation the measures considered to reduce adverse effects associated with fish passage past an STP alternative option centred upon:

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

Where possible these measures were incorporated into the alternative option outline designs which have been assessed within this paper. As demonstrated by the assessment of effects however, these measures would not completely reduce the adverse effects associated with development of an alternative option. Accordingly, further measures to prevent or reduce remaining adverse effects were considered. These included:

- Construction prevention and reduction measures:
  - Timing of works; noise effect to include prevention, reduction or discouragement of fish; reduction or prevention of sediment movement/resuspension; reduction or prevention of accidental release of pollutants.
- Operation prevention and reduction measures:
  - Operational regime; innovation and advancement in turbine design; noise minimisation; fish passage; fish exclusion and diversion; predator control; pheromone release; trap and transport, fish stocking and freshwater habitat enhancement.

It is considered that these measures may be only partially effective.

Of the prevent/reduce measures that have been considered, five have been recommended for inclusion within the suite of SEA measures to be taken forward for the majority of species. These

include construction measures to reduce the effects from noise and vibration and sediment disruption/displacement, alterations to the operating regime to increase permeability, improving fish passage through the redesign of sluices and controlling piscivorous bird predation.

Additional measures for salmon that cannot be recommended for inclusion this stage on the basis of available evidence, but should not be excluded from future STP assessments, include altering the timing of generation or creating generation cessation windows, incorporating fish bypasses into the plan alternative designs, including fish locks or lifts into the plan alternative designs and boosting populations through addressing factors limiting stocks within the freshwater environments. No additional measures have been recommended to be taken forward for Shad. A number of measures would require further consideration for eel, these include timing of generation / cessation of generation (seasonally and / or diurnally during peak migration periods), fish bypasses, inclusion of fish lifts and locks and addressing limiting factors in the freshwater environment. It is recommended that fish stock enhancement, which cannot be recommended for inclusion this stage on the basis of available evidence, should not be excluded from future STP assessments.

In addition to the five measures recommended for the migratory species, intertidal habitat enhancement/creation in the context of topographic modification only, has also been recommended for the marine and estuarine fish species. Incorporation of fish bypasses and lifts/locks to assist with fish passage past the structure are considered to offer some reduction potential for marine and estuarine species but on the basis of independent advice are not recommended for inclusion at this stage.

The potential effects to the migratory and estuarine fish topic from the measures to prevent or reduce effects proposed by other topics are summarised below.

- Operational management of barrage/lagoon regime. Various measures have been proposed. Of these, measures such as additional sluicing are considered likely to be complementary and would result in reduced adverse effects upon the fish receptors. Adaption to ebb and flow would be contradictory to the aims of the measures suggested in this topic and would result in negative effects upon the fish receptors.
- Topographic modification, inclusion of locks, installation of training walls, increasing water exchange through the structure, reconfiguration of Hinkley Point intakes and outfalls, timing of construction to avoid other large construction projects, and minimising lighting would all be considered likely to be complementary and to result in reduced adverse effects upon the fish receptors.
- Dredging is considered likely to be contradictory to the aims of the measures suggested in this topic and could result in negative effects upon the fish receptors.

Offsetting measures within this SEA are those measures that make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA ‘compensation’, a subset of offsetting is only used in relation to those measures needed under the Habitats Directive.

It is possible that when combined the proposed measures to prevent or reduce the effects of an STP option may only be partially effective. As such, offsetting methods, as identified below may be required. The identified offsetting measures within the migratory and estuarine fish topic paper (that may also qualify as compensation measures under the Habitats Directive as they concern SAC features) are:

- Operation offsetting measures:
  - Fish stocking and translocation;
  - Intertidal habitat enhancement/creation;
  - Addressing limiting factors in the freshwater environment;
  - Fisheries buyout;
  - Pheromone release.

The following potential compensation measure under the Habitats Directive was also considered:

- Additional sites for inclusion in the SAC list.

For further information on the possibility of additional Severn Estuary/Môr Hafren SAC site designations, reference should be made to the study to inform the Habitats Regulations Assessment within the STP Feasibility Study.

Freshwater habitat enhancement/creation is recommended for inclusion as an SEA STP offsetting measure for salmon, eel, river lamprey, sea lamprey, twaite and allis shad. Whether these measures to be additional to other planned conservation measures however, would need to be carefully considered. Fisheries buyouts are recommended for inclusion as an STP offsetting measure for salmon, eel, marine stragglers and marine migrants. Intertidal habitat enhancement and creation is recommended for eel, marine stragglers, marine migrants and estuarine residents and should be given further consideration for twaite and allis shad. Further consideration of stocking (and translocation) is recommended in the case of salmon and twaite/allis shad. This measure would require a further feasibility study and would likely require ongoing intervention. The notification of additional SAC sites is not recommended at this stage but should not be excluded from further consideration for salmon, twaite/allis shad and lamprey. No STP offsetting measures are considered appropriate for freshwater stragglers. Pheromone release has not been recommended for inclusion in the suite of SEA offsetting measures for any of the fish receptors under consideration.

The potential effects to the migratory and estuarine fish topic from the offsetting measures proposed by other topics are summarised below.

- Regulated tidal exchange (RTE) as proposed by the marine ecology topic. Effectively this is another form of intertidal habitat creation, discussed above. Such measures that would maintain important estuarine habitat are considered likely to be complementary and result in reduced adverse effects upon the fish receptors.
- Controls of inputs of contaminants from other sources in the Estuary. Measures to maintain or improve water quality within the Estuary are considered likely to result in reduced adverse effects upon the fish receptors.

Assessment against SEA Objectives

This topic paper includes a full assessment of how each alternative option performs against each SEA Objective.

In summary:

With regard to SEA Objective 1 (to avoid adverse effects on designated wildlife sites for fish or national and international importance) there is a risk that all of the alternative options could fail to meet this objective, primarily due to major negative effects associated with alteration to migratory cues, disruptions to route of passage and anthropogenic noise disturbance.

With regard to SEA Objective 2 (to avoid adverse effects on the populations of other protected fish species and habitats) there would be a risk that all of the alternative options could fail to meet this objective, for the same reasons as for SEA Objective 1.

With regard to SEA Objective 3 (to avoid adverse effects on national and local biodiversity target features that include fish habitats and species) there would be a risk that all of the alternative options could fail to meet this objective. This would primarily be due to major negative effects associated with disruptions to route of passage and anthropogenic noise disturbance. The alternative options B3, B4, B5 and L2 also had the potential for negative effects associated with changes to water quality.

With regard to SEA Objective 4 (to avoid adverse effects on recreational and heritage fishing) there would be a risk that all of the alternative options could fail to meet this objective due to major negative effects on recreational fishing (particularly salmonid). It is considered likely that the level of significance of a negative effect for the L3d alternative option would be less, with a minor negative effect predicted.

With regard to SEA Objective 5 (to avoid adverse effects on commercial fish resources) there would be a risk that all of the alternative options could fail to meet this objective. This is due to major negative effects being associated with options B3, B4, B5 and L2 and minor negative effects associated with the L3d alternative option.

With regard to SEA Objective 6 (to minimise the risk of introduction of non-native invasive fish) it is considered that this is not an issue in relation to the implementation of any of the alternative options and as such all of the plan alternatives would meet this objective.

Plan Implementation

Legislation and policy compliance

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

It is considered that all of the alternative options would be at risk of not complying with key EC directives including the Habitat Directive and the Water Framework Directive due to the potential for fish losses which could affect the sustainability or integrity of designated fish features. These alternative options are also considered to be at risk of not complying with international and national legislation regarding the free or safe passage, or escapement of fish. Conservation limit targets set within Salmon Action Plans would also likely not be met in the future. There is also the risk of non-compliance with the management and protection of marine, estuarine and migratory fish as set out in The UK Marine and Coastal Access Act. Additionally, the Wales Fishery Strategy may also be at risk of not being complied with due to negative effects associated with these options. With regard to the L3d alternative option, while the magnitude of effects associated with this option are frequently of a lower order than for the other alternatives, the potential for a major negative effect remains, particularly for rare species such as shad which have a very limited distribution.

Monitoring of significant environmental effects

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

<u>Measures recommended pre plan implementation to aid in assessment of effects and option development</u>

To underpin the more detailed assessment that would be required for implementation of an STP plan alternative, suggestions have been provided on the nature, type and frequency of monitoring that might be required. It should be noted that a significant monitoring programme would be required covering all receptors and for an extended period of time, at least five years pre-construction as a minimum.

Studies which could enhance the assessment of effects of an STP option which are recommended for consideration for any future phase of an STP SEA are summarised below:

- Development of estimates of baseline receptor populations

- Provision of detailed option design
- Study to investigate the response of key fish receptors to changes to water quality and the presentation of anthropogenic noise
- Study of the behaviour of migratory, estuarine and marine fish species within the Severn Estuary
- Valuation of the fisheries of the Severn Estuary and its tributary rivers
- Determination of detailed turbine specifications
- Study of observation of fish passage through tidal turbines
- Study of turbine fluid dynamics
- Assessment of the applicability of experimental and laboratory fish injury/mortality data
- Assessment of risk of multiple passage through turbines
- Study of effects of turbine passage
- Efficacy of operational and management refinement
- Fish passage feasibility study
- Feasibility of proven measures
- Efficacy of novel techniques.

Measures recommended post implementation to monitor potential effects

The outline measures that have emerged during scoping and feasibility are:

- Monitoring of migratory and estuarine fish population pre and post construction. The pre-construction monitoring period should be for five years as a minimum.
- Continuation of historical monitoring where it is of sufficient detail to determine a significant change (e.g. condition assessment monitoring).
- Adoption of statistical tools such as Bohlin and power analysis to determine the appropriate number of sites to detect a level of change equivalent to a halving or a doubling of the population.
- Utilisation of power station entrainment monitoring for use within STP monitoring suite.
- Trials and monitoring programmes for measures to prevent, reduce or offset effects for which confidence is currently unknown to be implemented prior to STP implementation.

SECTION 1

INTRODUCTION

1 INTRODUCTION

1.1 Introduction

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

1.1.2 The Feasibility Study is split into two phases:

- Phase One: Examining the scope of work and analysis required to make an evidence-based decision on whether to support a tidal power project in the Severn and what potentially feasible schemes exist for converting this energy. Phase one ended with the publication of the consultation document in January 2009.

- Phase Two: Work on environmental, regional, economic, commercial, technical and regulatory issues to inform the study conclusions including whether any of the potential schemes are feasible.

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

1.1.4 In parallel to the Feasibility Study, the Severn Embryonic Technologies Scheme is helping developers of emerging technologies map their development path. They are not being assessed as part of this SEA currently, as they are not at the stage whereby they can be considered reasonable alternatives.

1.1.5 The scope of the SEA, published by the Government in January 2009 (DECC, 2009a) is based on the assessment of a defined set of issues within 'topic papers'. These papers will be aggregated into 'theme' papers to ensure that the interrelationships between effects are considered and understood – see Section 1.2. The topic and theme papers will provide supporting information to the Environmental Report that is needed to fulfil the requirements of the SEA Directive.

1.1.6 This is the migratory and estuarine fish topic paper within the biodiversity theme.

1.1.7 This document represents the topic paper for migratory and estuarine fish and contains a summary of the SEA STP assessment. This paper is supported by 8 technical annexes covering the detailed technical information required to inform the assessment of alternative option effects. These annexes are intended to be read alongside this paper for the full technical assessment to be presented.

1.1.8 The 8 technical annexes are as follows;

- Annex 1: Evaluation of plan alternatives
- Annex 2: Measures to prevent and/or reduce STP plan alternative effects
- Annex 3: Measures to offset STP plan alternative effects
- Annex 4: Migratory fish life cycle models
- Annex 5: Fish passage through tidal power turbines
- Annex 6: Review of the recreational and commercial fisheries of the Severn Estuary
- Annex 7: Fish behaviour and ecology
- Annex 8: Assessment of current telemetry technologies and fish tracking techniques

1.1.9 During the STP SEA scoping phase the following effects were identified as potentially representing significant issues to the migratory and estuarine fish species of the Severn Estuary:

- Alterations to migratory cues and their associated effects upon the migratory and estuarine fish populations.
- Disruptions to route of passage including turbine passage related effects.
- Effects upon migratory and estuarine fish populations with regards to changes in intertidal habitat availability and quality.
- Effects upon migratory and estuarine fish populations with regards to changes to water quality.
- Effects upon migratory and estuarine fish populations with regards to anthropogenic noise disturbance.
- Effects upon recreational and commercial fisheries.
- Wider indirect effects upon estuarine/marine and freshwater fish species.

1.1.10 The potential significant issues identified above represent the scope of assessment for this Topic Paper. All potential ecological effects upon migratory, estuarine, marine and freshwater fish species are covered within this Topic Paper. Potential effects upon other aspects of biodiversity including the wider marine and freshwater environments are included within separate Topic Paper's and will be summarised alongside potential effects upon the fish species within the Biodiversity Theme Topic Paper. Potential effects to recreational and commercial fisheries owners resulting from fish losses identified within this Topic assessment are discussed within this Paper however wider economic effects are discussed within the Communities Topic Paper.

1.1.11 A prioritised programme of studies to assist with the assessment of the above potential effects were identified during the STP SEA scoping phase and undertaken during this plan alternatives assessment phase to fully understand the potential risks to migratory and estuarine fish and aid the assessment of an STP project. Studies were prioritised towards informing the high-level decision-making entailed within the SEA and wider Feasibility Study; whilst still contributing to subsequent assessment of the potential effects and solutions for a specific STP option.

Turbine passage study: Injury and mortality sustained from passage through turbines were identified during Phase 1 as likely to have one of the greatest effects upon migratory fish populations. As such a review was undertaken to assist with the identification and assessment of potential effects resulting from passage through a tidal turbine. The information identified within this review has formed the basis for the determination of effects upon the fish receptors as a result of turbine passage. In addition to assisting with the assessment of potential effects from turbine passage this review has informed the identification and determination of feasibility of a number of measures to prevent/reduce effects including innovative and advanced turbine technologies and fish passage mechanisms. The outputs of this study are contained within Annex 5.

Valuation of the recreational and commercial fisheries of the Severn estuary and its tributary rivers: As part of the plan alternatives assessment of the Migratory and Estuarine Fish Topic the commercial and recreational fisheries within the Severn Estuary and its tributary rivers have been valued. The outputs of this study are contained within Annex 6.

Assessment of current telemetry technologies: A thorough review of current available telemetry technologies and their capabilities was undertaken to inform future field based work to determine the behaviour of fish within the Severn Estuary. The outputs of this study are contained within Annex 8.

Life cycle modelling: A requirement of the Phase 2 STP Migratory and Estuarine Fish Topic Paper was to assess the potential effects upon migratory and estuarine fish receptors resulting from each of the alternative options. To enable this assessment it was identified within Phase 1 of the STP study that life cycle models were required for the key designated fish receptors that could potentially be affected by an STP option. It was intended that life cycle models were developed within which turbine passage related mortality, and where possible other potential effects, could be integrated to assess STP relative effects and population losses. Life cycle models were developed to predict the baseline population scenarios within which effects could be integrated. The outputs of this study are contained within Annex 4.

Assessment of the effect of anthropogenic noise: It was identified within the Phase 1 SEA assessment that anthropogenic noise during construction, operation and decommissioning has the potential to affect estuarine and migratory fish receptors within the Severn Estuary. To inform the assessment a review was undertaken regarding the hearing thresholds and noise outputs of construction and operation activities and identified potential direct and indirect effects which may be experienced by each of the fish receptors. The outputs of this study are contained within Annex 1.

Studies to determine the feasibility, success and confidence of measures to prevent, reduce or offset STP plan alternative effects: The confidence surrounding the success of a number of measures proposed during Phase 1 were ranked as being unknown or low. This was primarily as a result of such measures

having not been undertaken before on this scale or the techniques being novel. As such within Phase 2, desk based investigations were undertaken to help determine the feasibility and potential of each identified measure.

An in depth assessment of the feasibility, confidence and likelihood of success of the prevent/reduce and offsetting measures identified during Phase 1 was undertaken. Additionally any new potential measures arising during the Phase 2 processes were discussed.

The following measures were discussed: construction measures to prevent or reduce adverse effects, operational regime, fish passageways, fish screening and deterrents, predator control, fisheries buyout, habitat enhancement and creation, fish transportation and herding, stocking and translocation, pheromone release and additional sites for inclusion in the SAC list. The outputs of this study are contained within Annexes 2 and 3.

1.1.12 The location of the Severn Estuary is shown in Figure 1.1.

1.2 Interfaces between topics and other work conducted within Feasibility Study

1.2.1 Each SEA topic paper sits within a theme of related topics – see Table 1.1 below. The theme papers reflect the many inter-relationships associated with the Severn estuarine system, and provide an additional tier of technical reporting to ensure that the many complex issues that are not self-contained within a given topic are recognised and their implications understood.

Table 1.1 SEA themes and topics

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

1.2.2 The SEA, and its supporting studies captured within each topic paper, comprise part of the Feasibility Study. Other relevant studies within the Feasibility Study but not contained within the SEA include supply chain, electricity grid connection, and ecosystem goods and services valuation studies.

1.3 Consultation

1.3.1 Both the Feasibility Study and the SEA within it have included a programme of formal and informal consultation activities. These include the public consultation exercise in early 2009, technical workshops during both Phase 1 and 2, and informal meetings and other communications. These are summarised for this topic below.

Scoping Consultation

1.3.2 In January 2009, Government launched a consultation on the conclusions of the first phase of the Feasibility Study (DECC, 2009a). The consultation included a recommended short-list of schemes for more detailed analysis, and provided the scope of the SEA. The Government's consultation response published in July 2009 confirmed the shortlist of alternative options, and the scope of the SEA (DECC, 2009b).

1.3.3 Comments on the Phase 1 Scoping Topic Paper for Migratory and Estuarine Fish were received from representatives from the Countryside Council for Wales (CCW), the Institution of Civil Engineers (ICE), the Environment Agency (EA), WAG, Natural England (NE) and Cefas. Most comments related to clarification or modification of text contained in the Phase 1 Report. An overview of the key outcomes of this consultation, and how they have been taken forward within the Phase 2 assessment are detailed below.

1.3.4 The EA commented that noise and vibration were not considered during Phase 1. Text was subsequently added to the Phase 1 report and this subject has been considered in detail during Phase 2.

1.3.5 Following comment from WAG and the EA, data from non-SAC rivers, including coalfield rivers, were considered during Phase 1. Upon identifying short-list options, the assessment of effects was made with regards to all potentially affected river systems, SAC and non-SAC.

1.3.6 The statutory authorities requested that the legal implications of the Eel Directive, particularly the 40% escapement target, should be included during the Phase 2 assessment, and this has been considered throughout.

1.3.7 The EA requested more consideration of the marine and estuarine species. Whilst it is simply not possible to consider all of the fish species individually at the SEA level, priority was given in Phase 2 to protected migratory fish species, although consideration was also given to the marine/estuarine fish species and the fish community as a whole. Assessment took the form of an ecological guild approach (marine migrants, marine stragglers, freshwater stragglers and estuarine species) to provide greater coverage.

Technical Workshops and Update Teleconference Calls

1.3.8 A series of 'Technical Workshops' and Update Teleconference Calls were convened during phase 1 and 2 of the Feasibility Study, principally to provide the opportunity for technical specialists across many organisations to input into the developing SEA. Table 1.2 below summarises the workshops and update teleconference calls held in support of this topic.

Table 1.2 SEA Technical workshops for migratory and estuarine fish SEA topic

Phase, date, workshop/update teleconference call	Workshop/Update Teleconference Call purpose
Phase 1, 8th July 2008, workshop	To undertake a preliminary scoping of the issues and assessment approach needed within phase 1 of the SEA.
Phase 2, 4th June 2009, workshop 1	To confirm the scope of SEA work planned in phase 2 and review key aspects of assessment methodology.
Phase 2, 4th September 2009, Update Teleconference Call 1	Update on progress to date and any key messages
Phase 2, 18th November 2009, Update Teleconference Call 2	Run-through of preliminary findings, determination of whether a technical workshop was required and discussion of what content should be included/provided in advance.
Phase 2, 26th November 2009, workshop 2	To review preliminary findings and approaches to identifying measures to prevent, reduce and as fully as possible offset significant environmental effects.

1.3.9 Overviews of the main outcomes from the Technical Workshops and Update Teleconference Calls are given below.

1.3.10 ***Phase 1:*** Technical Workshop attendees included representatives from APEM, B & V, CCW, Cefas, EA, Liverpool University, NE, University of the West of England, and Usk and Wye Foundation. Issues discussed included: the species to be considered, potential effects of an STP option, water quality, turbines, habitats, angling, measures to prevent or reduce adverse effects and compensation, and priorities.

1.3.11 The need to consider the economic value of the potential effect of an STP option in terms of the various fisheries (recreational, commercial and heritage) was raised. Further data collection and assessment regarding this issue was carried out during Phase 2.

1.3.12 ***Workplan meeting***: A meeting was held in September 2008 to further discuss the proposed workplan for the Phase 2 feasibility study. Discussions focused upon developing a priority list of desk and field based studies which were incorporated into the Phase 2 migratory and estuarine fish work plan.

1.3.13 ***Phase 2:*** Technical Workshop 1. Attendees to this workshop included representatives from APEM, B & V, the British Trust for Ornithology (BTO), Cardiff University, Cefas, CCW, DECC, EA, NE, Salmon and Trout Association, and WAG. The work plan and assessment methodology was discussed in detail with the attendees, and general agreement of the approaches reached.

1.3.14 More specific comments made by the workshop attendees in particular those regarding the scope of the assessment and the importance of legislative drivers have been considered throughout the Phase 2 process for this Topic.

1.3.15 ***Phase 2***: Update Teleconference 1. Due to the early stage in the assessment during which this teleconference call was undertaken a brief overview of the techniques and data sets being used were presented by APEM. Clarifications regarding specific aspects presented were sought by attendees.

1.3.16 ***Phase 2***: Update Teleconference 2. A brief overview of assessment techniques were presented followed by preliminary findings. Extensive discussions were held regarding turbine passage in particular the risk of multiple passes past the plan alternatives. Comments were taken on board and changes made to the modelling approach accordingly.

1.3.17 ***Phase 2***: Technical Workshop 2. Assessment techniques were briefly discussed followed by preliminary findings via a case study of the B4 option.

1.3.18 Numerous specific comments were made by the workshop attendees and discussions held in particular regarding the risk of multiple passes past each plan alternative, the behaviour of fish approaching and passing an option and the feasibility of prevent/reduce measures among others. Where appropriate these comments and discussions have been included within this Topic Paper and its technical Annexes.

Other Consultation

1.3.19 A number of other consultations with stakeholders and technical experts were held to discuss specific aspects of the Phase Two assessments.

Turbines – Early discussion and liaison with consortium engineers was undertaken during the optimisation process, building on expert advice to ensure inclusion of key fish effect minimisation design elements. In addition consultation took place with specialists and interested parties at a meeting held in April 2009. External attendees to this meeting were Dr David Solomon (independent consultant), Dr Andy Turnpenny (Jacobs) and three EA fish specialists.

Discussions were also held with the operators/engineers of specific installations employing similar turbine technologies and/or requiring fish protection measures for example La Rance and Annapolis Royal. Correspondence was established with relevant scientists and installation operatives both within Europe and North America. A site visit was made to the La Rance Tidal Power Project enabling discussions with EDF operation staff and COEUR scientists; the environmental researchers for the tidal power plant. Consultation was also undertaken with turbine manufacturers and those currently researching new technologies and modifications.

Life cycle modelling – Extensive meetings, teleconferences and email discussions were held with an EA fish specialist between June and September to discuss and agree on the specifics of the life cycle modelling, especially in relation to those developed for shad and eel. In addition, a meeting was held on the 28th July 2009 between APEM, two EA fish specialists and Ted Potter (Cefas). This meeting focussed on discussion of the specifics of the life cycle models developed for salmon, shad, eel and lamprey. The aim of the meeting was to discuss the values and approaches used in the models with relevant experts.

A further meeting regarding the salmon life cycle model was held with two EA fish specialists at the EA Buckley office on 28th September. Discussions included marine age-specific survival and maturation rates for use within the life cycle modelling.

Fisheries economic assessment - Email conversations were held with EA fish specialists to discuss information on fishing clubs and associated costs. Telephone conversations were also held with an EA fish specialist to discuss in general terms the economic value of salmon fisheries throughout the study area. The Shropshire Anglers Federation Chairman and a staff member at a tackle Shop, Prince Albert Angling Club and Worcester & District United Angling Association were contacted to

inform an assessment of the value of salmon fisheries on the River Severn. Six individual charter skippers operating within the Severn Estuary were contacted by telephone to provide financial details, including their annual economic turnover. The Marine and Fisheries Agency (MFA) was contacted by telephone and email to discuss small and large boat commercial marine fishing. The SW Sea Fisheries Committee was also contacted by email to provide general information regarding commercial marine fisheries within the study area. Email and telephone conversations were held with an EA Fisheries specialist regarding nursery habitats and general issues relating to policy and economics of fisheries within the Severn Estuary and Bristol Channel.

Assessment of telemetry technologies and tracking techniques - Email conversations were held with an EA fisheries specialist to discuss his experiences of tracking fish within the Lower Usk Estuary and Cardiff Bay (Severn Estuary). Email conversations and subsequent telephone conversations were also held with a number of major acoustic tag suppliers/manufacturers to determine tag vitals. Companies contacted included: Hydroacoustic Technology, Inc. (HTI), USA; LOTEK Wireless Inc., Canada; SONOTRONICS, USA and VEMCO Ltd., Canada. Personal communication during a Vemco Hydroacoustic Workshop (American Fisheries Society Annual Conference, 2008) also informed identification of environmental conditions that effect hydroacoustic technologies discussed within the report.

1.4 Assumptions, limitations and uncertainties

1.4.1 There are a number of data and knowledge gaps which have complicated the assessment of STP alternative options with respect to migratory and estuarine fish which should be noted by any reviewer of this topic paper and the technical annexes. Detailed below are summaries of the assumptions, limitations and uncertainties relevant to each of the sections of this topic paper, their potential implications for this assessment and suggestions for further study to address them where possible. Further information regarding the assumptions, limitations and uncertainties of each specific assessment approach and prevent/reduce or offsetting measure are contained within the individual sections within this paper and the relevant technical annex.

Baseline environment

1.4.2 There have historically been very few attempts to quantify population size for the majority of migratory, estuarine or marine fish species within the UK as a whole or more specifically the Severn Estuary and its tributary rivers. There is therefore no existing baseline from which to undertake the assessment of STP effects against. As part of this study, life cycle models have been developed for the key fish receptors concentrating upon the protected migratory species. Where life cycle models have not been possible however, it has been necessary to make qualitative expert judgement based assessments of the baseline populations of the fish receptors.

1.4.3 For the majority of species under consideration within the life cycle modelling there are no or extremely limited examples of life cycle models within the UK and worldwide. The models therefore represent unprecedented novel attempts to quantify populations of these species, with some such as lamprey and shad representing the first of their kind. Furthermore, life history parameters in particular river or estuary specific are extremely limited for the majority of species which has necessitated a largely site unspecific use of scientific literature based parameters during the model development. Wherever possible this information has been based upon species specific UK population data. There are however, instances where this has not been

possible and non-UK river or surrogate species information has been utilised with notes of appropriate caution. Where a paucity of information has been identified even within scientific literature, assumptions have been necessary. Where such assumptions have been required an expert judgement based approach has been used. It should be noted that there is no inference that these assumptions would represent the real situation but are necessary expert judgement based best estimates. On the provision of further information to fill the life history parameter knowledge gaps it is considered highly likely that these assumptions could change which could alter the findings detailed within this assessment. The estimates of population size determined within this modelling assessment should therefore be taken as indicative only.

1.4.4 Due to the limitations and gaps in knowledge for available life history parameter data a level of caution should be taken upon assessing the population estimate model outputs. Despite these inherent limitations however, the population estimates represent for the majority of species the first of their kind and best available estimates at present and are considered suitable at this stage for a relative assessment of STP plan alternative effects.

Evaluation of plan alternatives

1.4.5 There is extremely limited precedent for the assessment of a tidal power project both within the UK and worldwide. Although evidence exists for run-of-river hydropower schemes they are not on the scale of an STP plan alternative, consider a restricted species range (exclusive to freshwater and migratory fish species) and the conditions experienced are not directly comparable to an estuarine scheme.

1.4.6 Assessments have also been restricted in a number of cases by limited detail regarding for example specific construction activities and the period over which they would be implemented. Information from which to undertake the assessment of the effects of turbine passage and the assessment approaches themselves were limited or absent in a number of cases. Furthermore, where turbine injury/mortality modelling approaches exist they require detailed specifications which were not available for this feasibility stage. It has therefore been necessary to make a number of expert judgement based assumptions throughout the STP plan alternatives assessment. There is however, no inference that such assumptions would represent the actual circumstances and it is strongly recommended that the requirements for further study identified throughout technical annex 1 be undertaken to improve knowledge gaps and decrease the uncertainty associated with the assessments. On the collection of this information it is considered likely that the assumptions made could change and with them the assessment outputs. The assessment provided within this annex should therefore be considered as indicative only. A fundamental knowledge gap is the behaviour of the fish receptors within the Severn Estuary for which very little information is known precluding a fully informed assessment of effects.

1.4.7 It should be noted that a number of assessments within this topic are reliant upon each other as well as those made outwith the fish topic. There are varying levels of uncertainty associated with each individual assessment which are likely to be compounded resulting in cumulative uncertainty within the final assessment outputs.

1.4.8 For the majority of effect categories it has been possible to undertake qualitative assessments only. Where quantitative assessments have been possible they therefore only represent minimum estimates of effect. Quantitative assessments have been incorporated into the key species life cycle modelling to assist with predictions upon populations as a whole. To take into consideration those effects for which it has

not been possible to quantify the life cycle model outputs have been supplemented with qualitative expert judgement based assessments of the potential consequences of compound effects upon the fish receptor populations.

Prevent/reduce and offsetting measures

1.4.9 A number of the prevent/reduce and offsetting measures would undoubtedly be unprecedented at the scale likely to be required for an STP development and involve novel techniques. The potential application of the measures is therefore in the majority of cases likely to be limited and could offer only partial benefit. Although it has been noted for a number of the identified measures that they have potential to partially prevent/reduce STP plan alternative effects it should be emphasised that there is no indication that the combination of such measures could result in complete prevention of effects. It is not considered possible at this time to accurately and completely quantify the potential extent, effectiveness or success of the measures identified and as such studies have been recommended to assist with this process during any future STP assessment. Where possible an assumption expert judgement based approach has been undertaken. It should be noted however, that it is considered unlikely that upon implementation, a combination of measures could completely prevent STP effects and as such there is potential for residual effects to remain.

1.4.10 A number of enhancement initiatives may already be planned or required to meet the conservation objectives under drivers such as Natura 2000 and the WFD. As such, the prevent/reduce and offsetting measures may in some instances not be seen as additional to measures already planned within conservation management plans. Measures that may not be additional to measures already proposed outside the STP have been included within this assessment however, a note has been added recommending that that further consideration be given to this possible complication during any future STP assessment and before implementation of any measures.

1.4.11 It should be noted that the unprecedented scale of measures likely to be required for an STP plan alternative and the fact that many of them are novel is likely to result in the uncertainty of their success being high in a number of cases. To take into consideration the potential requirement for further investigations to reduce this uncertainty, assess the feasibility and determine potential extent, measures have been assessed on the basis of whether they could be implemented by 2020. Where it is considered that the required investigations would be of a level precluding their completion by 2020 the measure has either been excluded from further STP assessments or recommended for further consideration depending upon the level of investigations likely to be required and the extent of uncertainty surrounding it. An indication of the investigations likely to be required has been given where applicable for each measure.

1.4.12 Where possible the potential efficacy of individual measures has been estimated. Due to a paucity of detail, scientific knowledge and precedent on the scale likely to be required, a number of assumptions have been necessary during this assessment. Where necessary an expert judgement based best estimate approach has been adopted for the derivation of these assumptions. There is however, no inference that such assumptions would represent the actual circumstance and it is suggested that the investigations identified throughout this annex be undertaken to improve potential efficacy ranges prior to design and implementation of prevent/reduce measures for an STP plan alternative. On the collection of this information it is considered likely that the assumptions made could change and with them the efficacy ratings. The

assessment provided within this paper should therefore be considered as indicative only.

1.5 SEA Objectives

1.5.1 SEA Objectives are a recognised tool for comparing alternative options. This technique is proposed in the SEA Practical Guide (ODPM *et al*., 2005). SEA Objectives usually reflect the desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given option, but the degree to which they do will provide a way of identifying preferences when comparing options.

1.5.2 This approach requires judgments to be made on the performance of alternative options against each SEA Objective. 'Assessment criteria' and 'indicators' have also been developed to aid these judgements. The assessment criteria are a series of questions developed to guide the judgement of objective compliance. An indicator is the measure of a variable over time, often used to assess the achievement of objectives.

1.5.3 The SEA Objectives, assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage. The Government response to the consultation for the most part confirmed the SEA Objectives and in some cases made some minor modifications (DECC, 2009b).

1.5.4 There were no topic specific changes to the SEA Objectives, assessment criteria or indicators resulting from scoping. The SEA objectives are detailed in Table 1.3.

Table 1.3 SEA Objectives, Assessment Criteria and Indicators for migratory fish, marine/estuarine fish and recreational fisheries

SEA Objective	Assessment Criteria	Indicators
To avoid adverse effects on designated wildlife sites for fish of international and national importance. To avoid adverse effects on the populations of other protected fish species and habitats. To avoid adverse effects on national and local biodiversity target features that include fish habitats and species. To avoid adverse effects on recreational and migratory commercial fishing. To avoid adverse effects on commercial fish resources. To minimise the risk of introduction of non-native invasive fish species.	Will the option result in adverse effects upon the conservation status and hence integrity of status of internationally designated sites supporting fish? Will the option adversely affect the achievement of conservation status for internationally and nationally important fish species or their capacity to recover if currently designated as in unfavourable condition? Will the option result in changes in the populations of designated fish species of national importance, i.e. SSSI features? Will the option maintain UK BAP fish species in line with UK BAP targets? Will the option affect other statutory or non-statutory wildlife sites important for fish?	Changes in designated features and designation status for fish. Abundance of populations of internationally and nationally important fish species. Changes in the range of internationally and nationally designated fish species. Changes in the physical (biological and chemical) parameters upon which the fish species rely'. Abundance of populations of fish species caught by recreational anglers. Abundance of populations of fish species caught in commercial fisheries.

SECTION 2

BASELINE ENVIRONMENT

2 BASELINE ENVIRONMENT

2.1 Introduction

2.1.1 Baseline information provides the basis for predicting and monitoring environmental effects. Both qualitative and quantitative information can be used for this purpose.

2.1.2 The baseline information is described for the area that may be affected in terms of a range of 'receptors'. A receptor is an entity that may be affected by direct or indirect changes to an environmental variable. Relevant receptors were identified and consulted upon during the SEA scoping stage.

2.1.3 Alternative options considered within this Feasibility Study would only be developed several years into the future and would have a long life. It is therefore necessary to project a 'future baseline' against which to compare effects, rather than using the present day baseline. This is an especially important concept when considering dynamic systems such as estuaries that are subject to climate change effects such as sea level rise.

2.1.4 The approach taken is therefore to describe baseline information in the following stages:

- Baseline environment and receptors up to 2009, including environmental problems and opportunities;
- Future baseline during construction: 2014-2020, including anticipated problems and opportunities;
- Future baseline during operation 2020-2140, decommissioning and longer term trends, including anticipated problems and opportunities.

2.1.5 This paper describes the baseline for the relevant receptors with this topic. It will thereby inform the description of the baseline environment for the affected area as a whole, contained within the SEA Environmental Report.

Study area

2.1.6 A number of the designated fish receptors residing within and passing through the Severn Estuary, which could potentially be affected by an STP plan alternative, can exhibit natural excursion straying behaviour such that they may be from or subsequently go to a designated site outside of the immediate area potentially affected. Moreover they may form part of a larger UK or wider geographical population. Therefore effects of an STP plan alternative could not only affect the Severn stock but also the UK or even European populations as a whole. Exposure pathways would however, be greatest in the nearfield and less in the far field. To this end an understanding of the biogeographic distribution and known behaviour of these species is required

Receptors

2.1.7 Over 100 fish species have been recorded within the Severn Estuary. All of these species represent the fish receptors included within the STP feasibility study under

the migratory and estuarine fish topic and ultimately biodiversity theme. Included within this fish assemblage are a number of internationally and nationally designated estuarine and migratory fish species. Alongside these protected fish features, non-protected fish receptors utilising the Severn Estuary have also been considered following the ecological guild groupings as detailed within the Phase 1 Fish Topic Paper.

2.1.8 Internationally designated species protected via Annex II of the European Habitats Directive and encompassed within Natura 2000 sites within the study area include the following diadromous species; Atlantic salmon (*Salmo salar*), twaite shad (*Alosa fallax*), allis shad (*Alosa alosa*), sea lamprey (*Petromyzon marinus*) and river lamprey (*Lampetra fluviatilis*). In addition to Natura 2000 designated migratory fish species the internationally protected catadromous European eel (*Anguilla anguilla*) have also been included as a fish receptor under this study via European eel management plan legislation (Eel Recovery Plan, Council Regulation No 110/2007). Sturgeon (*Acipenser sturio*) have also been included where appropriate within the assessment. Nationally protected species under the UK Biodiversity Action Plan (UK BAP) list of priority species and habitats include; sea trout (*Salmo trutta*), cod (*Gadus morhua*), herring (*Clupea harengus*), plaice (*Pleuronectes platessa*), sole (*Solea solea*), whiting (*Merlangius merlangus*), blue whiting (*Micromesistius poutassou*), hake (*Merluccius merluccius*), horse mackerel (*Trachurus trachurus*), ling (*Molva molva*) and saithe (*Pollachius virens*). Marine/estuarine UK BAP species alongside the non-protected fish receptors have been grouped into the following ecological guilds within this STP feasibility study; estuarine species, marine migrants, marine stragglers and freshwater species (including freshwater stragglers).

Receptor biogeographic distribution

2.1.9 Salmon home to their natal river and as such a number of genetically distinct salmon populations pass through the Severn Estuary including those inhabiting the rivers of the Severn Estuary. Natural excursion straying does however occur and an STP plan alternative therefore has the potential to not only affect the Severn catchment salmon populations but also fish from other rivers. Sea trout also exhibit homing and natural excursion straying behaviour, and are considered to stray to a greater extent than salmon, so similarly an STP plan alternative also has the potential to affect fish from other rivers. The main salmon and sea trout populations which could potentially be directly affected by the STP plan alternatives are those of the Rivers Severn, Wye, Usk and Taff/Ely, as those rivers enter the Estuary within (east of) the Cardiff Weston barrage line, or are immediately adjacent to the other STP plan alternative locations. It is assumed that salmon and sea trout population within other rivers further west than the Taf are unlikely to be affected, the closest being the combined eastern and western Cleddau entering the sea through Milford Haven. The extreme limit for salmonids to which no effect is expected for this assessment is considered to be the Tywi on the Welsh coast and the Tamar and Torridge on the English coast. There is the possibility that fish from the east coast of Ireland (or possibly further afield) could stray to the Severn, although the degree of straying is considered to be very low (e.g. Swain, 1982). Further discussion on this matter may be required during a later stage of this, or any other STP assessment.

2.1.10 Shad populations (allis and shad) are genetically structured, with a pattern of population isolation by distance (Alexandrino et al., 2006). The British twaite shad population represents a distinct group in comparison to other Atlantic twaite shad populations (Alexandrino et al., 2006). Three distinct British population groups of twaite shad have been defined; Tywi, Usk and the Severn group which encompasses the Wye, Teme and Severn rivers (Alexandrino et al., 2006). Their genetic uniqueness is currently unknown. Natural excursion straying shad (both allis or twaite) from other European countries,

such as France, may be seen within UK waters including the Severn Estuary. Such natural excursion straying is however considered to be unlikely and an STP plan alternative is only likely to effect the Severn and Bristol Channel catchment populations.

2.1.11 The biogeographic distribution of river and sea lamprey is poorly understood however, it is believed that neither species home to their natal river although do migrate into rivers with resident ammocoete conspecifics using a migratory pheromone. In the absence of more definitive information and on the basis that it is considered that there is potential that river lamprey remain within estuarine and coastal waters during their marine life stages it has been assumed for the purpose of this assessment that river lamprey individuals found in the Severn catchment are part of a UK stock. There is limited genetic evidence available for sea lamprey which indicates a panmictic European population (OSPAR, 2009). On this basis and following the assumption that sea lamprey undertake greater marine phase migrations than river lamprey, sea lamprey have been considered within this assessment as forming part of a European stock. It has therefore been assumed within this assessment that an STP plan alternative has the potential to affect the UK population for river lamprey and the European population for sea lamprey.

2.1.12 The European eel population is most likely panmictic (Dabbewitz et al., 2005, in Aprahamian et al., 2007) which means that any affect on individuals passing through the Severn Estuary has the potential to affect the entire European population.

2.1.13 The marine migrant and straggler species recorded in the Severn Estuary are likely to represent individuals belonging to a UK population. There is however the possibility that they may migrate from marine waters elsewhere outside the UK. An STP plan alternative therefore also has the potential to have an effect upon far field stocks. Although it has been assumed that these species form part of a UK stock the importance of the Severn Estuary and Bristol Channel as a marine fish species nursery ground is recognised. There is therefore potential that in particular the juveniles within the Severn Estuary may support a wider stock. The estuarine species in the Severn Estuary however likely represent discrete populations and therefore for the purpose of this assessment it would be considered that effects of an STP plan alternative have the potential to affect the Severn Estuary population only.

Designated sites within the study area

2.1.14 Likely zones of effect have been identified for each plan alternative (See Hydraulics & Geomorphology Topic Paper). From this it is possible to determine which designated sites may potentially be affected by each plan alternative, and should therefore be considered as part of the plan alternatives assessment.

2.1.15 Sites on the east coast of Ireland are not considered here as these do not fall within the UK Habitats Regulations[1]. It is however recognised that there could be an effect on sites in this area.

2.1.16 Consideration would be given during the assessment for each plan alternative to potential effects on the sites which have fish features as part of their designation. For all five plan alternatives this includes the following sites:

- Afon Eden – Cors Goch Trawsfynydd SAC – Annex II species present: Atlantic salmon.

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

- Afon Teifi/ River Teifi SAC – Annex II species present: Atlantic salmon, river lamprey and sea lamprey.
- Afon Tywi/ River Tywi SAC –Annex II species present: river lamprey, sea lamprey, allis shad and twaite shad.
- Afonydd Cleddau/ Cleddau Rivers SAC – Annex II species present: river lamprey and sea lamprey.
- River Camel SAC – Annex II species present: Atlantic salmon.
- River Usk/ Afon Wysg SAC– Annex II species present: Atlantic salmon, river lamprey, sea lamprey, allis shad and twaite shad.
- River Wye/ Afon Gwy SAC– Annex II species present: Atlantic salmon, river lamprey, sea lamprey, allis shad and twaite shad.
- Cardigan Bay/ Bae Ceredigion SAC – Annex II species present: river lamprey and sea lamprey.
- Pembrokeshire Marine/ Sir Benfro Forol SAC – Annex II species present: river lamprey, sea lamprey, allis shad and twaite shad.
- Severn Estuary/Môr Hafren SAC – Annex II species present: river lamprey, sea lamprey and twaite shad.
- Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd SAC – Annex II species present: river lamprey, sea lamprey, allis shad and twaite shad.
- Severn Estuary Ramsar - This site is important for the run of migratory fish between sea and river via estuary. Species include Atlantic salmon, river lamprey, sea lamprey, allis shad, twaite shad, sea trout, and eel.

2.1.17 All plan alternatives have the potential to affect sites connected to the Severn Estuary, and to a lesser degree effect populations along the Welsh coast.

2.2 Methodologies used to develop the baseline

Sources of Data

2.2.2 Data and information used within this review have been obtained from various sources including data and reports produced by the statutory bodies (EA, CCW and NE), local, national and international government bodies and consultancies.

2.2.3 Consultations have been held with experts on several of the fish species and information gathered as part of this exercise has been included and taken into consideration throughout this topic paper.

2.2.4 Individual sources of data and information have been detailed throughout the report and a comprehensive reference list is given at the end of this document.

2.2.5 Life cycle models were developed to predict the baseline population scenarios to which effects could be integrated. These life cycle models focussed upon the designated migratory fish receptors; Atlantic salmon, twaite shad, river lamprey, sea lamprey and European eel (please see Annex 4: Migratory fish life cycle models for more details). For those species for which life cycle modelling has not been undertaken a qualitative assessment of baseline under the current, directive and climate change cases has been undertaken.

Base (current) case

2.2.6 Present day estimates of life history parameters (survival, growth, fecundity etc) were used to establish steady state age structure. The base case is that population size and structure existing in the presence of current life table variables (survival, fertility etc.) and in the absence of any additional pressures of climate change, or the STP options and for the purposes of this assessment will be considered representative of the baseline environment up to 2009.

Directive case

2.2.7 The Directive case assumes compliance of European Directive targets such as favourable conservation status, conservation limit and escapement. Where possible directive compliance was assumed to be met and was incorporated into the models through alteration of life history parameters. For the purposes of this assessment the Directive case model outputs were considered representative of the baseline environment from 2014 to 2020. For each species, the directives used were as follows:

- Eel - conservation of eel populations within the UK are outlined in the Eel Management Plan / Reference Condition Model (RCM) after Aprahamian *et al*. (2007). A reduction in glass eel recruitment led to the EC initiating an Eel Recovery Plan (Reg. No. 11002007); nationally established as an Eel Management Plan (EMP). The EMP aim is to achieve an escapement of silver eel to the spawning population that equals or exceeds 40% of the potential biomass that would be produced under conditions with no anthropogenic disturbance due to fishing, water quality or barriers to migration. In the UK, EMPs are set at the River Basin District (RBD) level as per the Water Framework Directive. Management options are recommended to ensure the long-term viability of eel populations within UK rivers.

- Salmon - the directive case is the stock equivalent to the Management Target stock level that would apply if a river stock was compliant with Environment Agency's Conservation Limit, i.e. spawning level => CL. The Conservation Limit, as a widely recognised reference point, which is a national policy objective for the EA, corresponding with the policy aims for the Water Framework Directive and for SAC rivers as set by EU Habitats Directive. If salmon stocks are currently compliant with the EA's CL (as in the rivers Severn and Usk) then Base Case equals (Severn) or is above (Usk) Directive case. However, for those rivers (the Wye and the Taff) which have current stocks below their Conservation Limit (thus below the Directive case) management actions are in hand to bring them up to or above Directive case level. The actions themselves are a mixture of regulatory practices, environmental restoration or enhancement, but for practical reasons, they cannot be finely tuned to exactly meet CL, or to exceed it by some predetermined amount.

Lamprey – The UK populations of lamprey are internationally important and both sea, brook and river lamprey are listed in annex II (and Va for river lamprey only) of the Habitats Directive, Appendix III of the Bern Convention, and as a Long List Species in the UK Biodiversity Action Plan. Several areas have been proposed as candidate SACs, particularly for river lamprey. River action plans have been developed for all three species within the UK, however, no defined conservation limits have been described aside from regulatory provisions to protect those habitats used by lamprey species. Targets of the River Action Plans are to determine the current distribution and population of lamprey, and to introduce management practices, particularly in areas of favourable habitat for spawning, to maintain the distribution and population size of those species.

Shad - Shad are listed under Annex II and V of the EU Habitats Directive and also Appendix III of the Bern Convention. UK Biodiversity Action Plans (BAPS) have been implemented throughout the UK to ensure the continued survival of shad around the UK. There are currently no direct conservation targets, however, conservation objectives are to identify and characterise spawning sites; protect and positively manage juvenile and adult habitats, and facilitate access to those regions. Life in UK rives (Natura 2000) has taken initial steps to set conservation objectives and outline management and monitoring strategies to assess whether populations are meeting favourable condition status.

Climate change case

2.2.8 Climate change is forecast to change environmental conditions in all the rivers and at sea. In turn this may have effects upon river carrying capacity, juvenile production, life history variables and population features of the fish receptors. The effect of climate change has the potential to be significant, even major; however the enormous complexity and uncertainties in the processes involved and lack of data on fish species responses to climate driven environmental factors preclude informed adjustment to all the life history variables likely to be affected. Therefore a restricted range of effect levels have been applied to the base case to offer a range of possible stock changes potentially resulting from climate change.

2.2.9 The requirement to predict for 140 years takes the projections of all climate scenarios well beyond their model capabilities and it was not considered defensible to go beyond the 2080s time frame of the UKCP forecasts. Accordingly, the maximum predicted effects by 2090 (the end of the 2080 series) are estimated and assumed to increase linearly over time up to that point and, for the purposes of the 140yr projection, beyond to 140 years.

2.2.10 For the purposes of this assessment the climate change case is considered representative of the baseline environment from 2020 to 2140.

Climate change scenarios

2.2.11 To ensure that all STP topics base their assessment upon the same climate change information a process document was issued by the STP consortium regarding the scenarios to be used across all topics. The climate change parameters to be used within the STP study are those released within UKCP09 which are considered to be the most up to date source of climate change predictions.

2.2.12 The medium emission 50% probability projection has been taken forward for all variables as the primary case within the models. Sensitivity testing was however also undertaken where receptors were considered to be sensitive to specific changes.

2.2.13 Data predictions have utilised the land square 1542 and marine square 23478 both of which are under the Newport search location. It is considered that within the Estuary that there is little variation for variables between adjacent squares and the use of the above squares will ensure consistency between the STP themes.

2.2.14 In view of the uncertainties and in the absence of any available projections beyond 2100, the STP SEA will be based upon climate change parameters to 2100 (which for most parameters is covered by the 2080s epoch) with a qualitative assessment only beyond that point.

2.2.15 UKCP09 provides climate change values for the following parameters;

- Sea level rise;
- Air temperature;
- Precipitation;
- Sea surface temperature (available from Sep-09); and
- Surface shortwave and longwave flux.

2.2.16 Sea surface temperature data is currently not available via the UKCP09 User Interface. As an interim measure the UKCP09 maps have been used to obtain estimated values.

STP case

2.2.17 The models for each case establish the stock size and age structure that would be obtained under steady state conditions, when the age composition has stabilised (Stable Age Structure, (SAD)). After that state has been reached no further change will occur, assuming that the model input variables remain constant.

2.2.18 The approach in this study has been to setup the models with terms that can be adjusted to examine the effect of any proportional change (e.g. 0 to 1) from Base or Directive cases in survival. This offers a form of look-up relationship to which data, knowledge or expert opinion on the proportional changes could be applied to estimate potential STP effects.

Assumptions, limitations and uncertainty

2.2.19 It is important to acknowledge the assumptions, limitations and uncertainties inherent in predicting changes to complex systems at a strategic level. Where possible, generalised assumptions and approaches for dealing with uncertainty have been developed to be applied consistently across the topics, as is the case with Climate Change and Policy. Where this is not possible and topic-specific consideration is required, the assumptions, limitations and uncertainty are clearly identified. Further detail is given below.

General Assumptions Concerning Application of Government Policy

2.2.20 It also has been assumed that, in general, existing Government policies relating, for example, to climate change response and biodiversity, will continue to apply into the future.

Topic Specific Assumptions, Limitations and Uncertainty

Migratory fish species

2.2.21 There are several areas of uncertainty and limitations in relation to the life cycle modelling used to determine the baseline environment. In general, the primary limitation to any model is the quality and availability of data for the model whereby the model is only as realistic as the sum of its parts. For several of the species in this assessment, particularly eel and lamprey, there is a great paucity of data describing specific and important life stages in that species life-history, resulting in either their exclusion or use of parameters from non-UK rivers to predict population changes.

2.2.22 The species specific assumptions, limitations and uncertainty are described in turn below.

Salmon

2.2.23 A thorough review of life history models previously developed for salmonid populations was undertaken at the commencement of this study and precedent exists for the use of the type of model selected for this study within the assessment of hydro power schemes. Where possible the information from which life history parameters were derived, was informed by the EA's SAP conservation limit assessment process. This enabled comparison between the two techniques (model and SAP) of salmon population assessment within the rivers under consideration. Inherent uncertainties regarding the accuracy of these parameters, in particular marine survival, remain resulting in a degree of uncertainty regarding the baseline environment model outputs. Moreover, the limited understanding regarding the potential effects of climate change upon the populations of this species preclude any confident assessment of its long term baseline.

Shad

2.2.24 Shad are currently classified as in unfavourable status for all of their designated rivers (Usk, Wye and Tywi). The models developed as part of this assessment are the first of their kind and use a novel approach to estimate shad population density in UK rivers based on parameters derived from published literature and personal communications and data from Dr Miran Aprahamian (EA). A paucity of empirical data describing life-history parameters in UK rivers has resulted in greatly limited population estimates. As such, density estimates have not been developed as no specific management initiatives have been established or are planned beyond those detailed under the Water Framework Directive and Habitats Directive actions. As such it has not been possible to predict future baseline for this species under a directive compliance scenario.

Lamprey

2.2.25 The non-natal homing of lamprey species presents significant difficulties in modelling their persistence within UK rivers. A paucity of data describing the transitional stage from parasitic juvenile (transformer) to adult prevents any accurate estimate of adult biomass/abundance. Coupled with non-natal homing, the development of cyclical

models i.e. those that describe the entire life-cycle, are not possible with our current level of knowledge about lamprey species as recruitment is decoupled from production.

2.2.26 The models developed for this assessment utilise a novel approach to estimating lamprey populations in UK rivers. Where possible, life-history parameters have been derived from available literature, although in several instances, these data are derived from non-UK (primarily North American) rivers and may not be representative of UK lamprey populations. While they provide a novel approach to estimate baseline populations for lamprey species in the UK, further work would be required, particularly focused on the parasitic juvenile to adult transition, and propensity to return to a given river to eliminate the uncertainty inherent with using information from non UK populations.

Eel

2.2.27 Similar to lamprey species, the marine component of an eel's life-history (transport from the Sargasso Sea to UK rivers) decouples recruitment from production i.e. adult abundance. Previous models of UK rivers have relied on glass eel recruitment estimates derived from fisheries data, however, such data is recognised as being greatly limited and unreliable. Given the limitations of these data, it was considered not appropriate for inclusion within the population models developed as part of this study and therefore, the models were limited to robust empirically derived data describing yellow and silver eel population characteristics.

2.2.28 The model developed as part of this assessment uses a novel approach including previously unreported data sets (Aprahamian unpublished data) and includes life-history parameters described from published literature where possible. Similarly to lamprey, several of these parameters have been derived from eel in non-UK rivers which may limit the estimates to some extent. Even given these limitations, the base model is considered to be robust and realistic based on previous estimates and anecdotal evidence.

Sea Trout

2.2.29 The life cycle of sea trout are so complex, inextricably bound up with non-migrant components of trout populations and subject to strong, but poorly understood, environmental and genetic influences that modelling was not appropriate within the timescale of this project. It is noted that an Interreg IV research project beginning in 2009 (The Celtic Sea Trout Programme) will examine these topics, but too late for this present assessment.

Marine and Estuarine Species

2.2.30 Due to availability of information knowledge regarding the life history of estuarine and marine fish receptors and the shear number of species within each guild it was not considered feasible within the timeframe and scope of this STP SEA to develop or run life history models for these fish receptors. It will not therefore be possible to quantify within this SEA the effects of an STP option upon the marine/estuarine fish features. It will therefore be necessary to formulate a qualitative expert judgement assessment of the effects upon these species.

2.3 Links to existing legislation and policy

2.3.1 A review has been conducted of relevant national, regional and local policies, plans and programmes, to assist with the identification of synergies and potential

inconsistencies with the Feasibility Study, and thus contributing to the development of SEA Objectives (STP, 2009a). Existing legislation and policy of particular relevance to this topic are summarised below.

2.3.2 The Policy, Plan and Programme Review (PPP) sets out which international, national, regional and local policies, plans and objectives must be taken into account in the SEA. An overview of those relevant to the migratory and estuarine fish topic is given below.

2.3.3 Freshwater Fish Directive (78/659/EEC) (updated in 2006 by Directive 2006/44/EC on the Quality of Fresh Waters Needing Protection or Improvement in Order to Support Fish Life). Aims to protect and improve the quality of rivers and lakes to encourage healthy fish populations. This Directive requires Member States to designate freshwaters (including estuaries) needing protection or improvement to support fish life. It sets water quality standard and monitoring requirements for these areas. The SEA should consider whether an STP option will affect the aspects of the River Severn that are designated under the Freshwater Directive as salmonid waters.

2.3.4 Salmon and Freshwater Fisheries Act (Department for Environment, Food and Rural Affairs, 1975) (SAFFA): The Salmon and Freshwater Fisheries Act 1975 applies to salmon, trout (including sea trout) and freshwater fish. The 1975 Act contains rules governing the: Prohibition of Certain Modes of Taking or Destroying Fish, Obstructions to Passage of Fish, Times of Fishing and Selling and Exporting Fish, Fishing Licences, Administration and Enforcement. The EA has powers to require the provision of fish passes and screens to enable the migration of salmon and sea trout through new obstructions or those undergoing significant alteration. The SEA will need to assess the effects of an STP option upon movements of fish species, in this case particularly diadromous species. Potential measures to prevent or reduce STP plan alternative effects to be considered should take into account the requirements of this Act and consultation made with the EA regarding which measures should be included..

2.3.5 Conservation of Natural Habitats and Wild Fauna & Flora (Directive 92/43/EC) (The Habitats Directive): The Habitats Directive requires each Member State to prepare and propose a national list of sites for evaluation in order to form a European network of Sites of Community Importance (SCIs). Once adopted, these are designated by Member States as SACs, along with Special Protection Areas (SPAs) classified under the EC Birds Directive. The aim of this Directive is to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States to which the Treaty applies. Measures taken pursuant to the Directive shall be designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest. Measures taken pursuant to this Directive shall take account of economic, social and cultural requirements and regional and local characteristics. The SEA should take into account the habitats and species that have been identified under the Directive, and should include provision for the preservation and protection of the environment. Information about the location of internationally designated sites should be collated. If inappropriately developed, new tidal structures have the potential to adversely affect wildlife and habitats both directly and indirectly. The STP Feasibility Study should carefully consider the location of potential sites in relation to European Designated Sites.

2.3.6 UK Marine and Coastal Access Act 2009: The UK Government has introduced a Marine and Coastal Access Act that includes within its area of responsibility a new framework for the seas, based on marine spatial planning, that balances

conservation, energy and resource needs. The key themes of the act include; marine management organisation, marine planning, marine licensing, marine nature conservation, fisheries management and marine enforcement, environmental data and information, migratory and freshwater fisheries, coastal access and coastal and estuary management. The act could have a significant bearing on the development of an STP option administratively (in terms of the organisation of marine planning activities). It will also be important that the SEA objectives reflect the act's themes, in particular protection of the marine environment.

2.3.7 Eel management plans for the Severn River Basin District. Draft 3.3. (June 2008); The European Commission has initiated an Eel Recovery Plan (Council Regulation No 1100/2007) to try to return the European eel stock to more sustainable levels of adult abundance and glass eel recruitment. Each Member State is required to establish national Eel Management Plans (EMPs). These plans aim to achieve an escapement of silver eel to the spawning population that equals or exceeds a target set at 40% of the potential biomass that would be produced under conditions with no anthropogenic disturbance due to fishing, water quality or barriers to migration. Escapement in this context is the silver eel (adult eel life stage) which successfully migrate downstream and out to sea and form the breeding population. As eel only undertake a single breeding migration a sufficient level of escapement to sea is required to sustain eel numbers. In the UK the EMPs have been set at the River Basin District (RBD) level, as defined under the Water Framework Directive, and the aim of the EMP is to describe the nature of the eel population and fishery in the RBD, to assess whether the stock is meeting its 40% escapement target, and to present management options that will ensure the long-term viability of the eel population. The SEA should consider whether an STP option would affect the likelihood of the Severn RBD meeting its targets under the EMP. Compliance of the 40% management target has a bearing on the future baseline of eel under the Directive compliance scenario and has been considered within the life cycle modelling for this species (2014-2020). The Eel Regulation (2010) will require consideration of the passage/screening requirements for eel on a risk based approach.

2.3.8 Salmon Action Plans (SAPs) for the Severn Estuary, River Usk, River Wye, River Taff and Ely; The EA's strategy for the management of salmon fisheries in England and Wales requires the production of an individual SAP for each principal salmon river. As well as updating these plans at regular intervals, they will be progressively integrated into the 6-yearly WFD Planning Cycle. The SEA should consider whether an STP option would affect the aspects of the rivers that are designated under SAPs. The management actions specified within SAP's for each of the study rivers have the potential to effect the baseline population for migratory salmonids and are considered within the Directive case scenario life cycle modelling for salmon where possible and appropriate.

2.3.9 UK Biodiversity Action Plan: This Plan has been prepared in response to Article 6 of the Convention on Biological Diversity 1992, to develop national strategies for the conservation of biological diversity and the sustainable use of biological resources. The Action Plan is monitored, reviewed and updated when required. The overall goal of the UKBAP is 'To conserve and enhance biological diversity within the UK and to contribute to the conservation of global biodiversity through all appropriate mechanisms'. The plan contains 391 action plans for 381 priority species and 10 priority species-groups. Individual plans have been developed for 45 priority habitats. Specific targets are established for each of these action plans. The protection of biodiversity sources should be an important theme of the SEA and should include SEA objectives relating to the protection of biodiversity resources. Information about

designated sites and nature conservation should be obtained through the baseline review.

2.3.10 A Better Environment, Healthier Fisheries: Better Fisheries for our nations 2006-2011 (Environment Agency, 2006): Objectives are to improve fish stocks and create a better environment for wildlife and people, provide more chances for people and fish to help fisheries perform better, and help sustainable fisheries boost the local economy. The SEA should consider whether the STP options would have any implications on the achievement of these objectives.

2.3.11 Environment Agency River Basin Management Plan, Severn River Basin District, December 2008; River Basin Management Plans set out in general terms how the water environment will be managed. The target set out in the Draft River Basin Management Plan, Severn River Basin District is that by 2015 just under 20% of the length of each of the rivers within the RDB should be classed as good quality. It will be important to assess the effect of an STP option on all relevant river systems in terms of the effects it could have on enabling this target to be met.

2.3.12 Wales Fisheries Strategy (Welsh Assembly Government, 2008): A long term strategy for the management and development of fisheries in Wales across all sectors of aquaculture, commercial fisheries, and recreational fisheries for 2020. The vision of the Wales Fisheries Strategy is to: "Support the development of viable and sustainable fisheries in Wales as an integral part of coherent policies for safeguarding the environment". The SEA should consider whether an STP option would affect fisheries within the Severn Estuary and elsewhere.

2.3.13 Wales Environment Strategy Action Plan 2008-2011: Key objectives of this plan are to: meet international biodiversity obligation, maintain and enhance the quality of the marine environment, and work actively with stakeholders to manage the marine environment in Wales over the longer term, provide opportunities for people to safely enjoy their surroundings and natural environment, ensure that the principle of evidence-based policy making and partnership working across the public sector is actioned through partnership on research and evidence, and develop and implement a local environmental quality strategy. A number of targets are set which include: bringing designated sites into favourable condition, designate Highly Protected Marine Reserves by 2012 to support ecosystem recovery and meet International, European and UK commitments, by end March 2009 deliver for the coast path, 35km of new access for walkers, 10km for cyclists, 15km of new bridleway and 15kms of new access which meets least restrictive access standards, all communities to enjoy improved local environment quality by March 2011. The SEA objectives should address environmental protection including protecting biodiversity, conserving landscapes, protecting the coastal environment, and improving recreational access.

2.3.14 The Passage of Fish Regulations (Department for Environment, Food and Rural Affairs, consultation ended April 2009): These proposed regulations arose from the Fisheries Legislative Review. They contain proposals to introduce fish passes in obstructions and screening of water abstraction and discharge points. The intention is to enable the free passage of all freshwater fish species and eel (although the latter will be picked up separately). Following government review the decision on whether to take forward these regulations has been postponed until at least 2012. As such the implications of these regulations were they to be taken forward would need to be considered as part of any later environmental assessment of an STP option.

2.3.15 EU Marine Strategy Framework Directive: The aim of the EU's Marine Strategy Framework Directive is for EU marine waters to achieve good environmental status by

2021 and to protect the resource base upon which marine-related economic and social activities depend. This Directive constitutes the environmental component of the EU's future maritime policy which has been designed to achieve the full economic potential of the oceans and seas in harmony with the marine environment. Under the Directive each Member State within a marine region is required to develop strategies for their marine waters. These must contain a detailed assessment of the state of the environment, a definition of "good environmental status" at a regional level and the environmental targets and monitoring programmes to be established. Cost-effective measures must be drawn up which include an impact assessment detailing cost-benefit analysis of the proposed measures. The overall goal of the Directive is in line with the objectives of the WFD which requires surface freshwater and ground water to be ecologically sound by 2015 and that the first review of the River Basin Management Plans should take place in 2020. This Directive may have particular relevance for an STP plan alternative in terms of underwater noise.

2.3.16 There are a number of policy assumptions associated with these plans and programmes which could have a bearing on the future baseline. If the requirements/targets of these plans and programmes were met, e.g. favourable conservation status, conservation limits and escapement targets, then populations would be assumed to increase in the future all other factors remaining constant.

2.4 Baseline Environment

2.4.1 This SEA baseline environment describes the area that may be affected in terms of 'receptors', and has examined the potential for significant effects in relation to these. The receptors were developed during Phase 1 SEA scoping. The list of receptors was subsequently consulted upon as part of the Phase 1 consultation.

2.4.2 A review has been conducted of other projects in and around the Severn Estuary that may have an influence on the future baseline (STP, 2009b). Those projects that are considered to be reasonably foreseeable as implemented by 2014, have been considered part of the future baseline environment.

Receptor A: Atlantic salmon

Baseline environment (up to 2009)

2.4.3 A thorough overview of the condition of salmon stocks in the Severn catchment is given in the Phase 1 Scoping Report which discusses and presents all of the available data pertaining to this species within the study area.

2.4.4 The River Wye/ Afon Gwy SAC and River Usk/ Afon Wysg SAC are both subject to periodic condition assessment using Habitat Directive protocols. During recent condition assessments the salmon populations within both of these rivers were classed as being in unfavourable condition.

2.4.5 Salmon catches have reduced considerably in recent decades; in the three major Severn Estuary tributaries (Severn, Wye and Usk) in common with many other parts of the eastern North Atlantic.

2.4.6 Although widespread throughout the UK, ICES estimates suggest the spawning population for the UK salmon stock is currently approximately 50% down on the ten-year average.

2.4.7 A continued minor reduction over the next five years is predicted in River Wye salmon stocks. A long-term decline in multi-sea-winter (MSW) numbers has been observed in the River Usk, with modest post 1999 improvements since the drift net buyout. The Conservation Limit for this River has been achieved during the last 10 years. The River Severn has achieved its Conservation Limit in 6 of the last 10 years.

2.4.8 Stocks of migratory fish in the South Wales coalfield rivers (Rivers Ely, Ebbw, Taff and Rhymney) are currently small in comparison to the other Severn Estuary tributaries. Stocks have however begun to recover over the last 30 years and are likely to improve further into the future. The Rivers Taff and Ely, while not being renowned salmon rivers, have a salmon run and both are recovering rivers. The Ely fishery currently relies largely upon stocked and stray fish from other catchments to make up this run. Declared rod catch of salmon on the River Taff has increased over the past couple of years after no fish were declared in 2003. This is likely a result of the water quality improvements seen in these once heavily polluted rivers.

2.4.9 As part of the life cycle modelling (see Annex 4:Migratory fish life cycle models) egg depositions were used to index the status of salmon stocks. This was used as the base case and reflects the current state of the stocks (mean of 2004 – 2008). At base (current) conditions the egg depositions for the Severn, Wye, Usk and Taff/Ely were 16.1, 24.5, 19.5 and 0.9 million respectively. Corresponding proportions of 1 sea-winter (1SW) fish in the models were estimated to be 0.38, 0.37, 0.73 and 0.98 respectively with the remainder of the run proportion being represented by 2 and 3 sea winter fish.

Table 2.1 Summary outputs of base case (observed egg deposition, proportion of sea age categories in catch and rod catch (adjusted for reporting rate), 2004-2008 means.)

Measure	Severn	Wye	Usk	Taff/Ely
EGGS (m)	16.07	24.52	19.44	0.91
P1SW	0.38	0.37	0.69	0.98
P2SW	0.49	0.50	0.25	0.02
P3SW	0.12	0.13	0.06	0.00
mean rod catch	369	755	1,089	18

Baseline during construction (2014 – 2020)

2.4.10 Future status of the River Usk is uncertain with a slight upward trend predicted. Recent records of salmon rod catch (2004) on the River are similar to the maximums recorded in the past. The potential for further stock improvement on the Usk is therefore currently uncertain. Compliance of the River Severn with its Conservation Limit is also uncertain, although a slight upward trend is predicted to 2012. On the Rivers Taff and Ely a continued downward trend is predicted into the future based on data to 2006. It may be, however, that with recent improvements this trend could be reversed in the future. These figures are however based on rod catch data alone and cannot take account of any catchment improvements or changes in pressure on fish stocks, which is also applicable to the data presented in the preceding section.

2.4.11 Existing data have been reviewed to determine the baseline population scenarios as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given below.

2.4.12 Under Directive conditions (i.e. when a stock is meetings the river's Conservation Limits and the average stock size is therefore at, or above, the Management Target), at which the populations of the four rivers are at or (in case of the Usk) above their Conservation Limits, simulated by adjusting marine mortality within observed 95% confidence limits, the egg depositions for the Severn, Wye, Usk and Taff/Ely were 16.6, 39.6 19.5 and 3.4 million eggs respectively. The errors in the projected estimates of egg deposition are typically high, due to the uncertainty in the input parameters. Monte Carlo simulation, using Poptools, gave 95% confidence limits that were between x1.3 and x2.4 the estimated mean.

Table 2.2 Summary outputs of Directive cases (eggs per millions, P1SW to P3SW and smolt to spawner survival proportions, means as individuals)

Parameter	Severn	Wye	Usk	Taff/Ely
EGGS	16.59	39.54	19.46	3.44
P1SW	0.47	0.47	0.73	0.99
P2SW	0.45	0.44	0.19	0.01
P3SW	0.08	0.09	0.08	0.00
Eggs per spawner	3,412	3,418	2,593	1,675
Egg to smolt survival	0.0095	0.0109	0.0068	0.0120
Egg to spawner survival	0.0003	0.0003	0.0004	0.0006
Smolt to spawner survival	0.0307	0.0269	0.0563	0.0499
Mean rod catch	556	1,791	1,083	299
mean smolts	158,312	430,364	133,256	41,147
mean spawners	4,862	11,568	7,504	2,055

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

2.4.13 Existing data have been reviewed to predict the population scenarios in the future taking into account climate change as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.14 It was not considered feasible to directly model the effects of climate change on salmon stocks due to the complexity of salmon population responses, coupled with the current lack of knowledge of the likely processes and the uncertainties over long term climate shifts across the variety of salmon habitat in freshwater and at sea. Some components of the likely responses are known qualitatively or suspected, for example, smolt age is likely to decrease and incidence of 1SW fish is likely to increase, marine survival to decrease, river carrying capacity and overall smolt production are likely to decrease. However with current knowledge this cannot be assembled in a quantifiable, robust way that leads through to final stock outcome. Instead four alternative assumptions regarding a) propensity to return at age 1SW or later and b) marine and freshwater survival were tested to examine effects upon egg deposition and stable age composition. Also, a wider range of marine and freshwater survival variation was tested separately to investigate the relative effects on stock. The time course of the changes could not be directly modelled due to uncertainty over the marine/freshwater combined scenarios, but assuming the conditions prevailed as step change, the time for the population to stabilise was about 40-50 years for the Severn and Wye, about 20-30 years for the Usk and the Taff/Ely stock would remain unstable and cyclically fluctuating indefinitely. At the same propensity to return scenario as detailed above, but exploring survival change over a wider range, if a 25% reduction in marine and freshwater survival was assumed, then only the Usk

would have any remaining reproductive capacity. See Annex 4: Migratory fish life cycle models Section 5.3 for more details.

Table 2.3 Model outputs for salmon under four assumptions of climate-change induced change in survivals and propensity to return. nr = 5% level not reached by time of stable age distribution (means as individuals).

River	Parameter	Assumption (A)	Assumption (B)	Assumption (C)	Assumption (D)
SEVERN	Egg deposition (m)	7.37	0.13	6.06	0.05
	mean rod catch	410	7	430	4
	mean smolts	93,945	2,208	82,060	912
	mean spawners	3,284	59	3,706	32
	time to 5% EggDir	nr	52	nr	42
WYE	Egg deposition (m)	14.01	0.02	11.08	0.01
	mean rod catch	1,049	2	1,064	1
	mean smolts	200,386	371	166,017	158
	mean spawners	6,238	9	6,780	5
	time to 5% EggDir	nr	34	nr	31
USK	Egg deposition (m)	12.04	4.98	10.82	4.13
	mean rod catch	876	367	960	368
	mean smolts	109,239	58,629	105,200	51,077
	mean spawners	5,903	2,476	6,593	2,525
	time to 5% EggDir	nr	nr	nr	nr
TAFF/ELY	Egg deposition (m)	0.71	0.00	0.69	0.00
	mean rod catch	62	0	61	0
	mean smolts	11,274	2	11,038	2
	mean spawners	428	0	423	0
	time to 5% EggDir	nr	19	nr	3

Receptor B: Shad

Baseline environment (up to 2009)

2.4.15 Allis shad are rare in the UK with known spawning populations restricted to the Tamar Estuary and Solway Firth. Within the Severn catchment historical records of allis shad on the Rivers Wye and Usk exist and there have been several records in the Estuary. The last four rivers in the UK known to support a spawning population of twaite shad are the Rivers Tywi, Usk, Wye and Severn (including its tributary the River Teme). Although a rare species within the UK twaite shad can be observed in some numbers on the Rivers Usk, Wye and Severn with, at times, shoals of hundreds of fish. Shad are currently classified as in unfavourable status for all of their designated rivers (Usk, Wye and Tywi).

2.4.16 A thorough overview of the data available concerning shad stocks in the Severn catchment is given in the Phase 1 Scoping Report.

Baseline during construction (2014 – 2020)

2.4.17 Existing data have been reviewed to determine the baseline population scenarios as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.18 The model output indicated an average population size of 92,000 female shad. Given a sex ratio of 1:1, the total mean population of twaite shad aged between 3 and 9yr in the Rivers Severn, Wye, Usk and Tywi is estimated to be around 184,000, although population size in a given year may range between 112,000 and 596,000 adults.

2.4.19 The baseline model suggests that the largest river in terms of twaite shad is the River Wye, where approximately 46,000 female shad are considered to return each year. Based on the percentage contribution of the Severn and Usk rivers, returning shad numbers are estimated at around 18,000, while the fewest number of shad are predicted to be found in the River Tywi, where approximately 9,000 shad are expected (Table 2.4).

2.4.20 It was not possible to develop a Directive case model for shad due to a paucity of robust empirical data.

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

2.4.21 Existing data have been reviewed to predict the population scenarios in the future taking into account climate change as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.22 Under both 1 and 2^{o}C climate scenarios, shad are more likely to persist with increasing redundancy within the population as temperatures increase. This is in contrast to the baseline scenario (17.8^{o}C) where recruitment barely reaches the required magnitude in order for the stock to persist. The stock replacement under 1 and 2^{o}C scenarios suggests a surplus of 3,300,000 and 6,750,000 eggs, corresponding to ~75,000 and ~153,000 adult shad respectively (Figure 2.1, Table 2.4).

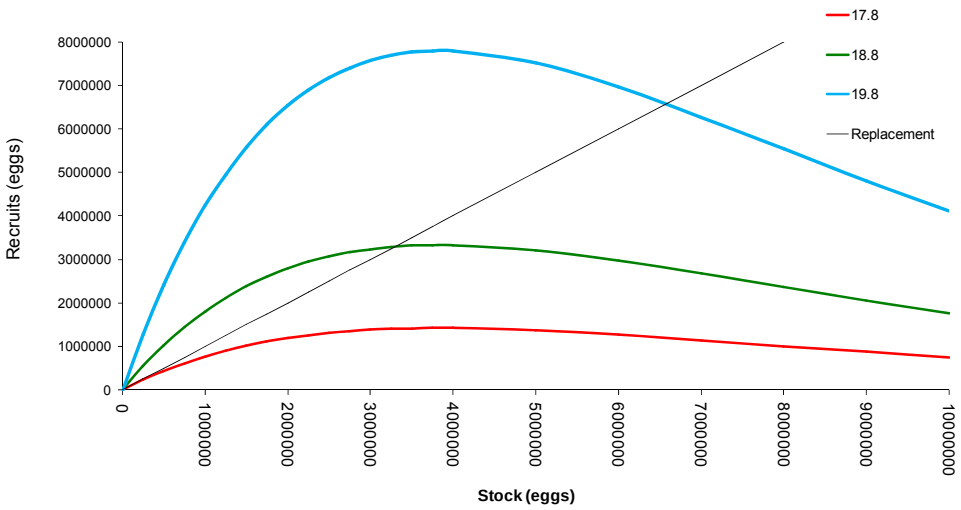

Figure 2.1 Stock recruitment of shad (eggs) under baseline and climate scenarios.

Table 2.4 Predicted adult twaite shad abundance in the four rivers in the Severn RBD under baseline and two climate scenarios.

River	% Contribution	Reference	1˚C	2˚C
Severn	20%	36902	65074	60272
Wye	50%	92254	162686	150680
Usk	20%	36902	65074	60272
Tywi	10%	18451	32537	30136
Total	**100%**	**184508**	**325372**	**301360**

Receptor C: Sea and River lamprey

Baseline environment (up to 2009)

2.4.23 Within England and Wales over half of the 20 SAC's designated for the presence of lamprey species are situated on the Welsh coast including the Rivers Wye and Usk and the Severn Estuary. These rivers are subject to periodic condition assessment using Habitat Directive protocols. During recent condition assessments (2007) all but the River Usk were classified as unfavourable for river lamprey and all but the River Wye as unfavourable for sea lamprey. The River Usk has the greatest *Lampetra* spp. ammocoete population across all British SAC rivers designated for the species while the River Wye has the greatest sea lamprey ammocoete population of all British SAC's designated for its protection (APEM, 2006).

Baseline during construction (2014 – 2020)

2.4.24 Existing data have been reviewed to determine the baseline population scenarios as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.25 The numbers of lamprey in each stage class have been estimated for the River Usk and River Wye (Table 2.5). Markov Chain Monte Carlo (MCMC) simulations were used to estimate the mean population size from the model output and indicate an

average population of adult lamprey in the River Usk and Wye. These estimates have been based on best guesses of available habitat of 1% (APEM 2007) per metre length of river for sub-optimal habitat and per metre^2 of optimal habitat (see Annex 4: Migratory fish life cycle models for more detail regarding this approach).

2.4.26 Based upon the ammocoete densities used in the baseline model and outlined in Harvey *et al.* (2006), it is considered that both river and sea lamprey populations are currently in favourable condition under the Habitats Directive. Therefore no Directive case modelling was undertaken.

Table 2.5 Population estimates (mean ± SD) of ammocoete, parasitic juvenile (transformer) and adult river lamprey in the Rivers Usk and Wye. Shown are estimates based on 1% available habitat (optimal and suboptimal combined) within each river.

River lamprey

River (*percent habitat available*)	Ammocoetes	Parasitic Juvenile	Adult
Usk (*1.0*)	21,952,630 ± 1,985,605	3,424,610 ± 309,754	27,667 ± 4,696
Wye (*1.0*)	71,158,380 ± 5,598,596	11,100,707 ± 873,381	88,442 ± 14,324

Sea lamprey

River (*percent habitat available*)	Ammocoetes	Parasitic Juvenile	Adult
Usk (*1.0*)	14,397,293 ± 581,840	2,245,978 ± 90,767	3,069 ± 455
Wye (*1.0*)	56,875,906 ± 2,664,438	8,937,418 ± 417,532	12,200 ± 1,836

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

2.4.27 Existing data have been reviewed to predict the population scenarios in the future taking into account climate change as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.28 A paucity of available data predicting the effects of climate change on life history parameters prevents a meaningful modification of life-history parameters to simulate the effects of climate change on lamprey populations in the Severn RBD. It is considered that the only feasible option is to modify the amount of habitat available for lamprey ammocoetes. Lamprey have preferred water depths for nursery areas and spawning grounds as well as preferred substrate in both locations (Maitland, 2003).

Both water depth and substrate are to some extent dependent upon water quantity and velocity, which may be altered through climate change. Thus, to simulate a change in habitat that may result from changes in water levels, habitat availability is predicted to reduce from 1% to 0.5% and increase to 2% of predicted levels. This represents a halving or doubling of habitat availability from estimates applied in the baseline model (APEM 2007).

2.4.29 MCMC simulations were used to estimate the mean population size from the model output and indicate an average population of adult lamprey in the Rivers Usk and Wye. These estimates have been based on expert judgement of available habitat of 1%, a precautionary availability of 0.5% (APEM 2007) per metre length of river for sub-optimal habitat and per metre^2 of optimal habitat (**Table 2.6**) and an increase to 2%.

Table 2.6 Future population estimates (mean ± SD) of ammocoete, parasitic juvenile (transformer) and adult lamprey in the Rivers Usk and Wye for baseline during operation (2020-2140). Shown are estimates based on percent available habitat (optimal and suboptimal combined) within each river (2%, 1% or 0.5%)

River Lamprey

	Precautionary (0.5% habitat)				Baseline (1% habitat)				Climate Change (2% habitat)			
River	River Usk		River Wye		River Usk		River Wye		River Usk		River Wye	
Life Stage	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoete	10,906,416	475,479	36,012,837	2,946,327	21,952,630	1,985,605	71,158,380	5,598,596	43,566,277	3,592,157	141,341,271	13,892,587
Parasitic Juvenile	1,701,401	74,175	5,618,003	459,627	3,424,610	309,754	11,100,707	873,381	6,796,339	560,377	22,049,238	2,167,244
Adult	13,609	2,035	45,544	7,528	27,667	4,696	88,442	14,324	54,389	9,038	178,358	30,967

Sea Lamprey

	Precautionary (0.5% habitat)				Baseline (1% habitat)				Climate Change (2% habitat)			
River	River Usk		River Wye		River Usk		River Wye		River Usk		River Wye	
Life Stage	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoete	7,237,877	314,938	28,626,695	1,270,313	14,397,293	581,840	56,875,906	2,664,438	28,895,327	1,377,754	113,598,479	5,691,344
Parasitic Juvenile	1,129,109	49,130	4,498,407	199,933	2,245,978	90,767	8,937,418	417,532	4,507,671	214,930	17,850,616	889,301
Adult	1,545	231	6,133	919	3,069	455	12,200	1,836	6,175	931	24,447	3,692

Receptor D: Eel

Baseline environment (up to 2009)

2.4.30 The coastline of the Bristol Channel forms a large funnel in the path of larvae and migrating glass eel and the south-westerly orientation along with the high tidal range likely results in the large numbers of eel that enter the Severn. The Severn represents a major component of the UK eel stock with the glass eel fishery a major source of glass eel recruitment within England. Eel are distributed throughout the catchment, although few penetrate the source streams rising from the Cambrian Mountains, and they are reported as absent from the rivers draining the Birmingham urban area.

2.4.31 The draft Eel Management Plan for the Severn River Basin District concludes that downstream of Worcester the eel population is at carrying capacity; while the middle reaches of the Severn and Avon catchments are likely below carrying capacity.

Baseline during construction (2014 – 2020)

2.4.32 European-wide data from ICES shows a drastic decline in eel recruitment since the end of the 1970s, with glass eel recruitment dropping to just 1 – 5% of historic levels (pre-1980). Current ICES scientific advice is that the stock is outside safe biological limits and that existing fisheries are not sustainable (ICES 2007).

2.4.33 Existing data have been reviewed to determine the baseline population scenarios as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.34 The results of the model are given below in Table 2.7 and Figure 2.2.

Table 2.7. Area and biomass (kg/ha) of silver eel (male and female combined) in the River Severn RBD.

		Biomass (kg/ha)			
River	Area (ha)	Downstream	Upstream	Total (kg)	
Severn (d/s)	880	9.5	-	8360	Severn Total (kg)
Severn	2203	-	8.4	26865	
Avon	1156	-	8.4	9710	
Teme	730	-	8.4	6132	51067
Usk	407	9.0		3643	494
Wye	1610	9.0		14410	5861
Parrett*	1375	9.0		12375	Unknown
			Severn RBD (kg)		57423

** average of downstream and upstream sites.*

2.4.35 Data scaled to represent expected biomass output based on predicted river contribution rates based on glass eel fisheries data (ICES, 2004) are shown in Table 2.7.

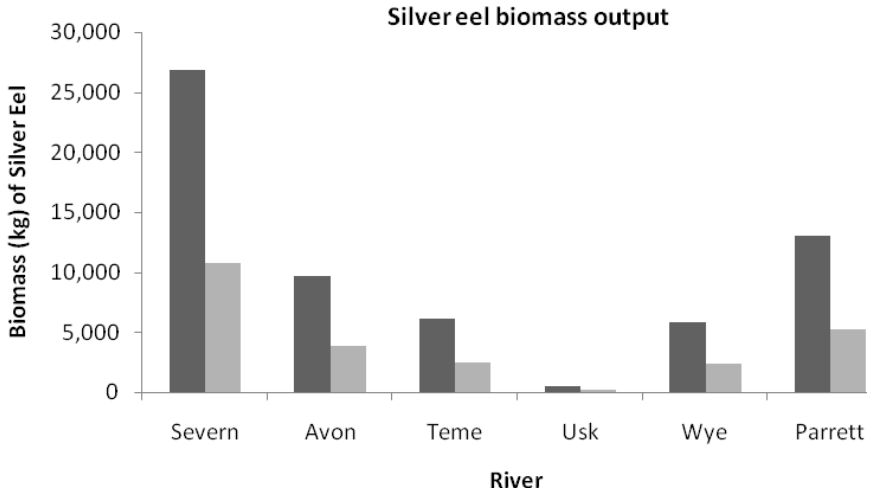

Figure 2.2 Silver eel biomass output (kg) from each of 6 rivers and escapement targets (light grey)

2.4.36 The output biomass of silver eel represents between 3.5% and 19% of the total yellow eel population in downstream and upstream regions respectively and corresponds to a total of 609,412 yellow eel and 157,043 silver eel within the Severn RBD.

2.4.37 The primary target of the Severn River Basin Eel Management Plan is to achieve 40% silver eel escapement by 2032. It is intended that this target will be achieved through the improvement of both access to habitat and the habitat itself.

2.4.38 Where initiatives are regarding improved fish passage the availability of additional habitat could be incorporated into the models such as those planned on the Lywd, Monnow, Lugg, Arrow and Taff. It is intended that these initiatives will take place between 2007 and 2009. It is not possible however to include the more generic actions planned for the period 2009 to 2012 where work is still to be undertaken to develop specific actions.

2.4.39 To date, there has been no assessment of the number of silver eel escaping from the River Severn and associated rivers, therefore it is impossible to ascertain as to whether the target escapement level outlined in the EMP are being achieved. Under baseline conditions 44,236 silver eel must escape from the population of 110,590 to satisfy the 40% escapement target.

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

2.4.40 Existing data have been reviewed to determine the predicted future baseline population scenarios as part of the life cycle modelling (see Annex 4: Migratory fish life cycle models for more detailed information). A summary of the model outputs is given here.

2.4.41 Climate change was simulated by manipulating the rate of growth in eel based on predictions that rising temperatures will result in increasing growth rates based on Yokouchi et al. (2009). Incorporation of increased growth rate(s) associated with higher temperatures would have a significant effect on the number of eel silvering in a given year.

2.4.42 For downstream reaches of the River Severn and associated rivers, the maximum biomass output is expected to be ~96 kg/ha and represents a total annual biomass output of 158,000 kg or 1.5 million eel based on the average mass of a male eel of 106 g. In upstream reaches, the maximum biomass output is expected to be ~18 kg/ha and represents a total annual biomass output of 42,704 kg or 75,183 eel based on the average mass of a female eel of 568 g.

2.4.43 Downstream regions of the Severn River are far more productive in terms of the biomass of silver eel produced, contributing 93% of the total silver population in comparison to upstream reaches which contribute the remaining 7%.

2.4.44 Under the climate change scenario, the proportion of yellow eel silvering in a given year and the subsequent output in terms of biomass of silver eel are described in **Table 2.8** and shown in Figure 2.3. Note that these values represent the biomass output (kg/ha) that would be expected for any river, with total population estimates derived from the area of available habitat and the predicted biomass.

Table 2.8. Silver eel biomass output (kg/ha) for 6 rivers in the Severn RBD.

Climate Change (Yokouchi et al. 2009)		Output (kg/ha)			
River	Area (ha)	Downstream	Upstream	Total (kg)	
Severn (d/s)	880	96	-	84480	Severn Total (kg)
Severn (u/s)	2203	-	18	39654	
Avon	1156	-	18	20808	
Teme	730	-	18	13140	158082
Usk†	407	57		23199	3146
Wye†	1610	57		91770	37330
Parrett*	1375	57		78375	?
			Severn RBD (kg)		198558

†Severn Total outputs for the Rivers Usk (3,146kg) and Wye (37,330kg) are scaled based on declared catch statistics for glass eel.

*The River Parrett is not included in the Severn RBD estimate as the percentage contribution of this river to the overall output is unknown.

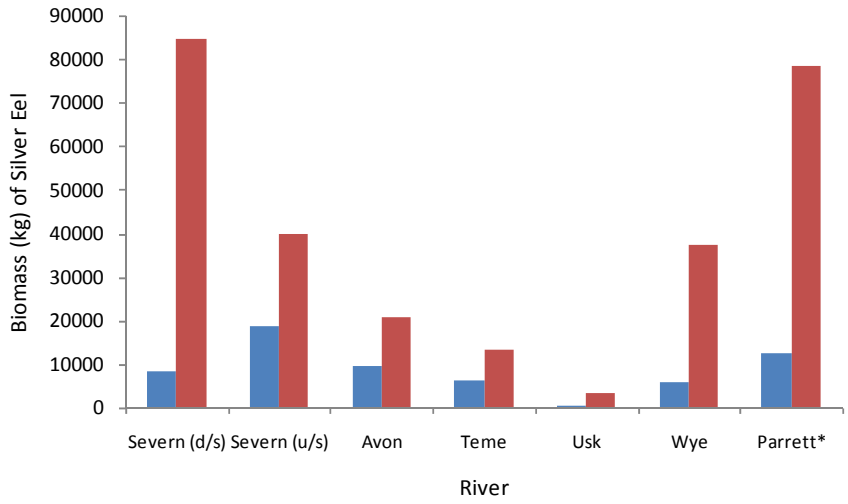

Figure 2.3 Biomass of silver eel within each of 6 rivers in the Severn river basin district under baseline (blue) and climate (red) scenarios. *Indicates estimated output from the River Parrett without scaling with glass eel catch data.

Receptor E: Sea trout

Baseline environment (up to 2009)

2.4.45 Sea trout are less abundant than salmon in the Severn Estuary tributaries and net catches in the drift nets and putchers of all Severn Estuary tributary rivers have generally been low since 1965, exceeding 100 individuals per year on only 10 occasions. No sea trout have been caught in any of these fisheries since 2000 principally due to fishery reduction or closure. The Rivers Usk and Severn have had the highest catches, although these have declined since ca. 2000.

Baseline during construction (2014 – 2020)

2.4.46 Life cycle modelling was not undertaken for sea trout owing to the complexities and variability of their life cycle therefore predictions of the baseline conditions during the construction period are not possible. Some of the climate change aspects detailed below could however also occur within this time frame but to a lesser extent.

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

2.4.47 Life cycle modelling was not undertaken for sea trout owing to the complexities and variability of their life cycle however, the issues associated with climate change are similar to those for salmon. In contrast however, trout (which have lower temperature preferences than salmon, e.g. Webb and Walsh, 2004) are predicted to display ever poorer growth rates under all scenarios as climate change increases from current levels (Davidson and Hazlewood, 2006). Some capacity for adaptation in juvenile life history traits to changing temperature regimes has been demonstrated (Jensen *et al*., 2008); but the rates of adaptive responses might be unable to cope with the comparatively fast rate of anticipated climate change (e.g. Freidland *et al*., 2003). In sea trout the anadromous (sea going) habit, is regarded as a threshold quantitative trait that appears to be finely balanced on the interactions between multiple genes and environmental factors (Ferguson, 2006). This makes the prediction of climate effects more difficult than for salmon. As speculation, adverse growing conditions in freshwater, leading to later maturity, may make the marine migration more advantageous; but the tradeoffs in terms of lifetime fitness will be influenced also by the feeding and growth opportunities in the marine environment.

Receptor F: Sturgeon

Baseline environment (up to 2009)

2.4.48 Sturgeon although listed on the UK BAP as a priority species is classed within it as a 'priority species not recorded in the last 10 years'. In addition, the IUCN Red List (1994) lists the common sturgeon as 'endangered' in the UK. There are however historical records of sturgeon utilising the Severn Estuary and its tributaries. The British Marine Life Study Society has collated a number of records. The most recent account was made by the EA of a fish caught between Newport and the Severn Bridge in the late 1980s. Numerous other records exist for the Rivers Severn and Wye dating back to 1718. Adolescent sturgeon originating from the Gironde were also reported from the mouth of the Severn, Usk, Wye and Tywi in the late 1980s and early 1990s (EA, *pers.comm.*). There is no confirmation that sturgeon have bred recently within British waters. Individuals have, however, been observed as far upstream as Shrewsbury on the River Severn.

Baseline during construction (2014 – 2020)

2.4.49 Although reintroductions of sturgeon are occurring within Europe no plan to introduce the species is currently in existence within the UK. There is potential however, that individuals from other European populations may venture into the Severn Estuary.

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

2.4.50 As with the period 2014 to 2020 it has been assumed for the purposes of this assessment that no introductions of sturgeon are planned within the UK. There is however, potential that individuals from other stocked European populations may venture into the Severn Estuary.

Receptor G: Marine Migrants

Baseline environment (up to 2009)

2.4.51 The marine migrants comprise the second most speciose estuarine use functional group (EUFG) in the inner Bristol Channel (28%) and in terms of abundance and diversity provide the greatest contribution to the fish assemblage. Five marine migrant species present in the Estuary are on the UK BAP list of priority species (cod, herring, plaice, sole, whiting).

2.4.52 In common with many UK estuaries, water quality improvements through the implementation of regulations to reduce the discharge of contaminants into the Severn Estuary have had beneficial effects on the fish community and over the past few decades the abundance of many marine migrant species (including bass, Dover sole, herring, sprat, thin-lipped grey mullet and whiting) has increased considerably. On the other hand, over the same period abundances of flounder, poor cod and sea snail have declined (Potter *et al.,* 2001).

2.4.53 Based on data from Hinkley B Power station which are considered to provide an indication of the stocks in the Estuary (Henderson *et al.,* 2007), cod numbers have generally increased since 1986 with peak abundances recorded between 1990 and 2000. The 2006/2007 season included the greatest single catch of herring in the Estuary and data would suggest that abundance is increasing. Plaice is the least common of the flatfish sampled at Hinkley B Power station with only a few individuals usually present in a 6 hr sampling period. Consistently high numbers of sole are recorded. Abundances of whiting peaked in the late 1990s and continues to be one of the most abundant species recorded at Hinkley Point B.

2.4.54 Of the marine migrant species present, sprat (*Sprattus sprattus*) is reported to be the most abundant (EA, *pers.comm*.), comprising the dominant functional group in both the Severn Estuary and Bristol Channel.

Baseline during construction (2014 – 2020)

2.4.55 Due to the vast number of marine migrant species in the Severn Estuary and a general paucity of information regarding their stock status it is not possible to predict any changes to the baseline conditions which may occur during the six year construction period. Some of the climate change aspects detailed below could however also occur within this time frame but to a lesser extent.

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

2.4.56 Increases in water temperature could be deleterious for certain species such as the common sea snail (*Liparis liparis*) which actively avoid warmer inshore waters during mild winters (Henderson & Holmes 1990). In contrast, an augmentation of water temperature would be potentially beneficial for bass and sole for which recruitment appears to be enhanced during warmer years. For example, Henderson & Seaby (2005) found sole abundance and growth in the Bristol Channel was correlated with seawater temperatures and the North Atlantic Oscillation Index (NAOI). In addition seawater temperature plays an important role in determining the growth and/or abundance of bass. Increased water temperatures could cause many species to continue to feed throughout the winter producing a change in seasonal production (Henderson, 2007).

2.4.57 A further consideration is that water temperature can be an important contributory factor to the distribution of many fish species. The Severn Estuary is close to the northern limit for the marine migrant thin-lipped grey mullet. Consequently, changes in temperature would be expected to influence the range of this species. In addition, species usually found at locations further south may be able to penetrate northwards and enter the Bristol Channel and/or Severn Estuary (Franco *et al*., 2008). The sea snail, which is close to the southern edge of its range in the Severn Estuary has been observed to become less abundant over the past few decades owing to increased average seawater temperature (Henderson, 2007). It may be in the future that this cold water loving species will no longer be found in the Severn Estuary.

2.4.58 Increased rainfall caused by climate change can lead to decreased salinity. A gradual decrease in salinity would potentially have a negative effect on common shrimp (*Crangon crangon*) as the females try to avoid salinities <12 ppt over winter. In order to find suitably saline waters, individuals which are ready to spawn would have to travel further and alterations in migration patterns of shrimp would potentially have knock-on effects on the movement of fish species such as 0+ whiting which are reliant on the shrimp food source. Henderson (2007) reports that total fish species in Bridgwater Bay has decreased over the past few decades with increasing salinity and this factor was also found to influence the distribution of individual species.

2.4.59 Henderson (2007) has carried out an assessment of a 25-year time series of monthly samples from Bridgwater Bay to predict the effects of future climate change on the fish community. The results show that the fish community is rapidly responding to changes in seawater temperature, salinity and the North Atlantic Oscillation (NAO). There has been a continuous increase in fish abundance and species richness over this 25 year period which could be related to increased temperature and decreased salinity in the outer Severn Estuary. There have been two discrete transitions to date, in 1986 and 1993. The first of these was a change in the relative abundance of the dominant species and was linked to changes in the NAO which brought about changes in the plankton in the north-east Atlantic. The second period represented a change in the occasional visitor species to the estuary and was linked to increased seawater temperatures.

2.4.60 A predicted 2°C increase in inshore seawater temperature, coupled with a decrease in salinity of 2 ppt was predicted by Henderson (2007) to lead to an increase in total species richness of fish in the Bridgwater Bay area by 10%, based on observation of the changes observed over the 25-year period. This increase in temperature will inevitably lead to a large change in the relative abundance of the dominant species in this area, including bass, grey mullet species, five-bearded rockling, pout and sole. Whilst the abundance of poor cod and sea snail would decline.

Receptor H: Marine Stragglers

Baseline environment (up to 2009)

2.4.61 The most common EUFG in the inner Bristol Channel (based on records for Bridgwater Bay) is the marine stragglers (59%). Five marine straggler species present in the estuary are on the UK BAP list of priority species (blue whiting, hake, horse mackerel, ling, saithe). The current baseline conditions for these species are unknown.

Baseline during construction (2014 – 2020)

2.4.62 Due to the vast number of marine straggler species and the paucity of data from which baseline conditions can be determined it is not possible to predict any changes to the baseline conditions which may occur during the six year construction period. Some of the climate change aspects detailed below could however also occur within this time frame but to a lesser extent.

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

2.4.63 Increased water temperatures and decreased salinity in the future is likely to affect the Severn Estuary marine straggler species in the same way as detailed above for marine migrants. This includes effects on growth, abundance and distribution. In addition, the predictions made by Henderson (2007), also detailed above, apply to the fish community as a whole and are therefore relevant to marine stragglers.

2.4.64 Water temperature can be an important contributory factor to the distribution of many fish species and the Severn Estuary is close to the northern limit for the marine straggler small-eyed ray, and is close to the southern limit for Norway pout and dab. Consequently, changes in temperature would be expected to influence the range of these species. Any species at its northern limit in the Severn Estuary should benefit from climate change with positive effects predicted. In addition, species usually found at locations further south may be able to penetrate northwards and enter the Bristol Channel and/or Severn Estuary (Franco *et al*., 2008). Seawater temperature has been identified as a key role in determining the growth and/or abundance of dab (Henderson, 2007). Indeed numbers of dab over the past few decades have decreased owing to increased average seawater temperature (Henderson, 2007).

2.4.65 Henderson (2007) predicts that a 2°C increase in average temperature in Bridgwater Bay would inevitably lead to a decrease in the number of dab but with an increase in species with ranges that extend further south, for example, the conger eel (*Conger conger*). Similarly occasional visitors to the estuary such as the red mullet, *Mullus surmuletus*, would probably become resident as the area is already acting as a summer nursery.

Receptor I: Estuarine Species

Baseline environment (up to 2009)

2.4.66 There are six estuarine species present in the Severn Estuary however only five are considered to be truly estuarine species: the black goby (*Gobius niger*), common goby (*Pomatoschistus microps*) sand goby (*Pomatoschistus minutus*), sand smelt (*Atherina boyeri*), three-spined stickleback (*Gasteosteus aculeatus* – which is however also classed as a freshwater species) and the worm pipefish (*Nerophis lumbriciformis*). These species comprise ≤5% of the fish assemblage of the Severn

Estuary. The abundance of sand goby in the estuary increased considerably between the 1970s and the late 1990s. The current baseline conditions for these species are unknown.

Baseline during construction (2014 – 2020)

2.4.67 Due to the paucity of data from which baseline conditions can be determined it is not possible to predict any changes to the baseline conditions which may occur during the six year construction period. Some of the climate change aspects detailed below could however also occur within this time frame but to a lesser extent.

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

2.4.68 It is unclear whether the increase in abundance of sand goby observed previously will continue in the future. Increased rainfall however caused by climate change can lead to decreased salinity and could affect the distribution of estuarine species in the estuary. Euryhaline species can tolerate freshwater and their distribution may not be affected by decreased salinity penetration into the Estuary. Less euryhaline species have their distribution governed by salinity, frequently moving location according to salinity to maintain an isotonic state. These species may move seaward if salinity penetration decreases.

Receptor J: Freshwater Stragglers

Baseline environment (up to 2009)

2.4.69 The proportion of freshwater straggler species in the estuary is far higher than in the Bristol Channel due to the greater proximity of the River Severn, and the freshwater discharges from the Rivers Usk and Wye. Roach (*Rutilus rutilus*), trout (*Salmo trutta*), common bream (*Abramis brama*), carp (*Cyprinus carpio*), silver bream (*Abramis bjoernka*), rudd (*Rutilus erythrophthalamus*), crucian carp (*Carassius carrasius*), dace (*Leuciscus leuciscus*), ten-spined stickleback (*Pungitius pungitius*), and single specimens of gudgeon (*Gobio gobio*), goldfish (*Carassius auratus*), and chub (*Leuciscus cephalus*) have all been recorded in the Severn Estuary (Potter *et al*., 1986). If use of the estuary by freshwater species has not changed considerably over the last decade or so, as an estuarine functional group freshwater stragglers could comprise up to 10% of the fish species present within the inner estuary (Potter *et al*., 1986), compared to ~2% in the inner channel. The current baseline conditions for these species are unknown.

Baseline during construction (2014 – 2020)

2.4.70 Due to the large number of freshwater straggler species recorded in the Severn Estuary and the paucity of data from which baseline conditions can be determined it is not possible to predict any changes to the baseline conditions which may occur during the six year construction period. Some of the climate change aspects detailed below could however also occur within this time frame but to a lesser extent.

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

2.4.71 Increased rainfall caused by climate change can lead to decreased salinity. Decreased salinity of estuarine waters could lead to greater penetration of freshwater species to more seaward locations.

2.4.72 Increased water temperatures and decreased salinity in the future is likely to affect the Severn Estuary freshwater straggler species in the same way as detailed above for marine migrants. This includes effects on growth, abundance and distribution. In addition the predictions made by Henderson (2007), also detailed above, apply to the fish community as a whole and are therefore relevant to freshwater stragglers.

2.5 Key Environmental Issues and Problems

2.5.1 A number of the protected species discussed above are currently failing to meet their conservation objectives or conservation limits as set out in a number of policies and plans (as discussed above). This is due to a number of factors which are outlined below.

2.5.2 A number of limiting factors on salmon stocks in the Rivers Severn, Usk and Wye have been indentified in the SAPs (EA, 1998, 2003ab) which include: restricted access to potential spawning and nursery areas, poor water quality, physical habitat degradation, avian predation of juvenile salmon, and over-exploitation of stocks for all three rivers and the additional effect of abstraction and water quantity for the Usk and low flows in the Severn.

2.5.3 The Core Management Plans for the River Usk/ Afon Wysg and River Wye/ Afon Gwy SACs list a number of issues affecting their designated features. For the River Usk these are abstraction causing flow depletion and fish entrainment, partial and total barriers to migration, degraded water quality due to agriculture, forestry and development pressures, siltation of spawning substrates, and exploitation (CCW, 2008a). These issues have been identified to affect both the salmon and shad populations in this river (CCW, 2008a). The main issue identified as effecting lamprey populations was entrainment into water abstractions (CCW, 2008a). In addition for sea lamprey the effect of flow depletion resulting from a number of major abstractions has been highlighted (CCW, 2008a).

2.5.4 On the River Wye the potential effect of flow depletion resulting from a small number of major abstractions was highlighted as presenting a risk to sea lamprey and shad populations and there are requirements for screening of intakes to reduce or remove the effect of impingement and entrainment of migrating fish (CCW, 2008b). Barriers to migration were highlighted as adversely affecting salmon and shad populations, in particular, temporary barriers (acoustic, physical and chemical) caused by development activities were highlighted as presenting a risk to shad (CCW, 2008b). Exploitation of shad and salmon was also highlighted as affecting stocks of these species (CCW, 2008b).

2.5.5 There is believed to have been a loss of eel habitat in the Severn catchment over the last-half century due mainly to construction of barriers (EA, 2009). In a recent assessment, a total of 448 potential obstructions within the Severn River Basin were identified including mills, sluices, weirs, bridge sills and dams (EA, 2009). Many of these obstructions are low down on river systems and therefore can prevent access to large areas of eel habitat (EA, 2009). Entrainment and hydropower may also present a risk to eel populations although the extent of this effect is largely unknown (EA, 2009).

2.5.6 As identified within the future baseline scenarios for a number of the species there is the potential for climate change to alter their population status either positively or negatively. Where it is predicted that climate change has a negative effect upon

population levels there could be a risk of failure of key pieces of legislation and policy in the absence of an STP plan alternative within which population targets are specified such as Conservation Limits for salmon within SAP's.

2.5.7 Other pressures upon the fish receptors are likely to include existing and planned industry in particular those that abstract water from the Estuary and its tributary rivers and fishery pressures whether recreational or commercial.

2.6 Value and Vulnerability of Receptors

2.6.1 The SEA seeks to identify those environmental effects which are likely to be significant. In forming a judgement on effect significance, in line with the SEA Directive, it is necessary to take into account the attributes of the affected area. In this SEA, the area likely to be affected is described in terms of receptors; and the most relevant receptor attributes are their value and vulnerability. These are defined as:

- **Value**: based on the scale of the geographic reference, rarity, importance for biodiversity, social or economic reasons, and level of legal protection;
- **Vulnerability**: the potential for a pathway for exposure of a receptor to a given environmental effect, brought about by a Severn Tidal Power option, together with the sensitivity of the receptor to that effect.

A standardised approach has been adopted across all topics of this SEA to the assignment of receptor attributes. Nonetheless this approach did allow for some flexibility to reflect the needs of each topic area. This is discussed further below for this topic.

2.6.2 Appendix x provides more detail on the process and approach used to assign value and vulnerability to each of the topic fish receptors. Determination of the value and vulnerability of each of the fish receptors under consideration followed a Technical Workshop with statutory and key consultees, which was held to discuss the process and approach used.

2.6.3 For the purpose of assigning value to the migratory and estuarine STP fish receptors the guidelines produced by the Institute of Ecology and Environmental Management[2] have been adopted.

2.6.4 The 'Migratory and Estuarine Fish Value, Vulnerability and Magnitude of Effect Briefing Note' sets out the values for the migratory and estuarine fish receptors. The Severn Estuary fish assemblage is assigned a high value due to its international protected status through the Severn Estuary/ Môr Hafren SAC and Severn Estuary Ramsar designations. This assemblage includes the migratory species sea lamprey, river lamprey, twaite shad, allis shad, salmon, sea trout and eel), as well as the following:

- Estuarine species
- Species typically occurring and breeding in estuaries
- Marine species occurring in large numbers in estuaries

[2] Institute of Ecology and Environmental Management (2006) *Guidelines for Ecological Impact Assessment in the United Kingdom* (version 7 July 2006). http://www.ieem.org.uk/ecia/index.html

- Marine species
- Predominantly marine species occurring infrequently in the Severn
- Freshwater species
- Species typically occurring and breeding in freshwater and recorded within the Severn Estuary/Môr Hafren SAC

Table 2.9 Value of Receptors

Receptor	Assigned Value
Atlantic salmon	High
Sea trout	High
Shad (allis and twaite)	High
Lamprey (river and sea)	High
Eel	High
Sturgeon	High
Marine migrants (sensitivity based on UK BAP species: cod, herring, plaice, sole and whiting)	High
Marine stragglers (sensitivity based on UK BAP species: blue whiting, hake, horse mackerel, ling & saithe)	High
Freshwater stragglers	Low (High)
Estuarine species	Low (High)

2.6.5 For freshwater stragglers and estuarine species values are assigned for the individual guilds and for the fish assemblage as a whole. The latter value is indicated in brackets.

2.6.6 Levels of vulnerability were assigned for each receptor based on its value (see above), an assessment of its sensitivity (based on factors such as recoverability and intolerance) and the level of exposure. The evaluation of relative exposure was based on the potential effects upon the migratory and estuarine fish receptors identified within Phase 1 of the STP feasibility study:

- Alterations to migratory cues;
- Disruption to route of passage;
- Habitat change and/or loss;
- Changes to water quality;
- Economic effects upon recreational and commercial fisheries

Based on these assessments the vulnerability levels as detailed in Table 2.10 were assigned to each fish receptor.

Table 2.10 Vulnerability of Receptors

Receptor	Assigned Vulnerability
Atlantic salmon	High
Sea trout	High
Shad (allis and twaite)	High
Lamprey (river and sea)	High
Eel	High
Marine migrants (sensitivity based on UK BAP species: cod, herring, plaice, sole and whiting)	Moderate
Marine stragglers (sensitivity based on UK BAP species: blue whiting, hake, horse mackerel, ling & saithe)	Moderate
Freshwater stragglers	Moderate
Estuarine species	Moderate

SECTION 3

EVALUATION OF PLAN ALTERNATIVES

3 EVALUATION OF PLAN ALTERNATIVES

3.1 Introduction

3.1.1 The SEA Directive requires the preparation of an Environmental Report on the 'likely significant effects' of implementing the plan, and reasonable alternatives. The main purpose of this topic paper is to inform the SEA Environmental Report and its assessment of likely significant environmental effects. This is by providing an assessment of effects in relation to the topic paper's relevant receptors. The Environmental Report will then consolidate the individual topic assessments to provide a description of all likely significant effects across the affected area.

3.1.2 The SEA Directive instructs that SEA is to be based on information that can reasonably be required, taking into account *inter alia* current knowledge and methods of assessment.

3.1.3 For the purposes of this SEA, the plan alternatives are the shortlisted options currently under consideration following the phase 1 consultation (DECC, 2009a). These are described as the alternative options in this document.

3.2 Assessment Methodology

3.2.1 The SEA Directive specifies in Annex II the criteria that should be taken into account when determining the likely significant effects of the plan. The criteria for identifying these significant effects are defined in the Directive in relation to determining whether an SEA is needed. These criteria will also be adopted for this assessment. In line with the SEA Regulations, the Practical Guide advises the use of these criteria for assessing significant environmental effects.

3.2.2 This topic paper therefore considers, the characteristics of the effects and of the area (i.e. relevant receptors) likely to be affected, having regard, in particular, to:

- the probability, duration, frequency and reversibility of the effects;
- the cumulative nature of the effects;
- the transboundary nature of the effects;
- the risks to human health or the environment (for example, due to accidents);
- the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected);
- the value and vulnerability of the area likely to be affected due to:
    - special natural characteristics or cultural heritage;
    - exceeded environmental quality standards or limit values; or
    - intensive land-use; and

- the effects on areas or landscapes which have a recognised national, Community or international protection status.

3.2.3 The magnitude of effects has been assigned values ranging from negligible to high based on the definitions set out below in Table 3.1.

Table 3.1 Thresholds for Magnitude of Effects

Magnitude	Definition
High	A permanent or long-term effect on the extent/integrity of a species population or assemblage. If adverse, this is likely to threaten its sustainability/ conservation status; if beneficial, this is likely to enhance its conservation status
Medium	A permanent or long-term effect on the integrity of a species population or assemblage. If adverse, this is unlikely to threaten its sustainability/ conservation status; if beneficial, this is likely to be sustainable but is unlikely to enhance its conservation status
Low	A permanent or long-term reversible effect on the integrity of a species population or assemblage whose magnitude is detectable but would not threaten or enhance its integrity
Very Low	A short-term but reversible effect on the integrity of a species population or assemblage that is within the normal range
Negligible	An effect to a species population or assemblage whose magnitude is not detectable.

3.2.4 The SEA Directive (Annex I) also states that these effects should include secondary, cumulative, synergistic, short, medium and long-term permanent and temporary, positive and negative effects. The Practical Guide recognises that some of these terms are not always mutually exclusive and for the avoidance of doubt, within this SEA the following approaches are adopted.

3.2.5 Direct effects are the original effect as a result of an option. Of relevance to the Migratory and Estuarine Fish Topic are the following:

- Changes in water exchange leading to changes in water column and sediment properties;
- Direct footprint of the plan alternative;
- Fish injury and death; and
- Physical structure including ancillary works during construction, operation and decommissioning activities.

3.2.6 Indirect effects are those which are not a direct result of a Severn Tidal Power alternative option, but occur away from the original effect or as a result of a complex pathway. There are many such interactions within estuarine systems that need to be taken into account in this assessment. The SEA does not use the term 'secondary effects' as this is covered by indirect effects.

3.2.7 There is the potential for effects to extend large distances from the Severn estuary. The assessments of these 'far field' effects will have greater uncertainty attached and are described separately.

3.2.8 Cumulative effects arise, for instance, where several developments each have insignificant effects but together have a significant effect. The plans and projects taken into account in the cumulative effects assessment have been identified and agreed (STP, 2009b). These are discrete projects or programmes which are expected to be implemented during the planned Severn Tidal Power project construction period (2014-2020) or during the operation period (2020-2140).

3.2.9 For simplicity, this SEA does not use the term 'combined' effects, as these are considered to be included within cumulative effects, nor does it use the term 'synergistic' effects, as these are considered within direct, indirect and cumulative effects.

3.2.10 A major tidal power scheme may facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'. The types of consequential development considered throughout the assessment have also been identified (STP, 2009b). These consequential developments are not well-defined and only a concise high level qualitative assessment of the likely effects is possible.

3.2.11 The topic specialist studies and methods used to assess options' effects are as follows:

- Desk-based research/literature review of potential effects resulting from alterations to migratory cues, anthropogenic noise disturbance and indirect effects upon the marine/estuarine and freshwater fish communities.
- Stochastic numerical models to determine potential effects arising from turbine passage inclusive of blade strike, pressure and shear stress injury rates.
- Numerical modelling to determine potential compound mortality rates resulting from turbine passage
- Qualitative expert judgement based assessment of remaining potential effects from disruption to route of passage based where possible upon plan alternative scheme specific information provided by the STP SEA consortium engineers.
- HR Wallingford fish movement model (salmon adults & smolts)
- Extrapolation and adjustment of HR Wallingford fish movement model to provide an indication of potential for multiple passes through turbine of all fish species or groupings.
- Qualitative assessment of effects of changes to habitat and water quality utilising WQ and Habitat loss models produced by other STP SEA consortium topic studies
- Evaluation of potential effects to fisheries informed by their valuation.

3.2.12 Qualitative expert judgement was used to assess remaining potential effects.

3.3 Alternative Options

3.3.1 Five options for the development of tidal power using the tidal range of the Severn Estuary have been identified as the preferred candidates for more detailed study. The five options comprise three tidal barrages and two tidal lagoons. The details of these options are described below. Figure 3.1 shows the location of alternative options.

Alternative Option B3: Brean Down to Lavernock Point Barrage

3.3.2 B3 'Brean Down to Lavernock Point' barrage is the largest of the barrage short-listed options being an approximately 16km long structure impounding the Bristol Channel between Lavernock Point near Cardiff and Brean Down, adjacent to Weston-Super-Mare. The deepest point of this barrage location is at its centre, reaching between 30 to 40m deep. The chosen variant (original) functions in ebb only mode. In total there are 216 Bulb-Kapeller type turbines with a rated output of 40MW. The estimated annual energy output for the variant (including 5% outages) is 15.1 to 17.0 TWh/year.

3.3.3 Key features include a total of 129 caissons of which 29 are plain caissons, 46 are sluice caissons and 54 are turbine caissons, spread across the length of the barrage. The central point includes a 778m long embankment flanked by two sets of the turbine caissons. The barrage also includes two locks, one main shipping lock towards Lavernock Point side and a small ship lock towards Brean Down.

Alternative Option B4: Shoots Barrage

3.3.4 The B4 Shoots Barrage is an approximately 7km long structure impounding the Inner Bristol Channel between land adjacent to West Pill on the Welsh side and Severn Beach on the English side. The proposed structure comprises a combination of embankments within the shallow water and caissons within the deeper channel. Variant 3 was chosen as the short-listed option. It operates in ebb only mode with 30 Bulb-Kaplan type turbines, with a rated output of 35MW. The estimated annual energy output for the variant (including 5% outages) is 2.7 to 2.9 TWh/year.

3.3.5 The barrage consists of a total of 46 caissons (6 plain, 25 sluice and 15 turbine/sluice caissons), enclosed on both sides by 2 embankments totalling approximately 5km (3km approximate length of embankment to the Welsh Side and 2.2km approximate length to the English side). A 40m wide shipping lock has been placed at the deepest section of the channel.

Alternative Option B5: Beachley Barrage

3.3.6 The B5 Beachley Barrage is the smallest of the short-listed barrage schemes. It is a 2km long structure running from Beachley on the Welsh side of the River Severn to land directly to the east on the English side. The original variant was chosen as the short-listed option, operating in ebb only mode with 50 Straflo type turbines with a rated output of 12.5 MW. The estimated annual energy output for the variant (including 5% outages) is 1.4 to 1.6 TWh/year.

3.3.7 Its key features include a total of 31 caissons (9 plain, 9 sluice and 13 turbine/sluice) spread across approximately 1.5km of the length of the barrage and flanked by two embankments. A 40m wide shipping lock is located on the English side of the barrage.

Alternative Option L2: Welsh Grounds Lagoon

3.3.8 L2 Welsh Grounds Lagoon is the largest of the lagoon short-listed options with an approximate length of 28km starting from land adjacent to the mouth of the River Usk, running in a general easterly direction across an area referred to as Welsh Grounds, continuing to the south of Denny Island and reaching land fall adjacent to the Second Severn Crossing. L2 variant 8 was based on a turbine selection proposed by the Fleming group. It was unique in this respect compared to other variants whose turbine selections have all been made by PB. Variant 8 operates in ebb only mode with 40 Bulb Turbines with a rated output of 25MW. The estimated annual energy output for the variant (including 5% outages) is 2.6 to 2.8 TWh/year.

3.3.9 Key features include a total of 32 caissons (8 plain, 14 sluice & 10 turbine caissons), and one shipping lock.

Alternative Option L3d: Bridgwater Bay Lagoon

3.3.10 L3D Bridgwater Bay Lagoon is a land connected tidal lagoon comprising approximately 16km long embankment, proposed to run from land falls at Brean Down in the north to just east of Hinckley Point in the south. The short-listed Variant 9 option is the only scheme to operate in ebb & flood mode, with a total of 144 Bulb-Kaplan turbines with a rated output of 25MW. The estimated annual energy output for this variant (including 5% outages) is 5.6 to 6.6 TWh/year.

3.3.11 Key features include a total of 42 caissons (6 plain and 36 turbine caissons), a 40m wide shipping lock and approximately 12km of embankment.

3.4 Summary of Potentially Significant Issues

3.4.1 During Phase 1 SEA Scoping, a review was conducted of the environmental issues that should be considered within the scope of the SEA (DECC, 2009a). The scope of issues was for the most part confirmed through the Government response to the consultation (DECC, 2009b). These issues formed the starting point for the assessment of likely significant environmental effects, and are discussed further for this topic below.

3.4.2 The potentially significant issues upon the migratory and estuarine fish receptors identified during scoping and subsequent technical workshops are:

- Alterations to migratory cues;
- Disruption to route of passage including turbine passage;
- Habitat change and/or loss;
- Changes to water quality;
- Anthropogenic noise disruption.

3.4.3 In addition, a potential reduction in the number of migratory fish in the rivers feeding the Severn Estuary, as a result of the effects discussed above, could potentially have

indirect effects on freshwater species present within the rivers. Similarly a reduction in the numbers of marine, estuarine and migratory fish in the Estuary could have knock-on effects upon other fish species. As these indirect effects have the potential to lead to a loss of individuals this could also have implications upon the recreational and commercial fisheries in the area which target them. There could also be potential effects in terms of access to fishing grounds; for example, the STP may act as a physical barrier and restrict access or alternatively increase the availability of fishing grounds to commercial boats.

3.5 Assessment of Likely Significant Effects on the Environment

3.5.1 This section considers, within this topic, the likely significant effects on the environment for each alternative option. These may arise from direct, indirect, far field, cumulative and consequential development effects during construction, operation and decommissioning phases, definitions of which are given above. It is considered that the far field, cumulative and consequential development effects for each potentially significant issue are applicable to all STP plan alternatives and therefore generic discussion of these is detailed below. Similarly the assumptions, limitations and uncertainties surrounding the assessments made are applicable to the effects themselves and not the plan alternative and are therefore within this generic discussion section only.

3.5.2 A detailed assessment of each of the STP plan alternatives is contained within Annex 1: Evaluation of plan alternative and a brief summary of the headline messages are provided below. For detailed information regarding potential effects and supporting information regarding the magnitude of effect classification assignment Annex 1: Evaluation of plan alternative should be read in conjunction with this Topic Paper.

Direct effects

Construction Phase

Alterations to migratory cues

3.5.3 The direct effects which could lead to alterations to migratory cues are:

- Changes to water exchange leading to delayed release of freshwater discharge into the Estuary downstream of the B3 STP plan alternative;
- Changes to the hydraulic mixing regime of water from each river;
- Changes to water quality brought about through changes in water exchange leading to changes in the water column.

Disruptions to route of passage

3.5.4 Fish passage through tidal power schemes, in particular turbine passage, would likely be the primary source of fish injury and mortality and consequently make the greatest contribution to overall STP effects upon fish populations within the Severn Estuary.

3.5.5 Injuries could lead to direct mortality of a fish. Additionally if injuries are not immediately lethal, fish could suffer delayed and indirect mortality sometime after passage. Not all fish species and life stages would suffer injuries and the extent of injury sustained would

differ. In addition to disruption to route of passage associated with turbine passage, there is also the potential for the effects of the STP alternative option structure on the hydrology of the Estuary to have implications upon active migration and passage utilising tidal transport. The passive delivery of species into sub-estuaries of the Severn Estuary for example could be affected by an STP plan alternative. This is likely to affect those species which migrate through the Estuary and into freshwater using passive tidal transport, for example glass eel. Disruption to route of passage may therefore result in the imposition of new migratory routes which could have adverse effects upon the fish receptors. It is considered likely that these effects would take the same or similar form as indirect and non-fatal effects potentially including mortality as well as reduced viability and long-term survival rates and success.

3.5.6 The potential for the construction phase of an plan alternative to have an effect upon the route of passage of fish species is largely dependent upon the nature of the construction activities. As the plan alternative was developed and the structure placed into position there would be potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement.

Habitat change and/or loss

3.5.7 The direct effects which could lead to habitat change and/or loss are:

- Changes in water exchange leading to changes in water column and sediment properties;
- Direct footprint of the plan alternative leading to a loss of habitats.

Changes to water quality

3.5.8 Changes to water quality could be brought about through change in water exchange leading to changes in the water column and sediment properties.

Anthropogenic noise disturbance

3.5.9 The source of the direct effects associated with the generation of anthropogenic noise disturbance would be the physical structure and associated ancillary works. Construction phase activities that would generate anthropogenic noise disturbance include rock breaking through the use of explosives and rock fill. The use of explosives can generate short term frequencies which are in the range of 2 Hz to ca. 1 kHz (the main energy typically is in the range of 6 to 21 Hz) with source levels of 272 to 287 dB re 1µPa for a charge of 1 to 100 lb TNT. Dredging and trenching activities would likely produce low frequency noise up to 1 kHz, although there is the possibility that frequencies up to 80 kHz could occur. Sound pressure levels are assumed to be between 100 and > 180 dB re 1µPa. The movement of vessels associated with construction would add further to the noise disturbance, and for this assessment are considered within the range of 20 to 5 kHz at sound pressure levels of between 110 and 179 dB re 1µPa. This gives an overall range of 2 Hz to 5 kHz, with the possibility of extension up to 80 kHz and an overall sound pressure range of 100 to 287 dB re 1µPa of noise disturbance that could be experienced during construction.

Effects on freshwater, marine and estuarine fish species

3.5.10 All of the direct effects detailed in the proceeding sections could lead to effects upon the ecosystem as a whole including the fish communities of the Estuary and its tributaries.

Effects on recreational and commercial fisheries

3.5.11 All of the direct effects detailed in the proceeding sections could lead to economic effects upon the fisheries, in particular losses to the populations of fish targeted by the various fisheries within the Severn Estuary and its tributaries.

Operational Phase

Alterations to migratory cues

3.5.12 The direct effects which could lead to alterations to migratory cues comprise changes to water exchange leading to delayed release of freshwater discharge into the Estuary downstream of the alternative option. In addition the hydraulic mixing regime of water from each river also has the potential to disrupt migratory cues. Marine and estuarine species may be affected by alterations to migratory cues as a result of changes to certain abiotic factors, principally salinity and temperature.

Habitat change and/or loss

3.5.13 The direct effects which could lead to habitat change and/or loss have been considered as changes in water exchange leading to changes in water column and sediment properties.

Changes to water quality

3.5.14 The direct effects which could lead to changes in water quality comprise changes in water exchange leading to changes in the water column and sediment properties.

Anthropogenic noise disturbance

3.5.15 The source of the direct effects will be the physical structure and the ancillary works. For this assessment it has been assumed that operational activities with the potential to cause noise effects would be turbine operation, movement of other mechanical components, and movements of vessels required for maintenance. Mechanical faults could change the expected range and duration of sound frequencies. For this assessment the assumed range of expected noise generated by a turbine unit was taken as being between 0 Hz and 8.5 kHz at a sound pressure level up to 200 dB. Infrasound from 18 to 30 Hz is assumed to be the dominant energy that would be produced.

Effects on freshwater, marine and estuarine fish species

3.5.16 All of the potential direct effects detailed in the proceeding sections could lead to effects upon the ecosystem as a whole including the fish communities of the Estuary and its tributaries.

Effects upon recreational and commercial fisheries

3.5.17 All of the direct effects detailed in the proceeding sections could lead to economic effects upon the fisheries, in particular losses to the populations of fish targeted by the various fisheries within the Severn Estuary and its tributaries.

Decommissioning Phase

Alterations to migratory cues

3.5.18 It is considered that direct effects arising from decommissioning would be similar to construction. These could comprise changes to water exchange during decommissioning leading to delayed release of freshwater discharge into the Estuary downstream of the alternative option. In addition changes to the hydraulic mixing regime of water from each river also has the potential to disrupt migratory cues. Marine and estuarine species may be affected by alterations to migratory cues as a result of changes to certain abiotic factors, principally salinity and temperature.

Habitat change and/or loss

3.5.19 Decommissioning activities and their associated effects would likely be similar to those experienced during construction. These comprise changes in water exchange leading to changes in water column and sediment properties.

Changes to water quality

3.5.20 Changes to water quality could be brought about through change in water exchange leading to changes in the water column and sediment properties.

Anthropogenic noise disturbance

3.5.21 Decommissioning phase activities would likely be similar to those experienced during construction. Accordingly an overall range of 2 Hz to 5 kHz, with the possibility of extension up to 80 kHz and an overall sound pressure range of 100 to 287 dB re 1µPa was assumed for this assessment.

Effects on freshwater, marine and estuarine fish species

3.5.22 All of the direct effects detailed in the proceeding sections could lead to effects upon the ecosystem as a whole including the fish communities of the Estuary and its tributaries.

Effects upon recreational and commercial fisheries

3.5.23 Upon decommissioning of the STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. It is considered that the magnitude of negative effects upon the fisheries would be negligible to medium.

Far field effects

3.5.24 There are potential for farfield effects to occur for all alternative options which it is not considered possible with current available information in particular regarding the natural excursion straying behaviour of migratory fish species to accurately

distinguish between the different alternative options. It is therefore considered that were individuals to enter the Severn Estuary then there is a risk that they could be affected by any of the alternative options. The below text is therefore considered applicable to all alternative options and will not be considered further within the individual option assessments.

Alterations to migratory cues

3.5.25 It is considered that only migratory fish from rivers impounded by the plan alternatives would be affected by alterations to migratory cues. Returning adult lamprey however could be affected by alterations to migratory cues and innate attraction odour cues from resident lamprey larvae which could reduce the density of lamprey in the impounded rivers. This could therefore represent an effect upon the UK river lamprey population as a whole and the European population of sea lamprey.

Disruptions to route of passage

3.5.26 In addition to the fish populations detailed within the plan alternatives assessment it is considered that there is also the potential to disrupt the route of passage of other more distant populations potentially resulting in adverse effects. Due to the straying nature of a number of the migratory species it is considered that fish from far field populations may pass through the Estuary and as such come into contact with a plan alternative. The populations potentially affected are as detailed within the determination of study area section above. There is potential that fish from populations designated under Natura 2000 sites outside of the Severn Estuary could be at risk of effect from a plan alternative. The list of sites potentially at risk are as detailed within the designated sites to be considered section above. It is considered that the potential of an effect to occur upon these protected species as a result of a plan alternative disrupting their route of passage is possible. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. The predicted magnitude of effect is considered to be low.

Habitat change and/or loss

3.5.27 In consideration of possible far field effects from habitat change and/or loss associated with the construction, operation and decommissioning of an STP plan alternative current knowledge of the biogeographic distribution of the migratory fish species provides the following assessment. The straying nature of both Atlantic salmon and sea trout leads to the possibility that fish returning to nearby rivers could instead enter the Severn Estuary and be affected by the consequent change and/or loss to habitats present. Movement into non-natal estuaries is also possible for both allis and twaite shad and habitat change and/or loss within the Severn Estuary could potentially effect far field populations. \there is potential that any impact to lamprey resulting from habitat change and/or loss associated with an STP plan alternative could effect the UK population as a whole with regard to river lamprey, and possibly the European population with regard to sea lamprey. The effects associated with habitat change and/or loss that originate within the Severn Estuary on European eel have the potential to effect the European population of this species. Effects resulting from habitat change and/or loss would have the potential to effect far field stocks of marine migrants. The estuarine species present are more likely to be from discrete populations within the Estuary, and as such effects resulting from habitat change and/or loss are considered likely to effect the Severn Estuary population only. There is potential that fish from populations designated under Natura 2000 sites outside of the Severn Estuary could be at risk of effect from a plan alternative. The list of sites

potentially at risk are as detailed within the designated sites to be considered section above.

Changes to water quality

3.5.28 On consideration of possible far field effects from changes to water quality associated with the construction, operation and decommissioning of an STP plan alternative, current knowledge of the biogeographic distribution of the migratory fish species provides the following assessment. Atlantic salmon and sea trout from other nearby rivers could be affected. Only the Severn and Bristol Channel catchment populations of shad are considered likely to be affected. The UK population of lamprey and possibly the European population of sea lamprey could be affected. The European population of eel could be affected. Far field stocks of marine migrants could be affected. The Severn Estuary population of estuarine species could be affected. With regard to freshwater stragglers, only the populations from the tributary rivers of the Severn Estuary could potentially be affected. There is potential that fish from populations designated under Natura 2000 sites outside of the Severn Estuary could be at risk of effect from a plan alternative. The list of sites potentially at risk are as detailed within the designated sites to be considered section above.

Anthropogenic noise disturbance

3.5.29 On consideration of possible far field effects from anthropogenic noise disturbance associated with the construction, operation and decommissioning of an STP plan alternative, current knowledge of the biogeographic distribution of the migratory fish species provides the following assessment. Atlantic salmon and sea trout from other nearby rivers could be affected. Only the Severn and Bristol Channel catchment populations of shad are considered likely to be affected. The UK population of lamprey (and possibly the European population of sea lamprey) are considered likely to be affected. The European population of eel are considered likely to be affected. Far field stocks of marine migrants could be affected. The Severn Estuary population of estuarine species is considered likely to be affected. There is potential that fish from populations designated under Natura 2000 sites outside of the Severn Estuary could be at risk of effect from a plan alternative. The list of sites potentially at risk are as detailed within the designated sites to be considered section above.

Effects on freshwater, marine and estuarine fish species

3.5.30 It is considered that if far field effects were to occur on migratory fish species from other rivers, that there is the potential for resident freshwater species within these rivers to be indirectly affected. It is however considered unlikely that the extent of effects upon migratory fish species would result in a significant adverse effect upon freshwater fish populations. There is potential that fish from populations designated under Natura 2000 sites outside of the Severn Estuary could be at risk of effect from a plan alternative. The list of sites potentially at risk are as detailed within the designated sites to be considered section above.

Effects on recreational and commercial fisheries

3.5.31 The Severn Estuary is a key nursery ground for marine and estuarine fish species which are targeted by the commercial fisheries of the Severn Estuary and beyond. Although the extent of the importance of the nursery grounds within the Severn Estuary for far field commercial fisheries is unknown there is potential for some effect to occur upon them. As with the direct and other indirect effects upon the migratory salmonids the natural excursion straying behaviour of these species could result in losses to far field

populations which could subsequently result in effects upon the salmonid recreational fisheries of other rivers within the potential far field zone of effect detailed within the introductory text above.

Cumulative effects

3.5.32 This review of alternative options considers any cumulative effects which could arise as a consequence of the STP alternative options and other projects, plans and programmes. A definitive list of projects, plans and programmes to be considered for cumulative effects is given in the following document: "Cumulative Effects & Consequential Developments". This includes construction-based projects which would be completed before the likely construction start date for an STP alternative option of 2014 and hence need to be considered as part of the future baseline (e.g. Prenergy Woodchip plant, Defence training academy facilities (RAF St Athan) and the Severn Sea Ferry) in addition to discrete projects or programmes which are expected to be implemented during the planned STP project construction period (2014-2020) or during the operation period (2020-2140) (e.g. Decommissioning of Uskmouth Power Station, future nuclear development at Oldbury, Hinkley Point "A" and "B" Nuclear Plant decommissioning and "C" development). Detailed information on the process of identifying the cumulative effects is also given in this document.

3.5.33 Due to the natural excursion straying behaviour of the migratory fish species and the area utilised by the marine species it is considered that there is the potential for cumulative effects to be experienced with any of the alternative options. With the current extent of available information it is not considered possible to distinguish between these effects for each of the alternative options. The below text is therefore considered applicable to all alternative options and will not be considered further within the individual option assessments.

Alterations to migratory cues

3.5.34 From the information available on the projects, plans and programmes for inclusion in this assessment it is not considered that any would lead to cumulative effects upon migratory cues. This is based on the assumption that none would involve the impoundment of rivers.

Disruptions to route of passage

3.5.35 From the information available on the projects, plans and programmes for inclusion in this assessment it is not considered that any would lead to cumulative effects upon the migration or movement of the fish species within the Severn Estuary. This is based upon the assumption that none of these would involve the impoundment of rivers or any section of the Estuary or involve substantial works within the Estuary.

Habitat change and/or loss

3.5.36 The following projects/plans and programmes could potentially lead to cumulative effects in terms of habitat change and/or loss:

3.5.37 Bristol Port Co. – Potential negative effects of the proposed development of a deep sea container terminal at Bristol on the intertidal and subtidal benthic communities were identified during the Environmental Scoping Report for this development.

3.5.38 Steart Coastal Management Project: Proposed managed realignment with habitat creation as part of a compensation plan alternative for the Bristol Port Deep Sea

Container Terminal. This has the potential to have beneficial effects in terms of the habitats in the Severn Estuary.

3.5.39 The applications for marine aggregate dredging would also potentially result in loss of habitat in the subtidal areas of the Estuary. The numerous Power Station plans (e.g. Helius Energy, Oldbury, Hinkley) also have the potential to lead to small local-scale habitat loss or change if facilities were built in the intertidal or subtidal area.

Changes to water quality

3.5.40 When considering possible cumulative effects to changes in water quality that might be expected to occur within the lifetime of an STP plan alternative it is apparent that the potential exists for further changes in water quality to occur, although these would likely happen at varying times and over various timescales. A qualitative overview is provided here, which is intended only to illustrate the range of conditions likely to be encountered. For example the existence of already operational power stations will contribute to what might be considered the current baseline water quality in the Severn Estuary. Should the decommissioning of any of these plants occur during the lifetime of an STP plan alternative there would, for a short duration, be potential changes in factors influencing water quality, such as sediment disturbance and accidental spills of fuel or building materials. The construction of other new power plants, industrial plants or container terminals would add to the potential for change in water quality during construction, and then a permanent change in water quality could occur during their individual lifetimes. If decommissioning of any of these structures should happen within the lifetime of an STP plan alternative then further cumulative effects to water quality within the Severn Estuary could also occur. Ongoing activities within the Severn Estuary area (e.g. coastal defence management, already licensed marine aggregate dredging) would contribute to the current baseline, while new managed realignment scenarios and new licenses for marine aggregate dredging would add cumulatively to the changing water quality effects present within the Severn Estuary. Building work on land bordering the Estuary whether small scale (localised to one site) or large scale (multiple sites or improvements to transport or energy infrastructure) have the potential to contribute to short term (relative to lifetime of an STP plan alternative) changes in water quality effects. Operation of a ferry service across the Severn Estuary or Bristol Channel could add a cumulative effect to changes in water quality effects during construction and decommissioning of ferry terminals should new buildings be required. There would also be the potential, during operation of ferry services, for accidental spills of fuel or grey water from the ships themselves.

Anthropogenic noise disturbance

3.5.41 When considering possible cumulative effects to anthropogenic noise disturbance that might be expected to occur within the lifetime of an STP plan alternative it is apparent that the potential exists for increases in anthropogenic noise disturbance effects to occur, although these would likely happen at varying times and over various timescales. A full assessment of the cumulative effects to noise disturbance would require the current baseline (or ambient conditions) of the Severn Estuary to be determined so that the increments in noise disturbance associated with other developments could be assessed. In the absence of this data a qualitative overview is provided which is intended only to illustrate the range of conditions likely to be encountered. For example the existence of already operational power stations and boat traffic would contribute to what might be considered the ambient noise level present in the Severn Estuary. Should the decommissioning of any existing plants within the Estuary occur during the lifetime of an STP plan alternative there could, for a short duration be an increase in the level of anthropogenic noise disturbance. The construction of other new power plants, industrial plants or container terminals would add to the level of anthropogenic noise disturbance

during construction, and then a continuous addition to anthropogenic noise levels would occur during their individual lifetimes. If decommissioning of any of these structures should happen within the lifetime of an STP plan alternative then further cumulative effects to anthropogenic noise disturbance within the Severn Estuary would also occur. Ongoing activities within the Severn Estuary area (e.g. coastal defence management, already licensed marine aggregate dredging) would contribute to the current baseline, while new managed realignment scenarios and new licenses for marine aggregate dredging would add cumulatively to the anthropogenic noise disturbance effects present within the Severn Estuary. Building work on land bordering the Estuary whether small scale (localised to one site) or large scale (multiple sites or improvements to transport or energy infrastructure) have the potential to contribute to a short term (relative to lifetime of an STP plan alternative) increase in anthropogenic noise disturbance effects (directly through transmitted sound or indirectly through increased use of the Estuary as conduit for equipment etc.). Operation of a ferry service across the Severn Estuary or Bristol Channel would add a regular cumulative effect to anthropogenic noise disturbance during operation of ferries as well as during construction and decommissioning of ferry terminals should new buildings be required.

Effects on freshwater, marine and estuarine fish species

3.5.42 There is the potential for cumulative effects on freshwater, marine and estuarine species to arise from future projects, plans and programmes. These could lead to effects such as habitat loss/change and changes in water quality which could further affect species inhabiting these areas.

Effects on recreational and commercial fisheries

3.5.43 There is the potential for cumulative effects upon the recreational and commercial fisheries of the Severn Estuary and its tributary rivers to arise from future projects, plans and programmes. Any effects arising from the projects, plans and programmes which lead to losses in the number of target fish, their distribution or access to fishing grounds could have deleterious effects upon the fisheries.

Consequential development effects

3.5.44 The “Cumulative Effects & Consequential Developments” document lists any consequential effects which could arise as a result of the construction of an STP plan alternative. Within the STP SEA ‘consequential development’ is defined as “Development facilitated or attracted by the presence of a tidal power alternative option e.g. tourism development, regeneration”. These developments themselves may adversely effect the Severn Estuary environment and constitute indirect effects. A detailed overview of the rationale and methodology for coverage of consequential development within the SEA is given in the “Cumulative Effects & Consequential Developments” document. Types of consequential development considered within this assessment are listed in this document e.g. provisions for altered water-based recreation and tourism and energy intensive industry to supplement that resulting from other new nuclear energy.

3.5.45 Due to the natural excursion straying behaviour of the migratory fish species and the area utilised by the marine species it is considered that there is the potential for consequential development from any of the alternative options to result in effects upon the receptors. With the current extent of available information it is not considered possible to distinguish between these effects for each of the alternative options. The below text is therefore considered applicable to all alternative options and will not be considered further within the individual option assessments.

Alterations to migratory cues

3.5.46 It is considered that only consequential developments which further reduce the freshwater flows into the Estuary, or alter the hydraulic mixing regime of this freshwater, would have additional affects on migratory cues. For example, if as part of alterations to water based recreation and tourism a marina is built which further impedes freshwater flow from rivers.

Disruptions to route of passage

3.5.47 It is considered that any consequential developments resulting from an STP plan alternative would be unlikely to have any significant adverse effects upon the route of passage of fish species within the Estuary.

Habitat change and/or loss

3.5.48 If water based recreation and tourism were to arise as a consequential development of an STP plan alternative this could lead to small local-scale habitat loss or change if facilities were built in the intertidal or subtidal area e.g. moorings, marinas, jetties. The activities themselves however are not expected to lead to any habitat loss or change. In terms of the development of energy intensive industry, habitat loss or change arising from these plan alternatives is considered unlikely however this would depend on the location of the plant and whether the footprint of the plan alternative requires land take from the intertidal or subtidal zone.

Changes to water quality

3.5.49 With regard to the potential effect of consequential developments from either energy intensive industries, residential developments, transport links, development of commercial aquaculture and fishing, or increased water-based recreational use of the area on changes to water quality, there is the potential for additional effects to occur. These would be associated with the construction and decommissioning of any necessary structures (e.g. plants or facilities associated with industries and, for example, marinas and club buildings associated with water-based recreational activities). Further, operational effluents from these enterprises could further alter water quality during the operational lifetime of an STP plan alternative and would therefore have the potential to change the level of effect on migratory fish receptors.

Anthropogenic noise disturbance

3.5.50 With regard to the potential effect of consequential developments from either energy intensive industries or increased water-based recreational use of the area on the anthropogenic noise disturbance associated with an STP plan alternative there is the potential for an increase in associated noise levels. These would be associated with the construction and decommissioning of any necessary structures (e.g. plants or facilities associated with industries and, for example, marinas and club buildings associated with water-based recreational activities). Further, operational noise from these enterprises would add to the level of anthropogenic noise disturbance present during the operational lifetime of an STP plan alternative and would therefore have the potential to change the level of effect on fish receptors.

Effects on freshwater, marine and estuarine fish species

3.5.51 There is the potential that consequential development in the Estuary, such as changes in the recreational use of the area, could have further effects on marine and estuarine species present.

Effects on recreational and commercial fisheries

3.5.52 Altered recreational usage of the Severn Estuary as a consequence of the development of an STP plan alternative has the potential lead to consequential development effects on the fisheries present. This could be through an increase in fishing pressure in the Estuary.

Assumptions, limitations and uncertainties

Alterations to migratory cues

3.5.53 The importance of environmental conditions in the migration of diadromous species is well known however the specific detail is often limited. A number of assumptions have however been made throughout this assessment. No specific information was found relating to migratory cues in sea trout however these are likely to be similar to those observed in salmon. The extent of disruption to marine and estuarine species as a result of changes to certain abiotic factors is currently unknown and assessment of the magnitude has been based here on expert opinion. The methods of construction and decommissioning are largely unknown at this feasibility stage precluding a full assessment of potential effects. In terms of cumulative effects none of the information available on the projects, plans and programmes to be considered indicated that these would involve the impoundment of any rivers, as such no cumulative effects were considered.

Disruptions to route of passage

3.5.54 There is extremely limited available information and precedent both with respect to the behaviour of fish within the Severn Estuary and the potential effects upon the fish populations that could result from an STP installation in particular from passage through a tidal turbine. The paucity of information has resulted in a number of limitations regarding background data and knowledge for use within this assessment resulting in the requirement for a number of assumptions to be made throughout. These limitations and necessary assumptions will have undoubtedly resulted in unavoidable uncertainty within the assessment outputs. It could however, be possible with further investigations to eliminate some of these uncertainties for any future STP assessments.

3.5.55 The use of stochastic models with a number of variable parameters has enabled the inclusion of some variability to provide an indication of uncertainty within the model outputs which has been identified throughout via the presentation of 5^{th} and 95^{th} percentiles alongside the means for each quantifiable assessment output.

Risk of multiple passage

3.5.56 Paramount to the assessment of potential effects of a tidal power option upon fish populations is to gain an understanding of the risk posed by the possibility of fallback whereby as a result of both fish behaviour and tidal exchange an individual fish could pass through the structure numerous times. An understanding of this potential risk is key as it represents the dominant factor in determining the extent of any effect. The above text discussing the general assessment approach has detailed the method applied to

providing an indication of the risk of multiple passage for this assessment which has required a theoretical modelling approach in the absence of site specific observations from which to inform the assessment. Where possible the modelling approach has been informed by literature and the expert judgement of species and Severn Estuary specialists. In the absence of definitive information however, it has been necessary to make a number of assumptions in particular regarding the behaviour of fish as they pass through or reside within the Estuary focusing upon their propensity to stray from their natal river and undertake movements with the tide around the Estuary.

3.5.57 The assumptions made during the development of the preliminary fish movement model by HR Wallingford and their potential limitations are detailed and the uncertainties which may result discussed within the model specific report and will not be discussed further here (STP Report EX6148). Upon analysis of the fish movement model outputs it was determined that the propensity of adult salmon to stray and move around the Estuary during their migration period was not fully represented. To further inform this straying and migratory movement nature of in particular upstream migrants Severn Estuary specific information was explored. The only study identified which was used as the basis of the movement model adaptation rules was the 1960's salmon tagging study reported on by Swain (1982). Although this study has been used within this assessment to provide an indication of the straying behaviour of adult salmon it must be noted that this was not the purpose of the investigation potentially greatly limiting its accuracy for this assessment. The reporting of recaptured adults was reliant upon commercial and recreational fishermen with no study specific recapture effort. The number of tagged fish reported as recaptured was therefore low (a maximum of 0.5% across the three rivers) and recapture sites were restricted to main fishing areas. Although the recaptures do therefore indicate that adult salmon migrate within the Estuary upstream of their natal river it does not inform the extent or timeframe over which this movement takes place. Despite its limitations this study represents the only Severn Estuary specific migratory fish observations and is the best available information from which to inform this assessment at present. It is recommended that for any future STP assessment that the behaviour of in particular the migratory fish species within the Estuary be investigated via on site observations to aid in the assessment of the risk of fish making multiple passages through the structure.

3.5.58 Due to an absence of information regarding the behaviour of the other migratory fish species it has been necessary to extrapolate the risk of multiple passes to these species from the adjusted model outputs for smolt and adult salmon. As it was not possible within the constraints of this project to create movement models for each of the species under consideration it has been necessary to adopt a fairly simplistic approach which does not take into account differing migratory behaviours. Furthermore, neither the salmon movement model nor the subsequent extrapolations take consideration of the potential for the behaviour of fish within the Estuary to change in particular on approach to the structure.

3.5.59 The extrapolation process has been based predominantly upon the sustained swimming ability of each of the different fish species and life stages. There is however a paucity of information available regarding the swimming ability of a number of the species under consideration which has required the consideration of just one study or the use of surrogate species.

3.5.60 The assessment of the risk of multiple passes by each of the marine, estuarine and freshwater fish species has been constrained by the requirement to use an ecological guild approach and a paucity of information regarding their behaviour, residence, distribution and population size. As such, only an indicative assessment of potential

effects upon the ecological guilds as a whole has been possible precluding an assessment of potential effects upon individual species.

Mechanical injury

3.5.61 Models for the determination of the probability of a fish of a given size being struck by a turbine blade and injured have been in existence in some form since the 1950's. Furthermore, the accuracy of such models has been explored by a number of authors in comparison with empirical data sets and there is a general confidence in their use for applications of this type.

3.5.62 Due to the lack of design detail made available for this assessment regarding the turbine units to be used within each of the STP plan alternatives it has been necessary to make assumptions regarding a number of the parameters involved within the blade strike models. Where possible these assumptions have been based upon information or guidance from specialists in the field or other such models. The turbine types and projects from which this information has been influenced however may differ from either all or some of the STP plan alternative specifications. Although the use of such assumptions enables a relative assessment to be made between STP plan alternatives it should be noted that the level of uncertainty which it creates may not be uniform between each of the plan alternatives.

3.5.63 Where possible fish behaviour has been incorporated into the blade strike models with respect to swimming behaviour and fish orientation during passage through the turbines. Due to a paucity of information regarding the behaviour of fish during turbine passage a range of scenarios have been investigated to give an indication of the sensitivity of these variables. Where information was lacking or limited in particular with respect to body length and depth ranges extrapolations from differing life stages or surrogates have been made. It is considered however that due to the wide range of lengths over which the models have been run to take account of the haphazard nature of presentation that this level of accuracy is suitable for this purpose. As with the risk of multiple passes, for some species and life stages sustained swimming ability may be based upon limited information or surrogate species with the same values being used throughout this assessment.

3.5.64 There were no species specific mutilation ratios available for inclusion within the blade strike models. As such, in particular for the species which do not have a regular fish shaped body form including lamprey and eel it was considered that a weight based approach was most suitable for the purposes of this assessment. It is recognised however, that due to the broad weight categories (<20 g, 20 to 200 g and >200 g) that the model outputs may be both under or over estimates as a result of this approach.

3.5.65 The vastly differing size ranges of species and life stages within each of the marine, estuarine and freshwater ecological guilds has precluded an accurate assessment of potential effects upon the species contained within these guilds. It is therefore recommended that the potential effects presented within this assessment be considered for the ecological guilds as a whole only and no interpretation be made for individual species for which the results may represent vast under or over estimates.

3.5.66 It is recommended for any future STP assessment that turbine manufacturers are engaged to gain more detailed turbine specifications from which an accurate assessment could be made.

3.5.67 For many of the other mechanical injury categories it has not been possible to undertake a quantitative assessment and as such in general an expert judgement approach has been followed.

Pressure

3.5.68 Limited information is available regarding the swimming behaviour of migratory fish species within an estuarine environment. To determine the acclimation pressure of individuals as they approach each of the STP plan alternative structures it has therefore been necessary to assume their swimming depth based where necessary upon their known behaviour within freshwater environments or observations of surrogate species. To correlate with known information regarding potential exposure pressure during passage through a horizontal turbine unit which has been determined for an in-river hydro site, acclimation pressures have been determined on the assumption of a freshwater environment. As the assessment is based on a ratio of change it is considered that this is the most appropriate approach. The relative water depths upstream of each of the STP plan alternative structures was provided by the STP SEA consortium engineers for use within this assessment.

3.5.69 Approximate acclimation pressures have been determined for each of the marine, estuarine and freshwater ecological guilds based upon a general swimming depth preference. Due to the wide variety of species within each guild however, the chosen acclimation pressure may not be suitable for all species resulting in both under and over estimates of potential effects and as such it is recommended that predicted approximate effects are not used directly to assess effects upon individual species.

3.5.70 The pressure injury determination equations used within this assessment are those derived by Turnpenny et al. (2000). These equations are based upon investigations undertaken by the authors and others under a pressure profile deemed to be typical of a tidal power turbine similar to that proposed for the STP plan alternatives. Although the equations are based on a single study it is considered relevant to the current assessment and represents the best available assessment tool for a study of this type.

Shear stress

3.5.71 Information is limited regarding the effects of exposure to shear stress by a number of the key fish species and where information is available it is often complicated by a differing use of terms (shear stress and strain rate) and units which are not directly comparable. Furthermore, there is very limited current data available regarding the values of shear stress which could be encountered by a fish during turbine passage in particular through a large horizontal axis turbine unit such as those proposed for the STP plan alternatives. It has therefore been necessary to inform this assessment through the use of two studies of shear stress within a turbine unit which differ dramatically. It is recommended that for any future STP assessment that shear stress be evaluated for a typical proposed turbine unit to increase the confidence in the assessment of this key injury causing mechanism.

Cavitation, indirect mortality and non-fatal effects

3.5.72 It has not been possible at this stage to quantify the potential effects associated with cavitation, indirect mortality and non-fatal effects upon the fish populations. A qualitative expert judgement approach has been taken and as such some uncertainty remains regarding the potential extent of these effects.

Compound mortality

3.5.73 An indication of the compound mortality potentially sustained during turbine passage has been given for each STP plan alternative through the development of a stochastic model including blade strike, pressure and shear stress predicted potential effects. All of the above identified limitations and assumptions detailed within the specific injury causal mechanisms are also inherent within the compound mortality. Furthermore, the elements of effects for which it has not been possible to quantify are not represented within this model and as such it represents a minimum estimate of effects.

Habitat change and/or loss

3.5.74 There are significant knowledge gaps regarding habitat use by the fish receptor species. Similarly there are knowledge gaps regarding habitat use by key prey items. This promotes a high degree of uncertainty in assessing the response of fish species to habitat change; the response of prey items to habitat change, and ultimately fish response to changes in prey items. Much of the available literature is from other geographical areas and it has been assumed that the observed results would be true for the Severn Estuary. The physical environment determines habitats within the Severn Estuary. The modelled changes in habitat used as the basis of the following assessments will be subject to their own assumptions, limitation and uncertainties, which could influence the outputs used in the following assessments. Accordingly, it should be noted that there is a high degree of uncertainty associated with the following assessments.

Changes to water quality

3.5.75 The assumptions, limitations and uncertainties associated with the following assessment are summarised as follows. There are knowledge gaps regarding the effects of key water quality parameters on the fish receptor species. For species where information is not available assumptions have been made regarding similarity of response to physiologically similar species. There is little available data on cumulative or synergistic effects of contaminants on receptor fish, even for the species for which greater study has been undertaken such as Atlantic salmon. This represents a limitation to the assessment, as such effects cannot be assumed. Accordingly the uncertainty of the assessment increases. The amount of information available varies by parameter, further the spatial coverage regarding the distribution and concentration of the various trace contaminants is also highly variable. This limits current knowledge of effects to migratory fish. New substances are continually being manufactured and released to the environment which may have synergistic or cumulative effects with other contaminants on the fish receptor species, but it is not possible to assess their potential effects, so adding further to the uncertainty associated with the assessment.

3.5.76 Where potential effects have been based on the outputs of water quality modelling there are further, inherent assumptions, limitations and uncertainties associated with those model outputs that should be considered. These are likely to include the detail of data available for inclusion in the models, which may well vary spatially, and be more focused towards the larger river systems present, requiring assumptions about the likely water quality in the tributaries. Further there may be bias in the source of the data, particularly for nutrients where it is probable that there is more information available for direct sources (e.g. WWTW) than diffuse (e.g. agricultural) sources. Where historical data is incorporated to provide better spatial coverage for the models, the changes in analytical method or limits of detection add to the associated uncertainties regarding contaminant concentration. Additionally there will be the errors associated with the models themselves which would add uncertainty to the outputs.

3.5.77 The potential for eutrophication has been highlighted for all of the plan alternatives as a consequence of decreased suspended sediment loads. Nutrient models assessing this potential for each plan alternative are not yet available, and accordingly it has not been possible to fully assess this effect. This represents a source of uncertainty and is a limitation in the assessment of each plan alternative.

3.5.78 There are further changes associated with climate change that are poorly understood that could effect water quality, both in terms of effects upon fish receptors and incorporating climate change effects into model outputs. Therefore it has not been possible to include these which represents a further limitation.

Anthropogenic noise disturbance

3.5.79 This assessment has been undertaken without baseline ambient noise data for the specific development site and without specific data relating to the likely noise levels generated during the construction, operation and decommissioning phase of the proposed STP plan alternatives.

3.5.80 Data on the peak hearing frequencies, hearing range and threshold at peak frequency are unavailable for some of the species of conservation and commercial interest e.g. lamprey, sea trout, dab, eel, sole, plaice, whiting, hake and saithe. Hearing thresholds when available for a species are also often based upon one study. There are potential for errors to have occurred during the derivation of audiogram hearing thresholds and the measurement of source levels. Furthermore, the sound levels produced from various activities can vary depending on local environmental conditions which it is not possible to account for without prior local knowledge.

3.5.81 Limitations associated with reference to literature and experimental studies into the hearing capabilities of fish and the effects of underwater noise include different matrices between studies making comparisons between studies difficult. Some studies do not reference or measure the frequency range across which a response was observed. Research effort varies between effects of different noise sources.

3.5.82 Specific project details i.e. nature of materials used, timing of operations and methods are currently unknown. A detailed assessment would need to be carried out when this information becomes available.

Effects on freshwater, marine and estuarine fish species

3.5.83 It has been assumed for the purposes of this assessment that there is the potential for both migratory fish population reductions and species extinctions within the rivers under consideration as a result of the effects of an STP plan alternative.

Effects on recreational and commercial fisheries

The majority of effects have been estimated based upon modelled predictions and expert judgement and anticipated changes in fish populations in response to the STP plan alternatives. In this respect, it is anticipated that effects upon the fisheries are subject to the same assumptions, limitations and uncertainties that have been discussed for other sections and could indirectly influence the viability of the fisheries.

Alternative Option B3: Brean Down to Lavernock Point Barrage

3.5.84 In assessing the magnitude of effects of this and the other plan alternatives consideration of prevent/reduce and offsetting of any effect has not been included.

Direct Effects

Construction Phase

Disruptions to route of passage

3.5.85 The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. It is considered that the magnitude of adverse effects would be medium for the migratory fish species and negligible to low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.86 The B3 option has a total device footprint of 451 hectares, of which 413 ha would be situated in the subtidal zone with the remaining 38 hectares situated in the intertidal zone. This amount of direct habitat loss would accrue as construction progressed.

Operational Phase

Disruptions to route of passage

3.5.87 It is considered that the likelihood of the B3 plan alternative representing a disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary would be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effects would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds negligible to medium.

Habitat change and/or loss

3.5.88 In addition the total device footprint of 451 hectares, of which 413 ha would be situated in the subtidal zone with the remaining 38 hectares situated in the intertidal zone would lead to loss of habitat equal to that area.

Decommissioning Phase

Disruptions to route of passage

3.5.89 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of potential disruption occurring is considered to be highly probable. The duration of effect would potentially be for the entire period of the decommissioning phase and the potential frequency of effect would be continuous over the decommissioning period. The magnitude of potential effects would medium for the

migratory fish species and negligible to low for the species contained within the ecological guilds.

Indirect Effects

Construction Phase

Alterations to migratory cues

3.5.90 The B3 option is downstream of most of the major Severn Estuary tributaries and it is therefore considered that all of the migratory species entering these rivers would be affected by a reduction in freshwater inflow into the Inner Bristol Channel and a change in the hydraulic mixing regime of this water and the possible resultant absence of olfactory cues to aid homing behaviour. This could lead to disruption and/or delays to migration. The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this option is highly probable. The duration of effects would likely be for the entire period of construction. The frequency of effect would be during each migratory cycle. The severity of these effects would depend upon the timing of the works and whether they coincide with sensitive migration periods for the fish species, as well as the methods of construction employed. It is considered that the magnitude of negative effects upon the migratory fish species would be medium.

Disruptions to route of passage

3.5.91 The potential for the construction phase of the B3 plan alternative to have an effect upon the route of passage of fish species is largely dependent upon the nature of the construction activities. As the plan alternative was developed and the structure placed into position there is potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for the migratory fish species and negligible to low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.92 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during construction activities would be certain. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible-low.

Changes to water quality

3.5.93 The probability of changes to water quality affecting the fish present in the Severn Estuary during construction activities is possible. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. It is considered that the magnitude of potential effects upon the receptor fish would be negligible – very low.

Anthropogenic noise disturbance

3.5.94 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during construction activities is probable. The duration of effects would be for the entire period of construction activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the construction period depending on the various construction activities employed at any one time and the construction method adopted. The severity of effects would depend upon the timing of the works. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of the specialist receptors, shad and herring, and low for the remaining receptor fish species within the generalist and non-specialist categories. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.95 The likelihood of freshwater, marine and estuarine fish species being indirectly affected during construction of this plan alternative is possible. The duration of effects would be for the entire period of construction. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.96 The likelihood of effects resulting from the construction of the proposed B3 plan alternative having subsequent effects upon the recreational, commercial and heritage fisheries of the Severn Estuary and its tributary rivers is certain. The duration of effects would be for the period of construction. The magnitude of negative effects is considered to be medium to high.

Operational Phase

Alterations to migratory cues

3.5.97 The likelihood of the migratory cues and natal homing of migratory fish species being disrupted by the B3 option would be highly probable. The duration of effects would be for the lifetime of the barrage. The frequency of effect would be during each migratory cycle. It is considered that the magnitude of negative effects upon the migratory fish species would be high.

Disruptions to route of passage

3.5.98 The likelihood of the B3 plan alternative representing a disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effects would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds negligible to medium.

Habitat change and/or loss

3.5.99 The probability of habitat change and/or loss affecting the fish present in the Severn Estuary during the operational phase would be certain. The duration of effects would be for the entire period of operation over the lifetime of the plan alternative. The frequency of effects would be constant although gradual long-term change in habitat

distribution may also occur. It is considered that, due to variation in species sensitivities the magnitude of potential effects would be negligible-high.

Changes to water quality

3.5.100 The probability of changes to water quality affecting the fish present in the Severn Estuary during the operational phase would possible. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. It is considered that the magnitude of potential effects would be low-medium.

Anthropogenic noise disturbance

3.5.101 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during the operational phase is possible. The duration of effects would be for the entire period of operation over the lifetime of the proposed development. The frequency of effects would be variable over the period of operation depending on the programme of operation and maintenance. The severity of effects would depend upon the details of the structure. The magnitude of potential effects upon the receptor fish is judged to be medium for hearing specialists such as shad and herring and low for the other fish receptors categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.102 The likelihood of the freshwater, marine and estuarine fish species being indirectly affected by a direct reduction in the numbers of fish as a result of this STP plan alternative would be probable. The duration of effects would be for the lifetime of the barrage. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.103 Based on the results of the life cycle models, commercial species that are most likely to be significantly, directly affected include eel and salmon. Worst-case scenarios predict up to an 83 % reduction in the number of eel on the River Wye. This would likely result in the Severn Estuary eel fishery becoming unviable. Similarly, a reduction in salmon numbers would have a similar effect upon freshwater angling and the commercial salmon fishing. The likelihood of the recreational and commercial fisheries being indirectly affected by a direct reduction in the numbers of fish as a result of the B3 STP plan alternative is certain. The duration of effects would be for the lifetime of the plan alternative. The magnitude of negative effects is considered to be medium to high. Again, it is considered by the EA that the effects on salmon and eel would likely be so profound that they would immediately seek to end commercial and heritage fishing operations that exploit these species (EA., *pers. comm*.).

Decommissioning Phase

Alterations to migratory cues

3.5.104 Upon decommissioning of the B3 option it is considered that any alterations to migratory cues would cease. As with effects during the construction phase the duration of effects would be for the entire period of decommissioning and the severity

would be dependent on the timing and nature of the works. It is considered that the magnitude of negative effects upon the migratory fish species would be medium.

Disruptions to route of passage

3.5.105 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and negligible to low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.106 The probability of habitat change and/or loss affecting the fish receptors during decommissioning would be certain. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. It is considered that the magnitude of potential effects upon the receptor fish would be negligible-low.

Changes to water quality

3.5.107 The probability of changes to water quality affecting the fish present in the Severn Estuary during decommissioning activities would be possible. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. It is considered that the magnitude of potential effects upon the receptor fish would be negligible – very low.

Anthropogenic noise disturbance

3.5.108 The likelihood of anthropogenic noise disturbance being generated during decommissioning is probable. The duration of effects would be for the entire period of decommissioning activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the decommissioning period depending on the various decommissioning activities employed at any one time and the decommissioning method adopted. The severity of effects would depend upon the timing of the works. There is the potential for improvements to techniques for prevent/reduce measures to have occurred, or for advances in construction technology that would reduce the noise generated during decommissioning in the intervening years. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of hearing specialists such as shad and herring and low for the remaining receptor fish species categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the decommissioning of this STP plan alternative. Once decommissioning is complete it is anticipated that anthropogenic noise disturbance would cease.

Effects on freshwater, marine and estuarine fish species

3.5.109 Upon decommissioning of the B3 option some of the effects on freshwater, migratory and estuarine species could persist depending upon the potential recolonisation of the Estuary and rivers by migratory and marine/estuarine species. The likelihood of effects is considered to be possible. The duration of effects would be for the entire period of decommissioning. It is considered that the magnitude of negative effects upon the migratory fish species would be low.

Effects upon recreational and commercial fisheries

3.5.110 Upon decommissioning of the B3 STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. The likelihood of effects is certain. The duration of effects would be for the period of decommissioning. The magnitude of negative effects upon the fisheries is considered to be low to high.

Summary of Likely Magnitude of Effects on the Environment

3.5.111 The following summarises the likely magnitude of effects (direct, indirect, far field, cumulative and consequential development effects) of the B3 alternative option on the receptors during construction, operation and decommissioning phases. The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

Alterations to migratory cues

3.5.112 Predicted magnitude of effects for each individual species and river system from alterations to migratory cues within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.2and Table 3.3.

Table 3.2 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from alterations to migratory cues from the B3 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	High	High	High
Sea trout	High	High	High
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	High	High	High
Eel	High	High	High

Table 3.3 Magnitude of effects upon marine and estuarine fish species resulting from alterations to migratory cues from the B3 option

Functional group	Magnitude of effect
Marine migrants	Very low
Marine stragglers	Very low
Estuarine species	Very low
Freshwater stragglers	Very low

Disruptions to route of passage

3.5.113 Predicted magnitude of effects for each individual species and river system from disruption to migration or movement within the Estuary potentially resulting in direct and

indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.4 and Table 3.5.

Table 3.4 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from disruption to route of passage from the B3 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	High	High	High
Sea trout	High	High	High
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	High	High	High
Eel	High	High	High

Table 3.5 Magnitude of effects upon fish species within the ecological guilds resulting from disruption to route of passage from the B3 option

Guild	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine residents	Medium
Freshwater stragglers	Negligible

Habitat change and/or loss

3.5.114 Predicted magnitude of effects for each individual species and river system from habitat change and/or loss within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.6and Table 3.7.

Table 3.6 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from habitat change and/or loss from the B3 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	High	High	High
Sea lamprey	Low	Low	Low
River lamprey	High	High	High
Eel	High	High	High

Table 3.7 Magnitude of effects upon marine and estuarine fish species resulting from habitat change and/or loss from the B3 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Negligible
Estuarine species	High
Freshwater stragglers	Negligible

Changes to water quality

3.5.115 Predicted magnitude of effects for each individual species and river system from changes to water quality within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.8 and Table 3.9.

Table 3.8 Magnitude of effects upon migratory and estuarine fish species from the Rivers Usk, Wye and Severn resulting from changes to water quality from the B3 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.9 Magnitude of effects upon marine and estuarine fish species resulting from changes to water quality from the B3 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Anthropogenic noise disturbance

Predicted magnitude of effects for each individual species and river system from anthropogenic noise disturbance within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.10 and

3.5.116 Table 3.11.

Table 3.10 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from anthropogenic noise disturbance from the B3 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.11 Magnitude of effects upon marine and estuarine fish species resulting from anthropogenic noise disturbance from the B3 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Effects to freshwater, marine and estuarine fish species

3.5.117 Predicted magnitude of effects for each individual species and river system from effects to freshwater, marine and estuarine fish species are detailed within Table 3.12.

Table 3.12 Magnitude of effects upon freshwater, marine and estuarine fish species resulting from the B3 option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Low
Estuarine species	Low
Freshwater stragglers	Low
Freshwater species	Low

Effects upon recreational and commercial fisheries

3.5.118 A summary of the magnitude of effects upon recreational and commercial fisheries is given below in Table 3.13.

Table 3.13 Magnitude of effects upon recreational and commercial fisheries resulting from the B3 option

Fishery	Magnitude of effect
Recreational - salmonid	High
Recreational - sea	Medium
Heritage	High
Commercial	Medium

Compound effects upon fish populations

3.5.119 The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations as well as the migratory fish populations of the River Parrett. Although point source effects are considered likely to be similar to those predicted for the River Usk overall population effects in terms of population reduction, collapse or extinction may differ and cannot be classified at this time.

3.5.120 The development of life cycle models for the key migratory fish species (as detailed within Annex: 5) enables where quantitative assessments have been undertaken, for the effects associated with each STP plan alternative to be put into the context of the populations as a whole. Quantitative assessments have however, only been possible

for disruption to route of passage in particular turbine passage. Furthermore, the predicted estimates of injury/mortality associated with turbine passage are considered to be minimums as they do not take into consideration all possible mechanisms for which quantitative assessment approaches are currently not possible. Although quantifiable compound effects can therefore be incorporated into the life cycle models to determine potential effects upon the populations they are considered to represent minimum estimates of effect. To aid in the overall assessment of STP plan alternative effects a qualitative indication has therefore been given for each key fish species or ecological guild.

3.5.121 It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

Sea trout

3.5.122 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the sea trout population due to the complexity of its life history within the freshwater environment. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.**

Allis shad

3.5.123 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the allis shad population due to the rarity of the species and paucity of available data regarding their presence within the study rivers. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.**

Marine migrants

3.5.124 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine migrant species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Marine stragglers

3.5.125 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of

effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Estuarine residents

3.5.126 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the estuarine resident species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Freshwater stragglers

3.5.127 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the freshwater straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Atlantic salmon

3.5.128 Although it has only been possible to quantify the effects associated with turbine passage, incorporation of these values into the life history models for Atlantic salmon demonstrate the potential minimum effects that could be sustained by the three main river populations. Against the future baseline between 2014 and 2020 under the assumption that all directive targets are met the inclusion of STP effects reduces the egg deposition by between approximately 12 and 53% of the directive target depending upon rivers and confidence limit.

3.5.129

Table 3.14 B3 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario

River	Parameter	Directive case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%	5%
SEVERN	Egg deposition (m)	16.59	12.71	14.02	9.58
	mean smolts	158,312	145,221	150,749	126,579
	mean spawners	4,862	3,742	4,125	2,826
	mean rod catch	676	523	576	396
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	39.63	28.00	32.26	18.71
	mean smolts	430,731	367,113	394,883	285,033
	mean spawners	11,438	8,115	9,343	5,433
	mean rod catch	2,142	1,526	1,756	1,024
	time to 5% EggDir	nr	nr	nr	nr
USK	Egg deposition (m)	19.41	15.78	17.12	13.09
	mean smolts	133,290	133,080	133,837	128,548
	mean spawners	7,465	6,105	6,618	5,078
	mean rod catch	1,128	926	1,003	772
	time to 5% EggDir	nr	nr	nr	nr

3.5.130 Under the future baseline between 2020 and 2140 represented by two climate change scenarios the egg deposition could be reduced by between 17 and 100% of the directive target. Furthermore, under climate change scenario B it is predicted that 5% of the egg directive target which is taken for the purpose of this assessment to represent population collapse could occur on the Rivers Severn and Wye under all confidence limits and on the River Usk under the 5% confidence limit. Population collapse under this scenario could occur within 13 years for the River Wye stock. Additionally, population collapse is also predicted on the River Wye under climate change scenario A under the 5% confidence limit. **It is therefore considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.**

Table 3.15 B3 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario A

River	Parameter	Climate (A) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	7.37	3.56	4.85	0.98
	mean rod catch	410	199	271	54
	mean smolts	93,945	54,205	69,475	16,956
	mean spawners	3,284	1,594	2,168	435
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	14.01	3.49	6.94	0.29
	mean rod catch	1,049	262	522	21
	mean smolts	200,386	59,676	111,402	5,487
	mean spawners	6,238	1,555	3,098	126
	time to 5% EggDir	nr	nr	nr	51
USK	Egg deposition (m)	12.04	8.62	9.96	5.94
	mean rod catch	876	632	729	437
	mean smolts	109,239	94,904	101,641	76,138
	mean spawners	5,903	4,249	4,903	2,937
	time to 5% EggDir	nr	nr	nr	nr

Table 3.16 B3 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario B

River	Parameter	Climate (B) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	0.13	0.00	0.01	0.00
	mean rod catch	7	0	1	0
	mean smolts	2,208	51	199	2
	mean spawners	59	1	5	0
	time to 5% EggDir	52	28	34	19
WYE	Egg deposition (m)	0.02	0.00	0.00	0.00
	mean rod catch	2	0	0	0
	mean smolts	371	5	25	0
	mean spawners	9	0	1	0
	time to 5% EggDir	34	19	24	13
USK	Egg deposition (m)	4.98	1.68	2.92	0.22
	mean rod catch	367	125	217	16
	mean smolts	58,629	23,980	38,666	3,545
	mean spawners	2,476	840	1,458	109
	time to 5% EggDir	nr	nr	nr	50

Twaite shad

3.5.131 Table 3.17 and Table 3.18 demonstrate the potential effects upon the future baseline of the twaite shad populations from the Rivers Usk, Severn and Wye over the periods 2014 to 2020 and 2020 to 2140 respectively. Population extinction is predicted for all Rivers under all baseline scenarios. **On the basis of this predicted minimum loss it is therefore considered that there is potential for the extinction of the twaite shad populations within the Rivers Usk, Wye and Severn. Furthermore, although it has not been possible to quantify farfield effects there is potential for effects to be seen within the remaining UK population within the River Tywi. Were B3 to result in significant population reductions within this river as well as those encompassed by this plan alternative there is potential for whole UK stock extinction.**

Table 3.17 B3 STP effects upon the individuals of the adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**
Usk	36,842	15,130	20*(21)	10
Severn	36,842	15,130	48*(23)	21
Wye	92,104	37,826	77*(23)	34

Table 3.18 B3 STP effects upon the individuals of the adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenarios (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Climate change case (1°C)				Climate change case (2°C)			
	Baseline population		STP effects population		Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Usk	42,626	4,538	22*(25)	9	31,278	3,083	17*(32)	8
Severn	42,626	4,538	54*(33)	22	31,278	3,083	41*(46)	20
Wye	106,565	11,346	88*(29)	36	79,104	7,708	64*(38)	32

Sea lamprey

3.5.132 Table 3.19 demonstrates the potential minimum effect upon the baseline sea lamprey population that could occur as a result of the construction and operation (up to 2020) of the B3 STP plan alternative. The predicted reduction in adult population size is approximately 20% for the River Wye and 22% for the River Usk. For transformers the population is predicted to reduce by approximately 35% on the Wye and 37% on the Usk. **The B3 plan alternative therefore has the potential to result in reductions in the population size of sea lamprey within the Rivers Usk and Wye and the European stock.**

Table 3.19 B3 STP effects upon the sea lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	14,397,293	581,840	11,296,552	792,710	56,875,906	2,664,438	45,551,324	2,275,252
Transformers	2,245,978	90,767	1,408,929	98,868	8,937,418	417,532	5,805,081	290,029
Adults	3,069	455	2,379	353	12,200	1,836	9,727	1,464

River lamprey

3.5.133 Table 3.20 provides an indication of the potential minimum effect upon the baseline river lamprey population that could occur over the period 2014 to 2020 as a result of the construction and operation (up to 2020) of the B3 STP plan alternative. The predicted reduction in adult population size is approximately 11% for the River Wye and 14% for the River Usk. For transformers the population is predicted to reduce by approximately 28% on the Wye and 30% on the Usk. **The B3 plan alternative therefore has the potential to result in reductions in the population size of river lamprey within the Rivers Usk and Wye and the UK stock.**

Table 3.20 B3 STP effects upon the river lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	21,952,630	1,985,605	19,094,497	668,841	71,158,380	5,598,596	62,778,819	3,621,195
Transformers	3,424,610	309,754	2,383291	83,482	11,100,707	873,381	8,014,395	462,776
Adults	27,667	4,696	24,209	4,109	88,442	14,324	78,696	12,745

Eel

3.5.134 Table 3.21 provides an indication of the potential effects of the B3 STP plan alternative upon the silver eel biomass output for the Rivers Severn, Wye and Usk over the period 2014 to 2140. It is predicted that the future stock from the River Severn with a B3 STP plan alternative in place would be reduced by approximately 16% of the climate case population, the River Usk by 17% and the River Wye by 16%. **There is therefore potential for reductions in the outputs of silver eel from these rivers which could make compliance with the EU Eel Regulations and associated escapement targets a significant challenge.**

Table 3.21 B3 STP effects upon the biomass output (Kg) of silver eel in the Rivers Severn, Usk and Wye under the 2014 to 2140 future baseline scenarios

River	Base case population	Climate case population	STP effects population
Severn	26,865	124,134	104,794
Usk	497	3,146	2,620
Wye	5,861	37,330	31,365

Summary of Likely Significant Effects on the Environment

3.5.135 Based on the magnitude of effects calculated, and the compound effects upon fish populations and with consideration of the value and vulnerability of the individual fish receptors together with the reversibility and permanence of the effects, the likely significance of the effects of the B3 alternative option have been calculated and are shown in Table 3.22.

Table 3.22 Alternative Option B3: Brean Down to Lavernock Point Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Atlantic salmon *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea trout *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities			*biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Shad *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency continual			*populations and wider biogeographic stocks.*			
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea lamprey *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
River lamprey	*Alterations to migratory*	*Indirect*	*High*	*Construction – S/M term,*	*Reversible*	*High*	*Affecting only migratory*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Value = H Vulnerability = H	*cues*			*frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Temporary*		*fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*			
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Eel *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary.*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities			*See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Marine migrants *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Marine stragglers *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities						
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Estuarine residents *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
Freshwater stragglers *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative / Positive*	*See text for details*	*Y*

Alternative Option B4: Shoots Barrage

Direct Effects

Construction Phase

Disruptions to route of passage

3.5.136 The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects would be medium for migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.137 The B4 option has a total device footprint of 93 hectares, of which 23 ha would be situated in the subtidal zone with the remaining 70 hectares situated in the intertidal zone. This amount of direct habitat loss would accrue as construction progressed.

Operational Phase

Disruptions to route of passage

3.5.138 The likelihood of the B4 plan alternative representing a disruption to migration or movement around the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary would be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.139 In addition to changes in water exchange the total device footprint of 93 hectares, of which 23 ha would be situated in the subtidal zone with the remaining 70 hectares situated in the intertidal zone would lead to loss of habitat equal to that area.

Decommissioning Phase

Disruptions to route of passage

3.5.140 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring would be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. It is considered that the magnitude of effects would be medium for the migratory fish species and low for the species contained within the ecological guilds.

Indirect Effects

Construction Phase

Alterations to migratory cues

3.5.141 The B4 option encompasses the Rivers Wye and Severn and as such migratory species from downstream of the structure are not likely to be as affected by alterations to migratory cues. Those migrating to rivers upstream however may be affected by a reduction in freshwater and therefore a reduction in migratory cues. The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this plan alternative is highly probable. The duration of effects would be for the entire period of construction. The frequency of effect would be during each migratory cycle. The severity of these effects would depend upon the timing of the works and whether they coincide with sensitive migration periods for the fish species, as well as the methods of construction employed. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to medium.

Disruptions to route of passage

3.5.142 The potential for the construction phase of the B4 plan alternative to have an effect upon the route of passage of fish species within the Severn Estuary is largely dependent upon the nature of the construction activities. As the option was developed and the structure placed into position there is potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.143 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during construction activities is certain. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible - low.

Changes to water quality

3.5.144 The probability of changes to water quality affecting the fish present in the Severn Estuary during construction activities would be possible. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.145 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during construction activities is probable. The duration of effects would be for the entire period of construction activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would

be variable over the length of the construction period depending on the various construction activities employed at any one time and the construction method adopted. The severity of effects would depend upon the timing of the works. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of the specialist receptors, shad and herring, and low for the remaining receptor fish species within the generalist and non-specialist categories. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.146 The likelihood of freshwater, marine and estuarine fish species being indirectly affected during construction of this plan alternative would be possible. The duration of effects would be for the entire period of construction. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.147 The likelihood of effects resulting from the construction of the proposed B4 plan alternative having subsequent effects upon the recreational, commercial and heritage fisheries of the Severn Estuary and its tributary rivers is certain. The duration of effects would be for the period of construction. It is considered that the magnitude of negative effects would be medium to high.

Operational Phase

Alterations to migratory cues

3.5.148 The likelihood of the migratory cues and natal homing of migratory fish species being disrupted by this plan alternative is highly probable. The duration of effects would be for the lifetime of the barrage. The frequency of effect would be during each migratory cycle. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to high.

Disruptions to route of passage

3.5.149 The likelihood of the B4 plan alternative representing a disruption to migration or movement around the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.150 The probability of habitat change and/or loss affecting the fish present in the Severn Estuary during the operational phase is certain. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. It is considered that, due to variation in species sensitivities, the magnitude of potential effects would be negligible to high.

Changes to water quality

3.5.151 The probability of changes to water quality affecting the fish present in the Severn Estuary during the operational phase would be possible. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be low-medium.

Anthropogenic noise disturbance

3.5.152 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during the operational phase is possible. The duration of effects would be for the entire period of operation over the lifetime of the proposed development. The frequency of effects would be variable over the period of operation depending on the programme of operation and maintenance. The severity of effects would depend upon the details of the structure. The magnitude of potential effects upon the receptor fish is judged to be medium for hearing specialists such as shad and herring and low for the other fish receptors categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.153 The likelihood of the freshwater, marine and estuarine fish species being indirectly affected by a direct reduction in the numbers of fish as a result of this STP plan alternative is probable. The duration of effects would be for the lifetime of the barrage. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.154 The likelihood of the recreational and commercial fisheries being indirectly affected by a direct reduction in the numbers of fish as a result of the B4 STP plan alternative is certain. The duration of effects would be for the lifetime of the plan alternative. It is considered that the magnitude of negative effects would be medium to high.

Decommissioning Phase

Alterations to migratory cues

3.5.155 Upon decommissioning of an STP structure it is considered that any alterations to migratory cues would cease. As with effects during the construction phase the duration of effects would be for the entire period of decommissioning and the severity would be dependent on the timing and nature of the works. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to medium.

Disruptions to route of passage

3.5.156 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.157 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during decommissioning is certain. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible - low.

Changes to water quality

3.5.158 The probability of changes to water quality affecting the fish present in the Severn Estuary during decommissioning activities would be possible. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.159 The likelihood of anthropogenic noise disturbance being generated during decommissioning is probable. The duration of effects would be for the entire period of decommissioning activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the decommissioning period depending on the various decommissioning activities employed at any one time and the decommissioning method adopted. The severity of effects would depend upon the timing of the works. There is the potential for improvements to techniques for measures to prevent or reduce adverse effects to have occurred, or for advances in construction technology that would reduce the noise generated during decommissioning in the intervening years. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of hearing specialists such as shad and herring and low for the remaining receptor fish species categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the decommissioning of this STP option. Once decommissioning is complete it is anticipated that anthropogenic noise disturbance would cease.

Effects on freshwater, marine and estuarine fish species

3.5.160 Upon decommissioning of the B4 option some of the effects on freshwater, migratory and estuarine species could persist depending upon the potential recolonisation of the Estuary and rivers by migratory and marine/estuarine species. It is considered that the magnitude of negative effects upon the migratory fish species would be low.

Effects upon recreational and commercial fisheries

3.5.161 Upon decommissioning of the B4 STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. It is considered that the magnitude of negative effects upon the fisheries would be low to high.

Summary of Likely Magnitude of Effects on the Environment

3.5.162 The following summarises the likely magnitude of effects (direct, indirect, far field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases. The following assessments have focused upon the three primary Severn Estuary tributaries; the

Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

Alterations to migratory cues

3.5.163 Predicted magnitude of effects for each individual species and river system from alterations to migratory cues within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.23 and Table 3.24.

Table 3.23 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from alterations to migratory cues from the B4 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Negligible	High	High
Sea trout	Negligible	High	High
Shad	Negligible	High	High
Sea lamprey	Negligible	High	High
River lamprey	Negligible	High	High
Eel	Negligible	High	High

Table 3.24 Magnitude of effects upon marine and estuarine fish species resulting from alterations to migratory cues from the B4 option

Functional group	Magnitude of effect
Marine migrants	Very low
Marine stragglers	Very low
Estuarine species	Very low
Freshwater stragglers	Very low

Disruptions to route of passage

3.5.164 Predicted magnitude of effects for each individual species and river system from disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.25 and Table 3.26.

Table 3.25 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from disruption to route of passage from the B4 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	High	High	High
Sea trout	High	High	High
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	High	High	High
Eel	High	High	High

Table 3.26 Magnitude of effects upon fish species within the ecological guilds resulting from disruption to route of passage from the B4 option

Guild	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine residents	Medium
Freshwater stragglers	Low

Habitat change and/or loss

3.5.165 Predicted magnitude of effects for each individual species and river system from habitat change and/or loss within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.27and Table 3.28.

Table 3.27 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from habitat change and/or loss from the B4 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Low	Medium	Medium
Sea trout	Low	Medium	Medium
Shad	Medium	High	High
Sea lamprey	Low	Medium	Medium
River lamprey	Medium	High	High
Eel	Medium	High	High

Table 3.28 Magnitude of effects upon marine and estuarine fish species resulting from habitat change and/or loss from the B4 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Negligible
Estuarine species	Medium
Freshwater stragglers	Negligible

Changes to water quality

3.5.166 Predicted magnitude of effects for each individual species and river system from changes to water quality within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.29 and Table 3.30.

Table 3.29 Magnitude of effects upon migratory and estuarine fish species from the Rivers Usk, Wye and Severn resulting from changes to water quality from the B4 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.30 Magnitude of effects upon marine and estuarine fish species resulting from changes to water quality from the B4 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Anthropogenic noise disturbance

3.5.167 Predicted magnitude of effects for each individual species and river system from anthropogenic noise disturbance within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.31 and Table 3.32.

Table 3.31 Magnitude of effects upon migratory and estuarine fish species from the Rivers Usk, Wye and Severn resulting from anthropogenic noise disturbance from the B4 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.32 Magnitude of effects upon marine and estuarine fish species resulting from anthropogenic noise disturbance from the B4 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Effects to freshwater, marine and estuarine fish species

3.5.168 Predicted magnitude of effects for each individual species and river system from effects to freshwater, marine and estuarine fish species are detailed within Table 3.33.

Table 3.33 Magnitude of effects upon freshwater, marine and estuarine fish species resulting from the B4 option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Low
Estuarine species	Low
Freshwater stragglers	Low
Freshwater species	Low

Effects upon recreational and commercial fisheries

3.5.169 A summary of the magnitude of effects upon recreational and commercial fisheries is given below in Table 3.34.

Table 3.34 Magnitude of effects upon recreational and commercial fisheries resulting from the B4 option

Fishery	Magnitude of effect
Recreational - salmonid	High
Recreational - sea	Medium
Heritage	High
Commercial	Medium

Compound effects upon fish populations

3.5.170 The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations as well as the migratory fish populations of the River Parrett. Although point source effects are considered likely to be similar to those predicted for the River Usk overall population effects in terms of population reduction, collapse or extinction may differ and cannot be classified at this time.

3.5.171 It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

Sea trout

3.5.172 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the sea trout population due to the complexity of its life history within the freshwater environment. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.**

Allis shad

3.5.173 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the allis shad population due to the rarity of the species and paucity of available data regarding their presence within the study rivers. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.**

Marine migrants

3.5.174 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine migrant species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Marine stragglers

3.5.175 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Estuarine residents

3.5.176 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the estuarine resident species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Freshwater stragglers

3.5.177 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the freshwater straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Atlantic salmon

3.5.178 Although it has only been possible to quantify the potential effects associated with turbine passage, incorporation of these values into the life history models for Atlantic salmon demonstrate the potential minimum effects that could be sustained by the three main river populations. Against the future baseline between 2014 and 2020 under the assumption that all directive targets are met the inclusion of STP effects could reduce the egg deposition by between approximately 7 and 100% of the directive target depending upon rivers and confidence limit (Table 3.35). Furthermore, under the 5% confidence limit scenario there is potential for population collapse on the River Wye after a period of 44 years.

Table 3.35 B4 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario

River	Parameter	Directive case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%	5%
SEVERN	Egg deposition (m)	16.59	10.67	15.40	7.17
	mean smolts	158,312	133,986	155,295	105,890
	mean spawners	4,862	3,144	4,532	2,117
	mean rod catch	676	440	633	297
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	39.63	6.69	18.87	0.12
	mean smolts	430,731	124,021	286,709	2,758
	mean spawners	11,438	1,941	5,472	35
	mean rod catch	2,142	366	1,030	7
	time to 5% EggDir	nr	nr	nr	44
USK	Egg deposition (m)	19.41	15.69	17.19	13.83
	mean smolts	133,290	132,998	133,853	130,243
	mean spawners	7,465	6,033	6,612	5,317
	mean rod catch	1,128	912	999	804
	time to 5% EggDir	nr	nr	nr	nr

3.5.179 Under the future baseline between 2020 and 2140 represented by two climate change scenarios the egg deposition could be reduced by between 17 and 100% of the directive target. Furthermore, under climate change scenario B it is predicted that 5% of the egg directive target which is taken for the purpose of this assessment to represent population collapse could occur on the Rivers Severn and Wye under all

confidence limits and on the River Usk under the 5% confidence limit (Table 3.36 and Table 3.37). A population reduction to less than 5% is also predicted for the River Severn and Wye stocks under the climate change scenario A. **It is therefore considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations in particular within the Rivers Wye and Severn and to a lesser extent the Usk.**

Table 3.36 B4 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario A

River	Parameter	Climate (A) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	7.37	1.72	4.17	0.16
	mean rod catch	410	96	233	9
	mean smolts	93,945	28,700	61,633	3,012
	mean spawners	3,284	771	1,865	70
	time to 5% EggDir	nr	nr	nr	56
WYE	Egg deposition (m)	14.01	0.33	0.30	0.00
	mean rod catch	1,049	24	22	0
	mean smolts	200,386	6,208	5,695	0
	mean spawners	6,238	143	131	0
	time to 5% EggDir	nr	52	51	13
USK	Egg deposition (m)	12.04	8.50	10.00	6.63
	mean rod catch	876	618	727	483
	mean smolts	109,239	94,203	101,833	81,737
	mean spawners	5,903	4,165	4,902	3,252
	time to 5% EggDir	nr	nr	nr	nr

Table 3.37 B4 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario B

River	Parameter	Climate (B) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	0.13	0.00	0.01	0.00
	mean rod catch	7	0	0	0
	mean smolts	2,208	6	98	0
	mean spawners	59	0	2	0
	time to 5% EggDir	52	19	30	18
WYE	Egg deposition (m)	0.02	0.00	0.00	0.00
	mean rod catch	2	0	0	0
	mean smolts	371	0	0	0
	mean spawners	9	0	0	0
	time to 5% EggDir	34	12	13	8
USK	Egg deposition (m)	4.98	1.57	2.95	0.42
	mean rod catch	367	116	218	31
	mean smolts	58,629	22,506	39,013	6,583
	mean spawners	2,476	779	1,468	207
	time to 5% EggDir	nr	nr	nr	62

Twaite shad

3.5.180 Table 3.38 and Table 3.39 demonstrate the potential effects upon the future baseline of the twaite shad populations from the Rivers Usk, Severn and Wye over the periods 2014 to 2020 and 2020 to 2140 respectively. Population collapse and effectively extinction is estimated for the River Severn and Wye populations under all baseline scenarios whereas depending upon the baseline scenario it is estimated that up to approximately 57% could be lost from the River Usk. **It is therefore predicted that there is potential for the extinction of the River Severn and Wye twaite shad populations with the B4 plan alternative. Furthermore, there is potential for reductions in the population size of the Rivers Usk and Tywi (from farfield effects) stocks. It is considered however, that on the basis of the predicted model outputs that populations although reduced in size would likely be retained within the Rivers Usk and Tywi.**

Table 3.38 B4 STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted)

	Baseline population		STP effects population	
River	Mean	SD	Mean	SD
Usk	36,842	15,130	15,796	5,289
Severn	36,842	15,130	0	0
Wye	92,104	37,826	0	0

Table 3.39 B4 STP effects upon the individuals adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenarios (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted)

	Climate change case (1°C)				Climate change case (2°C)			
	Baseline population		STP effects population		Baseline population		STP effects population	
River	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Usk	42,626	4,538	29,717	3,294	31,278	3,083	24,054	1,983
Severn	42,626	4,538	0	0	31,278	3,083	0	0
Wye	106,565	11,346	0	0	79,104	7,708	0	0

Sea lamprey

3.5.181 Table 3.40 demonstrates the potential minimum effect upon the baseline sea lamprey population that could occur as a result of the construction and operation (up to 2020) of the B4 STP plan alternative. The predicted reduction in adult population size is approximately 73% for the River Wye and 59% for the River Usk. For transformers the population is predicted to reduce by approximately 82% on the Wye and 59% on the Usk. **These predicted losses would represent a significant reduction in population size which with inclusion of additional effects for which it has not currently been possible to quantify could result in population collapse in particular on the River Wye and could reduce European stock size.**

Table 3.40 B4 STP effects upon the sea lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	14,397,293	581,840	5,924,192	384,609	56,875,906	2,664,438	15,040,802	959,412
Transformers	2,245,978	90,767	924,174	59,999	8,937,418	417,532	1,614,272	102,911
Adults	3,069	455	1,819	270	12,200	1,836	3,233	487

River lamprey

3.5.182 Table 3.41 provides an indication of the potential minimum effect upon the baseline river lamprey population that could occur over the period 2014 to 2020 as a result of the construction and operation (up to 2020) of the B4 STP plan alternative. The predicted reduction in adult population size is approximately 50% for the River Wye and 42% for the River Usk. For transformers the population is predicted to reduce by approximately 67% on the Wye and 42% on the Usk. **These predicted losses represent a significant reduction in population size which with incorporation of all compound effects could potentially put the population at risk of collapse and reduce the UK stock size**.

Table 3.41 B4 STP effects upon the river lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	21,952,630	1,985,605	12,816,446	727,583	71,158,380	5,598,596	34,544,594	1,654,283
Transformers	3,424,610	309,754	1,999,366	113,503	11,100,707	873,381	3,717,869	178,148
Adults	27,667	4,696	16,398	2,783	88,442	14,324	43,186	6,994

Eel

3.5.183 Table 3.42 provides an indication of the potential effects of the B4 STP plan alternative upon the silver eel biomass output from the Rivers Severn, Wye and Usk over the period 2014 to 2140. It is predicted that under the climate case scenario that the stock from the River Severn would be reduced by approximately 19% of the climate case population for the River Severn, 22% for the River Wye and no change for the River Usk. **It is considered that predicted reduced outputs for the Rivers Severn and Wye could represent population reductions and place compliance of the EU Eel Regulations at significant risk. Effects upon the outputs of the River Usk however, are considered unlikely to result in significant reductions in population size.**

Table 3.42 B4 STP effects upon the biomass output (Kg) of silver eel in the Rivers Severn, Usk and Wye under the 2014 to 2140 future baseline scenarios

River	Base case population	Climate case population	STP effects population
Severn	26,865	124,134	100,983
Usk	497	3,146	3,146
Wye	5,861	37,330	28,938

Summary of Likely Significant Effects on the Environment

3.5.184 Based on the magnitude of effects calculated, and the compound effects upon fish populations and with consideration of the value and vulnerability of the individual fish receptors together with the reversibility and permanence of the effects, the likely significance of the potential effects of the B4 alternative option have been calculated and are shown in Table 3.43.

Table 3.43 Alternative Option B4: Shoots Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Atlantic salmon *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea trout *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities			*biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Shad *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency continual			*populations and wider biogeographic stocks.*			
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea lamprey *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
River lamprey	*Alterations to migratory*	*Indirect*	*High*	*Construction – S/M term,*	*Reversible*	*High*	*Affecting only migratory*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Value = H Vulnerability = H	*cues*			*frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Temporary*		*fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*			
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Eel *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary.*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities			*See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Marine migrants *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Marine stragglers *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities						
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Estuarine residents *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
Freshwater stragglers *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative / Positive*	*See text for details*	*Y*

Alternative Option B5: Beachley Barrage

Direct Effects

Construction Phase

Disruptions to route of passage

3.5.185 The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish species and low for marine, estuarine and freshwater species within the ecological guilds.

Habitat change and/or loss

3.5.186 The B5 option has a total device footprint of 15 hectares, of which 10 ha would be situated in the subtidal zone with the remaining 5 hectares situated in the intertidal zone. This amount of direct habitat loss would accrue as construction progressed.

Operational Phase

Disruptions to route of passage

3.5.187 The likelihood of the B5 plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.188 In addition o changes to water exchange the total device footprint of 15 hectares, of which 10 ha would be situated in the subtidal zone with the remaining 5 ha situated in the intertidal zone.

Decommissioning Phase

Disruptions to route of passage

3.5.189 During the decommissioning phase upon the assumption that water would be allowed to move through the structure it is considered that effects would be reduced in comparison to operation.

Indirect Effects

Construction Phase

Alterations to migratory cues

3.5.190 The Beachley Barrage encompasses the River Severn as such migratory species from downstream of the structure are not likely to be as affected by alterations to migratory cues. Those migrating to the rivers upstream however could be affected by a reduction in freshwater and therefore a reduction in migratory cues. The Barrage hits land on the mouth of the River Wye, as such there is the potential for the Wye to be temporarily impounded during construction and decommissioning activities. Fish migrating to the Wye could therefore be temporarily affected during this period. The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this plan alternative is highly probable. The duration of effects would be for the entire period of construction. The frequency of effect would be during each migratory cycle. The severity of these effects would depend upon the timing of the works and whether they coincide with sensitive migration periods for the fish species, as well as the methods of construction employed. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to medium.

Disruptions to route of passage

3.5.191 The potential for the construction phase of the B5 plan alternative to have an effect upon the route of passage of fish species within the Estuary is largely dependent upon the nature of the construction activities. As the plan alternative was developed and the structure placed into position there is potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish species and low for marine, estuarine and freshwater species within the ecological guilds.

Habitat change and/or loss

3.5.192 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during construction activities is certain. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible - low.

Changes to water quality

3.5.193 The probability of changes to water quality affecting the fish present in the Severn Estuary during construction activities would be possible. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be low – very low.

Anthropogenic noise disturbance

3.5.194 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during construction activities is probable. The duration of effects would be for the entire period of construction activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the construction period depending on the various construction activities employed at any one time and the construction method adopted. The severity of effects would depend upon the timing of the works. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of the specialist receptors, shad and herring, and low for the remaining receptor fish species within the generalist and non-specialist categories. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.195 The likelihood of freshwater, marine and estuarine fish species being indirectly affected during construction of this plan alternative would be possible. The duration of effects would be for the entire period of construction. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.196 The likelihood of effects resulting from the construction of the proposed B5 plan alternative having subsequent effects upon the recreational, commercial and heritage fisheries of the Severn Estuary and its tributary rivers is certain. The duration of effects would be for the period of construction. It is considered that the magnitude of negative effects would be medium to high.

Operational Phase

Alterations to migratory cues

3.5.197 The likelihood of the migratory cues and natal homing of migratory fish species being disrupted by this plan alternative is highly probable. The duration of effects would be for the lifetime of the barrage. The frequency of effect would be during each migratory cycle. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to high.

Disruptions to route of passage

3.5.198 The likelihood of the B5 plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the m migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.199 The probability of habitat change and/or loss affecting the fish present in the Severn Estuary during the operational phase is certain. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be negligible-high.

Changes to water quality

3.5.200 The probability of changes to water quality affecting the fish present in the Severn Estuary during the operational phase would be possible. The duration of effects will be for the entire period of operation over the lifetime of the alternative option. The frequency of effects will be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be low-medium.

Anthropogenic noise disturbance

3.5.201 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during the operational phase is possible. The duration of effects would be for the entire period of operation over the lifetime of the proposed development. The frequency of effects would be variable over the period of operation depending on the programme of operation and maintenance. The severity of effects would depend upon the details of the structure. The magnitude of potential effects upon the receptor fish is judged to be medium for hearing specialists such as shad and herring and low for the other fish receptors categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.202 The likelihood of the freshwater, marine and estuarine fish species being indirectly affected by a direct reduction in the numbers of fish as a result of this STP plan alternative is probable. The duration of effects would be for the lifetime of the barrage. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.203 Based on the results of the life cycle models, commercial species that are most likely to be significantly, directly affected include eel and salmon. Worst-case scenarios predict up to an 83 % reduction in the number of eel on the River Wye. This would likely result in the Severn estuary eel fishery becoming unviable. Similarly, a reduction in salmon numbers would have a similar effect upon freshwater angling and the commercial salmon fishing. The likelihood of the recreational and commercial fisheries being indirectly affected by a direct reduction in the numbers of fish as a result of the B5 STP plan alternative is certain. The duration of effects would be for the lifetime of the plan alternative. The magnitude of negative effects is considered to be medium to high. Again, it is considered by the EA that the effects on salmon and eel would likely be so profound that they would immediately seek to end commercial and heritage fishing operations that exploit these species (EA., *pers. comm*.).

<u>Decommissioning Phase</u>

Alterations to migratory cues

3.5.204 Upon decommissioning of an STP structure it is considered that any alterations to migratory cues would cease. The likelihood of effects would be highly probable. As with effects during the construction phase the duration of effects would be for the entire period of decommissioning and the severity would be dependent on the timing and nature of the works. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to medium.

Disruptions to route of passage

3.5.205 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.206 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during decommissioning is certain. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible - low.

Changes to water quality

3.5.207 The probability of changes to water quality affecting the fish present in the Severn Estuary during decommissioning activities would be possible. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.208 The likelihood of anthropogenic noise disturbance being generated during decommissioning is probable. The duration of effects would be for the entire period of decommissioning activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the decommissioning period depending on the various decommissioning activities employed at any one time and the decommissioning method adopted. The severity of effects would depend upon the timing of the works. There is the potential for improvements to techniques for measures to prevent or reduce adverse effects to have occurred, or for advances in construction technology that would reduce the noise generated during decommissioning in the intervening years. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of hearing specialists such as shad and herring and low for the remaining receptor fish species categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the decommissioning of this STP plan alternative. Once decommissioning is complete it is anticipated that anthropogenic noise disturbance would cease.

Effects on freshwater, marine and estuarine fish species

3.5.209 Upon decommissioning of the B5 option some of the effects on freshwater, migratory and estuarine species could persist depending upon the potential recolonisation of the Estuary and rivers by migratory and marine/estuarine species. It is considered that the magnitude of negative effects upon the migratory fish species would be low.

Effects upon recreational and commercial fisheries

3.5.210 Upon decommissioning of the B5 STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. The likelihood of effects is certain. The duration of effects would be for the period of decommissioning. It is considered that the magnitude of negative effects upon the fisheries would be low to high.

Summary of Likely Magnitude of Effects on the Environment

3.5.211 The following summarises the likely magnitude of potential effects (direct, indirect, far field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases. The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

Alterations to migratory cues

3.5.212 Predicted magnitude of effects for each individual species and river system from alterations to migratory cues within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.44 and Table 3.45.

Table 3.44 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from alterations to migratory cues from the B5 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Negligible	Negligible	High
Sea trout	Negligible	Negligible	High
Shad	Negligible	Negligible	High
Sea lamprey	Negligible	Negligible	High
River lamprey	Negligible	Negligible	High
Eel	Negligible	Negligible	High

Table 3.45 Magnitude of effects upon marine and estuarine fish species resulting from alterations to migratory cues from the B5 option

Functional group	Magnitude of effect
Marine migrants	Very low
Marine stragglers	Very low
Estuarine species	Very low
Freshwater stragglers	Very low

Disruptions to route of passage

3.5.213 Predicted magnitude of effects for each individual species and river system from disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.46 and Table 3.47.

Table 3.46 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from disruption to route of passage from the B5 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	High	High	High
Sea trout	High	High	High
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	High	High	High
Eel	High	High	High

Table 3.47 Magnitude of effects upon fish species within the ecological guilds resulting from disruption to route of passage from the B5 option

Guild	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine residents	Medium
Freshwater stragglers	Low

Habitat change and/or loss

3.5.214 Predicted magnitude of effects for each individual species and river system from habitat change and/or loss within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.48 and Table 3.49.

Table 3.48 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from habitat change and/or loss from the B5 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Low	Medium	Medium
Sea trout	Low	Medium	Medium
Shad	Medium	High	High
Sea lamprey	Low	Medium	Medium
River lamprey	Medium	High	High
Eel	Medium	High	High

Table 3.49 Magnitude of effects upon marine and estuarine fish species resulting from habitat change and/or loss from the B5 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Negligible
Estuarine species	Medium
Freshwater stragglers	Negligible

Changes to water quality

3.5.215 Predicted magnitude of effects for each individual species and river system from changes to water quality within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.50 and Table 3.51.

Table 3.50 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from changes to water quality from the B5 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.51 Magnitude of effects upon marine and estuarine fish species resulting from changes to water quality from the B5 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Anthropogenic noise disturbance

3.5.216 Predicted magnitude of effects for each individual species and river system from anthropogenic noise disturbance within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.52 and Table 3.53

Table 3.52 Magnitude of effects upon migratory and estuarine fish species from the Rivers Usk, Wye and Severn resulting from anthropogenic noise disturbance from the B5 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.53 Magnitude of effects upon marine and estuarine fish species resulting from anthropogenic noise disturbance from the B5 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Effects to freshwater, marine and estuarine fish species

3.5.217 Predicted magnitude of effects for each individual species and river system from effects to freshwater, marine and estuarine fish species are detailed within Table 3.54.

Table 3.54 Magnitude of effects upon freshwater, marine and estuarine fish species resulting from the B5 option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Low
Estuarine species	Low
Freshwater stragglers	Low
Freshwater species	Low

Effects upon recreational and commercial fisheries

3.5.218 A summary of the magnitude of effects upon recreational and commercial fisheries is given below in Table 3.55.

Table 3.55 Magnitude of effects upon recreational and commercial fisheries resulting from the B5 option

Fishery	Magnitude of effect
Recreational - salmonid	High
Recreational - sea	Medium
Heritage	High
Commercial	Medium

Compound effects upon fish populations

3.5.219 The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

3.5.220 It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

Sea trout

3.5.221 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the sea trout population due to the complexity of its life history within the freshwater environment. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.**

Allis shad

3.5.222 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the allis shad population due to the rarity of the species and paucity of available data regarding their presence within the study rivers. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.**

Marine migrants

3.5.223 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine migrant species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Marine stragglers

3.5.224 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to

determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Estuarine residents

3.5.225 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the estuarine resident species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Freshwater stragglers

3.5.226 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the freshwater straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Atlantic salmon

3.5.227 Although it has only been possible to quantify the effects associated with turbine passage, incorporation of these values into the life history models for Atlantic salmon demonstrate the potential minimum effects that could be sustained by the three main river populations. Against the future baseline between 2014 and 2020 under the assumption that all directive targets are met the inclusion of STP effects reduces the egg deposition by between approximately 20 and 100 % of the directive target depending upon rivers and confidence limit (Table 3.56). It is predicted that effects against the baseline on the River Wye would result in population collapse under all confidence limits within between 9 and 56 years.

Table 3.56 B5 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario

River	Parameter	Directive case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%	5%
SEVERN	Egg deposition (m)	16.59	11.37	13.32	7.64
	mean smolts	158,312	138,227	147,914	110,451
	mean spawners	4,862	3,353	3,923	2,259
	mean rod catch	676	469	548	317
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	39.63	0	0.37	0
	mean smolts	430,731	6	8,015	0
	mean spawners	11,438	0	104	0
	mean rod catch	2,142	0	20	0
	time to 5% EggDir	nr	20	56	9
USK	Egg deposition (m)	19.41	10.85	13.85	7.72
	mean smolts	133,290	120,968	130,293	102,767
	mean spawners	7,465	4,173	5,327	2,970
	mean rod catch	1,128	631	805	449
	time to 5% EggDir	nr	nr	nr	nr

3.5.228 Under the future baseline between 2020 and 2140 represented by two climate change scenarios the egg deposition could be reduced by between 44 and 100% of the directive target. Furthermore, under climate change scenario B it is predicted that 5% of the egg directive target which is taken for the purpose of this assessment to represent population collapse could occur on the Rivers Severn, Wye and Usk under all confidence limits. Additionally, population collapse is also predicted on the River Wye under climate change scenario A for all confidence limits. **It is therefore considered that there is the potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye, Severn and Usk.**

Table 3.57 B5 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario A

River	Parameter	Climate (A) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	7.37	2.32	4.16	0.24
	mean rod catch	410	130	233	13
	mean smolts	93,945	37,475	61,579	4,501
	mean spawners	3,284	1,039	1,864	107
	time to 5% EggDir	nr	nr	nr	62
WYE	Egg deposition (m)	14.01	0.00	0.00	0.00
	mean rod catch	1,049	0	0	0
	mean smolts	200,386	0	0	0
	mean spawners	6,238	0	0	0
	time to 5% EggDir	nr	8	17	6
USK	Egg deposition (m)	12.04	3.66	6.66	0.90
	mean rod catch	876	266	484	65
	mean smolts	109,239	53,407	81,923	15,583
	mean spawners	5,903	1,796	3,264	441
	time to 5% EggDir	nr	nr	nr	121

Table 3.58 B5 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario B

River	Parameter	Climate (B) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	0.13	0.00	0.01	0.00
	mean rod catch	7	0	0	0
	mean smolts	2,208	13	98	0
	mean spawners	59	0	2	0
	time to 5% EggDir	52	24	30	18
WYE	Egg deposition (m)	0.02	0.00	0.00	0.00
	mean rod catch	2	0	0	0
	mean smolts	371	0	0	0
	mean spawners	9	0	0	0
	time to 5% EggDir	34	6	8	3
USK	Egg deposition (m)	4.98	0.02	0.43	0.00
	mean rod catch	367	1	31	0
	mean smolts	58,629	267	6,719	5
	mean spawners	2,476	7	211	0
	time to 5% EggDir	nr	29	65	18

Twaite shad

3.5.229 Table 3.59 and Table 3.60 demonstrate the potential effects upon the future baseline of the twaite shad populations from the Rivers Usk, Severn and Wye over the periods 2014 to 2020 and 2020 to 2140 respectively. Population collapse and effectively extinction is predicted for the River Severn and Wye populations under all scenarios whereas a loss of up to approximately 34% is estimated for the River Usk population under the climate change scenarios and population collapse after over 100 years under the base case. **The predicted effects associated with the B5 STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.**

Table 3.59 B5 STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**
Usk	36,842	15,130	3,992*(>100)	1,775
Severn	36,842	15,130	0	0
Wye	92,104	37,826	0	0

Table 3.60 B5 STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenarios

	Climate change case (1°C)				Climate change case (2°C)			
	Baseline population		STP effects population		Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Usk	42,626	4,538	15,970	2,993	31,278	3,083	17,374	1,545
Severn	42,626	4,538	0	0	31,278	3,083	0	0
Wye	106,565	11,346	0	0	79,104	7,708	0	0

Sea lamprey

3.5.230 Table 3.61 demonstrates the potential minimum effect upon the baseline sea lamprey population that could occur as a result of the construction and operation (up to 2020) of the B5 STP plan alternative. It is predicted that the River Wye population would become extinct 6 years after the commencement of this plan alternative. Although it is not anticipated that the River Usk population would become extinct it is estimated that the adult population could be reduced by 91% and the transformer population by 91% which may suggest that the population would no longer be viable. **It is therefore considered that there is potential for population collapse of the sea lamprey populations of the Rivers Wye and Usk and reductions in the European stock size**.

Table 3.61 B5 STP effects upon the sea lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	14,397,293	581,840	1,346,100	75,633	56,875,906	2,664,438	0	0
Transformers	2,245,978	90,767	209,992	11,799	8,937,418	417,532	0	0
Adults	3,069	455	284	42	12,200	1,836	0	0

River lamprey

3.5.231 Table 3.62 provides an indication of the potential minimum effect upon the baseline river lamprey population that could occur over the period 2014 to 2020 as a result of the construction and operation (up to 2020) of the B5 STP plan alternative. The predicted reduction in adult population size is approximately 91% for the River Wye and 66% for the River Usk. For transformers the population is predicted to reduce by approximately 92% on the Wye and 67% on the Usk. **There is therefore the potential for collapse of the river lamprey population on the Rivers Wye and Usk for the B5 STP plan alternative and reductions in the UK stock size.**

Table 3.62 B5 STP effects upon the river lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	21,952,630	1,985,605	7,308,582	333,570	71,158,380	5,598,596	6,326,612	361,778
Transformers	3,424,610	309,754	1,140,139	52,037	11,100,707	873,381	850,517	48,818
Adults	27,667	4,696	9,313	1,581	88,442	14,324	7,986	1,293

Eel

3.5.232 Table 3.63 provides an indication of the potential effects of the B5 STP plan alternative upon the silver eel biomass output from the Rivers Severn, Wye and Usk over the period 2014 to 2140. It is predicted that under the climate change scenario that the stock from the River Severn could be reduced by approximately 19% of the climate case population, by 10% for the River Wye and no change for the River Usk. Reductions in the outputs from the Rives Severn and Wye could result in significant threat to the compliance of the EU Eel Regulations. **It is considered that predicted reduced outputs for the Rivers Severn and Wye could represent population reductions and place compliance of the EU Eel Regulations at risk. It is not predicted that output from the River Usk would be reduced and as such there would be no non-compliance risk for this stock.**

Table 3.63 B5 STP effects upon the biomass output (Kg) of silver eel in the Rivers Severn, Usk and Wye under the 2014 to 2140 future baseline scenarios

River	Base case population	Climate case population	STP effects population
Severn	26,865	124,134	101,157
Usk	497	3,146	3,146
Wye	5,861	37,330	33,452

Summary of Likely Significant Effects on the Environment

3.5.233 Based on the magnitude of effects calculated, and the compound effects upon fish populations and with consideration of the value and vulnerability of the individual fish receptors together with the reversibility and permanence of the effects, the likely significance of the potential effects of the B5 alternative option have been calculated and are shown in Table 3.64.

Table 3.64 Alternative Option B5: Beachley Barrage

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Atlantic salmon *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea trout *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities			*biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Shad *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency continual			*populations and wider biogeographic stocks.*			
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea lamprey *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
River lamprey	*Alterations to migratory*	*Indirect*	*High*	*Construction – S/M term,*	*Reversible*	*High*	*Affecting only migratory*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Value = H Vulnerability = H	*cues*			*frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Temporary*		*fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*			
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Eel *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*High*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary.*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities			*See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Marine migrants *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Marine stragglers *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities						
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Estuarine residents *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
Freshwater stragglers *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative / Positive*	*See text for details*	*Y*

Alternative Option L2: Welsh Grounds Lagoon

Direct Effects

Construction Phase

Disruptions to route of passage

3.5.234 The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish and low for those within the ecological guilds.

Habitat change and/or loss

3.5.235 The Welsh Grounds Lagoon has an overall total device footprint of 1,088 ha. Of this footprint area 208 ha would be situated in the subtidal zone with the remaining 880 ha situated in the intertidal zone. The total lagoon area would be 7,466 ha of which 1,408 ha would be subtidal and the remaining 6,058 ha would be intertidal.

Operational Phase

Disruptions to route of passage

3.5.236 The likelihood of the L2 plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.237 Additionally to changes to water exchange, the overall total device footprint would be 1,088 ha. Of this footprint area 208 ha would be situated in the subtidal zone with the remaining 880 ha situated in the intertidal zone. The total lagoon area would be 7,466 ha of which 1,408 ha would be subtidal and the remaining 6,058 ha would be intertidal.

Decommissioning Phase

Disruptions to route of passage

3.5.238 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and low for the species contained within the ecological guilds.

Indirect Effects

Construction Phase

Alterations to migratory cues

3.5.239 The Welsh Grounds Lagoon does not encompass any rivers and therefore effects associated with alterations to migratory cues are expected to be minimal. There is however the potential for some of these cues to be sluiced into the lagoon, with the potential of fish to follow into the lagoon. This could be an especially important consideration in light of the close proximity of this plan alternative to the River Usk and placement of the sluices into the main channel downstream of the Rivers Wye and Severn.

3.5.240 The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this plan alternative is considered probable. If as part of the construction process water is drawn in from the main estuary channel this may contain migratory cues and could therefore have an effect on migratory species. The duration of effect would be for the entire period of construction. The frequency of effect would be during each migratory cycle. The severity of these effects would depend upon the timing of the works and whether they coincide with sensitive migration periods for the fish species, as well as the methods of construction employed. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to low.

Disruptions to route of passage

3.5.241 The potential for the construction phase of the L2 plan alternative to have an effect upon the route of passage of fish species within the Estuary is largely dependent upon the nature of the construction activities. As the plan alternative was developed and the structure placed into position there is potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish and low for those within the ecological guilds.

Habitat change and/or loss

3.5.242 Habitat loss during the construction phase would likely extend to an area greater than that to eventually be occupied by the plan alternative, partly because construction activities could lead to short-term changes in erosion and accretion patterns within the Severn Estuary. This could reduce or increase the amount of habitat available for individual fish species within the Estuary. Further where active construction is occurring it is likely that physical disturbances would prevent fish utilisation of such habitats which are present but would not be affected directly.

3.5.243 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during construction activities is certain. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible-low.

Changes to water quality

3.5.244 During construction remobilisation of sediment is likely to occur through dredging and construction activities. This would lead to increases in suspended sediment concentrations and increases in associated contaminants. There is also the possibility of leaks and spillages of fuels or construction materials. The main effects responsible for changes to water quality would be from progressive changes to water exchange and sedimentation as the barrage is built.

3.5.245 The probability of changes to water quality affecting the fish present in the Severn Estuary during construction activities would be possible. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.246 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during construction activities is probable. The duration of effects would be for the entire period of construction activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the construction period depending on the various construction activities employed at any one time and the construction method adopted. The severity of effects would depend upon the timing of the works. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of the specialist receptors, shad and herring, and low for the remaining receptor fish species within the generalist and non-specialist categories. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.247 The likelihood of freshwater, marine and estuarine fish species being indirectly affected during construction of this plan alternative would be possible. The duration of effects would be for the entire period of construction. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.248 The likelihood of effects resulting from the construction of the proposed L2 plan alternative having subsequent effects upon the recreational, commercial and heritage fisheries of the Severn Estuary and its tributary rivers is certain. The duration of effects would be for the period of construction. It is considered that the magnitude of negative effects would be medium.

Operational Phase

Alterations to migratory cues

3.5.249 The likelihood of the migratory cues and natal homing of migratory fish species being disrupted by this plan alternative is probable. The duration of effects would be for the lifetime of the plan alternative. The frequency of effect would be during each migratory cycle. It is considered that the magnitude of negative effects upon the migratory fish

species would be negligible to low. A number of internationally protected migratory fish species have the potential to be affected as a result of this plan alternative.

Disruptions to route of passage

3.5.250 The likelihood of the L2 plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.251 The probability of habitat change and/or loss affecting the fish present in the Severn Estuary during the operational phase is certain. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be negligible-high.

Changes to water quality

3.5.252 The probability of changes to water quality affecting the fish present in the Severn Estuary during the operational phase would be possible. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be low-medium.

Anthropogenic noise disturbance

3.5.253 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during the operational phase would be possible. The duration of effects would be for the entire period of operation over the lifetime of the proposed development. The frequency of effects would be variable over the period of operation depending on the programme of operation and maintenance. The severity of effects would depend upon the details of the structure. The magnitude of potential effects upon the receptor fish is judged to be medium for hearing specialists such as shad and herring and low for the other fish receptors categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.254 The likelihood of the freshwater, marine and estuarine fish species being indirectly affected by a direct reduction in the numbers of fish as a result of this STP plan alternative is probable. The duration of effects would be for the lifetime of the plan alternative. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.255 Based on the results of the life cycle models, commercial species that are most likely to be significantly, directly affected include eel and salmon. It is considered that a 73 % reduction in salmon egg deposition targets would likely result in the freshwater angling and commercial salmon fisheries becoming unviable on the Rivers Severn and Wye. Reductions in eel of up to 93 % on the River Wye, would make commercial

eel fisheries unviable on this river. The likelihood of the recreational and commercial fisheries being indirectly affected by a direct reduction in the numbers of fish as a result of the L2 STP plan alternative is certain. The duration of effects would be for the lifetime of the plan alternative. The magnitude of negative effects is considered to be medium to high.

Decommissioning Phase

Alterations to migratory cues

3.5.256 Upon decommissioning of an STP structure any alterations to migratory cues would cease because water (and as such potentially also migratory cues) would stop being drawn into the lagoon. As with effects during the construction phase the duration of effects would be for the entire period of decommissioning and the severity would be dependent on the timing and nature of the works. It is considered that the magnitude of negative effects upon the migratory fish species would be negligible to low.

Disruptions to route of passage

3.5.257 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.258 Decommissioning activities would likely be similar to those experienced during construction. The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during decommissioning is certain. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible-low.

Changes to water quality

3.5.259 The probability of changes to water quality affecting the fish present in the Severn Estuary during decommissioning activities would be possible. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.260 The likelihood of anthropogenic noise disturbance being generated during decommissioning would be probable. The duration of effects would be for the entire period of decommissioning activity during which anthropogenic sound would be emitted into the aquatic environment. The frequency of effects would be variable over the length of the decommissioning period depending on the various decommissioning activities employed at any one time and the decommissioning method adopted. The severity of effects would depend upon the timing of the works. There would be the potential for improvements to techniques for measures to prevent or reduce adverse effects to have occurred, or for advances in construction technology that would reduce the noise generated during decommissioning in the intervening years. The

magnitude of potential effects upon the receptor fish is judged to be medium in the case of hearing specialists such as shad and herring and low for the remaining receptor fish species categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the decommissioning of this STP scheme. Once decommissioning is complete it is anticipated that anthropogenic noise disturbance would cease.

Effects on freshwater, marine and estuarine fish species

3.5.261 Upon decommissioning of the STP plan alternative some of the effects on freshwater, marine and estuarine species could persist depending upon the potential recolonisation of the Estuary and rivers by migratory and marine/estuarine species. The likelihood of effects would be possible. The duration of effects would be for the entire period of decommissioning. It is considered that the magnitude of negative effects upon the fish species would be low.

Effects upon recreational and commercial fisheries

3.5.262 Upon decommissioning of the L2 STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. The likelihood of effects is certain. The duration of effects would be for the period of decommissioning. It is considered that the magnitude of negative effects upon the fisheries would be low to high.

Summary of Likely Magnitude of Effects on the Environment

3.5.263 The following summarises the likely magnitude of potential effects (direct, indirect, far field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases. The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

Alterations to migratory cues

3.5.264 Predicted magnitude of effects for each individual species and river system from alterations to migratory cues within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.65 and Table 3.66.

Table 3.65 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from alterations to migratory cues from the L2 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Low	Low	Low
Sea trout	Low	Low	Low
Shad	Low	Low	Low
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Negligible	Negligible	Negligible

Table 3.66 Magnitude of effects upon marine and estuarine fish species resulting from alterations to migratory cues from the L2 option

Functional group	Magnitude of effect
Marine migrants	Very low
Marine stragglers	Very low
Estuarine species	Very low
Freshwater stragglers	Very low

Disruptions to route of passage

3.5.265 Predicted magnitude of effects for each individual species and river system from disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.67 and Table 3.68.

Table 3.67 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from disruption to route of passage from the L2 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	High	High	High
Sea trout	High	High	High
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	High	High	High
Eel	High	High	High

Table 3.68 Magnitude of effects upon fish species within the ecological guilds resulting from disruption to route of passage from the L2 option

Guild	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine residents	Medium
Freshwater stragglers	Low

Habitat change and/or loss

3.5.266 Predicted magnitude of effects for each individual species and river system from habitat change and/or loss within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within. Table 3.69 and Table 3.70

Table 3.69 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from habitat change and/or loss from the L2 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Low	Low
Sea trout	Medium	Low	Low
Shad	High	Medium	Medium
Sea lamprey	Medium	Low	Low
River lamprey	High	Medium	Medium
Eel	High	Medium	Medium

Table 3.70 Magnitude of effects upon marine and estuarine fish species resulting from habitat change and/or loss from the L2 option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Negligible
Estuarine species	Medium
Freshwater stragglers	Negligible

Changes to water quality

3.5.267 Predicted magnitude of effects for each individual species and river system from changes to water quality within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.71 and Table 3.72.

Table 3.71 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from changes to water quality from the L2 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.72 Magnitude of effects upon marine and estuarine fish species resulting from changes to water quality from the L2 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Anthropogenic noise disturbance

3.5.268 Predicted magnitude of effects for each individual species and river system from anthropogenic noise disturbance within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.73 and Table 3.74.

Table 3.73 Magnitude of effects upon migratory and estuarine fish species from the Rivers Usk, Wye and Severn resulting from anthropogenic noise disturbance from the L2 option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.74 Magnitude of effects upon marine and estuarine fish species resulting from anthropogenic noise disturbance from the L2 option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Effects to freshwater, marine and estuarine fish species

3.5.269 Predicted magnitude of effects for each individual species and river system from effects to freshwater, marine and estuarine fish species are detailed within Table 3.75.

Table 3.75 Magnitude of effects upon freshwater, marine and estuarine fish species resulting from the L2 option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Low
Estuarine species	Low
Freshwater stragglers	Low
Freshwater species	Low

Effects upon recreational and commercial fisheries

3.5.270 A summary of the magnitude of effects upon recreational and commercial fisheries is given below in Table 3.76.

Table 3.76 Magnitude of effects upon recreational and commercial fisheries resulting from the L2 option

Fishery	Magnitude of effect
Recreational - salmonid	High
Recreational - sea	Medium
Heritage	High
Commercial	Medium

Compound effects upon fish populations

3.5.271 The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

3.5.272 It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

Sea trout

3.5.273 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the sea trout population due to the complexity of its life history within the freshwater environment. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.**

Allis shad

3.5.274 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the allis shad population due to the rarity of the species and paucity of available data regarding their presence within the study rivers. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.**

Marine migrants

3.5.275 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine migrant species due to the number of species represented by this guild and a paucity of information regarding

their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Marine stragglers

3.5.276 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Estuarine residents

3.5.277 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the estuarine resident species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Freshwater stragglers

3.5.278 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the freshwater straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Atlantic salmon

3.5.279 Although it has only been possible to quantify the effects associated with turbine passage, incorporation of these values into the life history models for Atlantic salmon demonstrate the potential minimum effects that could be sustained by the three main river populations. Against the future baseline between 2014 and 2020 under the assumption that all directive targets are met the inclusion of STP effects reduces the egg deposition to between approximately 56 and 94 % of the directive target depending upon rivers and confidence limit.

Table 3.77 L2 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario

River	Parameter	Directive case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%	5%
SEVERN	Egg deposition (m)	16.59	12.21	14.72	9.22
	mean smolts	158,312	142,764	153,190	123,837
	mean spawners	4,862	3,586	4,317	2,712
	mean rod catch	676	500	601	378
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	39.63	31.02	37.10	23.28
	mean smolts	430,731	387,380	420,022	329,371
	mean spawners	11,438	8,961	10,709	6,731
	mean rod catch	2,142	1,680	2,005	1,263
	time to 5% EggDir	nr	nr	nr	nr
USK	Egg deposition (m)	19.41	14.29	16.74	11.49
	mean smolts	133,290	131,128	133,712	123,539
	mean spawners	7,465	5,524	6,458	4,450
	mean rod catch	1,128	837	978	676
	time to 5% EggDir	nr	nr	nr	nr

3.5.280 Under the future baseline between 2020 and 2140 represented by two climate change scenarios the egg deposition could be reduced by between 18 and 100% of the climate case baseline population. Furthermore, under climate change scenario B it is predicted that 5% of the egg directive target which is taken for the purpose of this assessment to represent population collapse could occur on the Rivers Severn and Wye under all confidence limits and on the River Usk under the mean and 5% limits. A reduction in populations below 5% of the egg directive target is also predicted under scenario A for the 5% confidence limit on the River Severn. **It is considered that there is therefore the potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye, Severn and Usk.**

Table 3.78 L2 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario A

River	Parameter	Climate (A) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	7.37	3.06	5.51	0.76
	mean rod catch	410	170	307	42
	mean smolts	93,945	47,653	76,579	13,472
	mean spawners	3,284	1,365	2,458	339
	time to 5% EggDir	nr	nr	nr	122
WYE	Egg deposition (m)	14.01	5.76	11.49	1.12
	mean rod catch	1,049	432	861	83
	mean smolts	200,386	94,442	171,219	20,368
	mean spawners	6,238	2,565	5,118	494
	time to 5% EggDir	nr	nr	nr	nr
USK	Egg deposition (m)	12.04	7.13	9.57	4.34
	mean rod catch	876	522	699	318
	mean smolts	109,239	85,390	99,835	60,858
	mean spawners	5,903	3,509	4,702	2,140
	time to 5% EggDir	nr	nr	nr	nr

Table 3.79 L2 STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario B

River	Parameter	Climate (B) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	0.13	0.00	0.02	0.00
	mean rod catch	7	0	1	0
	mean smolts	2,208	29	385	1
	mean spawners	59	1	10	0
	time to 5% EggDir	52	28	35	19
WYE	Egg deposition (m)	0.02	0.00	0.01	0.00
	mean rod catch	2	0	1	0
	mean smolts	371	15	146	1
	mean spawners	9	0	3	0
	time to 5% EggDir	34	25	29	18
USK	Egg deposition (m)	4.98	0.64	2.54	0.04
	mean rod catch	367	47	188	3
	mean smolts	58,629	9,839	34,370	613
	mean spawners	2,476	318	1,266	17
	time to 5% EggDir	nr	34	nr	34

Twaite shad

3.5.281 Table 3.80 and Table 3.81demonstrate the potential effects upon the future baseline of the twaite shad populations from the Rivers Usk, Severn and Wye over the periods 2014 to 2020 and 2020 to 2140 respectively. Population collapse and effectively extinction is predicted for the River Severn, Wye and Usk populations under all scenarios. **The predicted effects associated with the L2 STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.**

Table 3.80 L2 STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**
Usk	36,842	15,130	699*(71)	332
Severn	36,842	15,130	186*(40)	94
Wye	92,104	37,826	1,349*(62)	692

Table 3.81 L2 STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenarios (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Climate change case (1°C)				Climate change case (2°C)			
	Baseline population		STP effects population		Baseline population		STP effects population	
River	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Usk	42,626	4,538	1,421*(>100)	649	31,278	3,083	1,410*(>100)	568
Severn	42,626	4,538	229*(60)	85	31,278	3,083	228*(>100)	83
Wye	106,565	11,346	2,364*(100)	973	79,104	7,708	8,449*(>100)	2,747

Sea lamprey

3.5.282 Table 3.82 demonstrates the potential minimum effect upon the baseline sea lamprey population that could occur as a result of the construction and operation (up to 2020) of the L2 STP plan alternative. The predicted reduction in adult population size is approximately 30% for the River Wye and 65% for the River Usk. For transformers the population is predicted to reduce by approximately 35% on the Wye and 66% on the Usk. **It is therefore considered that there is potential for collapse of the sea lamprey population on the River Usk, a significant reduction in population size on the Wye for the L2 STP plan alternative and reductions in European stock size.**

Table 3.82 L2 STP effects upon the sea lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	14,397,293	581,840	5,114,672	370,209	56,875,906	2,664,438	39,714,096	2,287,426
Transformers	2,245,978	90,767	757,675	54,842	8,937,418	417,532	5,785,128	333,759
Adults	3,069	455	1,088	161	12,200	1,836	8,550	1,287

River lamprey

3.5.283 Table 3.83 provides an indication of the potential minimum effect upon the baseline river lamprey population that could occur over the period 2014 to 2020 as a result of the construction and operation (up to 2020) of the L2 STP plan alternative. The predicted reduction in adult population size is approximately 20% for the River Wye and 46% for the River Usk. For transformers the populations are predicted to reduce by approximately 26% on the River Wye and 48% on the Usk. **The losses predicted from the river lamprey population would represent a significant reduction in the River Usk and Wye population size and a reduction in the UK stock size.**

Table 3.83 L2 STP effects upon the river lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case population		STP effects population		Base case population		STP effects population	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	21,952,630	1,985,605	12,083,490	657,411	71,158,380	5,598,596	56,422,934	3,441,087
Transformers	3,424,610	309,754	1,787,192	97,233	11,100,707	873,381	8,204,039	501,355
Adults	27,667	4,696	15,192	2,579	88,442	14,324	70,754	11,459

Eel

3.5.284 Table 3.84 provides an indication of the potential effects of the L2 STP plan alternative upon the silver eel biomass outputs for the Rivers Severn, Wye and Usk over the period 2014 to 2140. It is predicted that under the climate case scenario that the stock from the River Severn would be reduced by approximately 4% of the climate case population, by 3% for the River Wye and 7% for the River Usk. **It is considered that predicted reduced outputs for the Rivers Severn Wye and Usk could represent population reductions and place compliance of the EU Eel Regulations at risk.**

Table 3.84 L2 STP effects upon the biomass output (Kg) of silver eel in the Rivers Severn, Usk and Wye under the 2014 to 2140 future baseline scenarios

River	Base case population	Climate case population	STP effects population
Severn	26,865	124,134	119,702
Usk	497	3,146	2,931
Wye	5,861	37,330	36,177

Summary of Likely Significant Effects on the Environment

3.5.285 Based on the magnitude of potential effects calculated, and the compound effects upon fish populations and with consideration of the value and vulnerability of the individual fish receptors together with the reversibility and permanence of the effects, the likely significance of the effects of the L2 alternative option have been calculated and are shown in Table 3.85.

Table 3.85 Alternative Option L2: Welsh Grounds Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Atlantic salmon *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Low*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea trout *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Low*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities			*biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Shad *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Low*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency continual			*populations and wider biogeographic stocks.*			
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea lamprey *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Low*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
River lamprey	*Alterations to migratory*	*Indirect*	*High*	*Construction – S/M term,*	*Reversible*	*Low*	*Affecting only migratory*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Value = H Vulnerability = H	*cues*			*frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Temporary*		*fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*			
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Eel *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary.*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities			*See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*High*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Marine migrants *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Marine stragglers *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities						
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Estuarine residents *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
Freshwater stragglers *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative / Positive*	*See text for details*	*Y*

Alternative Option L3d: Bridgwater Bay Lagoon

Direct Effects

Construction Phase

Disruptions to route of passage

3.5.286 The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish and low for the ecological guilds.

Habitat change and/or loss

3.5.287 The Bridgwater Bay Lagoon has an overall total footprint of 302 ha. Of this footprint area 286 ha would be situated in the subtidal zone with the remaining 16 ha situated in the intertidal zone. The total lagoon area would be 8,602 ha of which 4,409 ha would be subtidal and the remaining 4,193 ha would be intertidal.

Operational Phase

Disruptions to route of passage

3.5.288 The likelihood of the L3d plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be medium to high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.289 Additionally to changes to water exchange, the footprint of the overall total device is 302 ha. Of this footprint area 286 ha would be situated in the subtidal zone with the remaining 16 ha situated in the intertidal zone. The total lagoon area would be 8,602 ha of which 4,409 ha would be subtidal and the remaining 4,193 ha would be intertidal.

Decommissioning Phase

Disruptions to route of passage

3.5.290 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for

the migratory fish species and low for the species contained within the ecological guilds.

Indirect Effects

Construction Phase

Alterations to migratory cues

3.5.291 The Bridgwater Bay Lagoon encompasses the Rivers Brue, Cary and Parrett. These rivers do not represent very significant rivers for any of the designated migratory species recorded in the estuary with the exception of eel for which the River Parrett is considered important. It is not considered however that eel use freshwater cues as part of their migration so the potential effects of a reduction in freshwater flow are expected to be negligible on this species. The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this plan alternative would be possible. The duration of effect would be for the entire period of construction. The frequency of effect would be during each migratory cycle. The magnitude of negative effects upon the migratory fish species is therefore considered to be negligible.

Disruptions to route of passage

3.5.292 The potential for the construction phase of the L3d plan alternative to have an effect upon the route of passage of fish species within the Estuary is largely dependent upon the nature of the construction activities. As the plan alternative was developed and the structure placed into position there is potential for the route of passage to be disturbed, although it has been assumed for the purposes of this assessment that water would be allowed to pass through the structure until the point of generation commencement. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the construction phase however, it is considered likely that it would be heightened during the latter half of this phase. The potential frequency of effect could be continuous over the construction phase period. The magnitude of adverse effects is considered to be medium for migratory fish and low for the ecological guilds.

Habitat change and/or loss

3.5.293 Habitat loss during the construction phase would likely extend to an area greater than that to eventually be occupied by the plan alternative, partly because construction activities could lead to short-term changes in erosion and accretion patterns within the Severn Estuary. This could reduce or increase the amount of habitat available for individual fish species within the Estuary. Further where active construction is occurring it is likely that physical disturbances would prevent fish utilisation of such habitats which are present but would not be affected directly.

3.5.294 The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during construction activities would be certain. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible.

Changes to water quality

3.5.295 During construction remobilisation of sediment is likely to occur through dredging and construction activities. This would lead to increases in suspended sediment concentrations and increases in associated contaminants. There is also the possibility

of leaks and spillages of fuels or construction materials. The main effects responsible for changes to water quality would be from progressive changes to water exchange and sedimentation as the barrage is built.

3.5.296 The probability of changes to water quality affecting the fish present in the Severn Estuary during construction activities would be possible. The duration of effects would be for the entire period of construction. The frequency of effects would be variable over the length of the construction period depending upon the various construction activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.297 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during construction activities is probable. The duration of effects would be for the entire period of construction activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the construction period depending on the various construction activities employed at any one time and the construction method employed. The severity of effects would depend upon the timing of the works. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of the specialist receptors, shad and herring, and low for the remaining receptor fish species within the generalist and non-specialist categories. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.298 The likelihood of freshwater, marine and estuarine fish species being indirectly affected during construction of this plan alternative would be possible. The duration of effects would be for the entire period of construction. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.299 In terms of fish availability those effects associated with construction of the L3d STP plan alternative as discussed above could result in the loss of fish from target populations as well as avoidance of key fishing areas. Additionally access to fishing areas may be restricted during construction activities.

3.5.300 The likelihood of effects resulting from the construction of the proposed L3d plan alternative having subsequent effects upon the recreational, commercial and heritage fisheries of the Severn Estuary and its tributary rivers is certain. The duration of effects would be for the period of construction. The magnitude of negative effects is considered to be low to medium.

Operational Phase

Alterations to migratory cues

3.5.301 The likelihood of migratory cues and natal homing of migratory species being disrupted during construction of this plan alternative would be possible. The duration of effects would be for the lifetime of the plan alternative. The frequency of effect would be during each migratory cycle. The magnitude of negative effects upon the migratory fish species is therefore considered to be negligible.

Disruptions to route of passage

3.5.302 The likelihood of the L3d plan alternative representing a disruption to route of passage potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary is considered to be certain. The duration of the effects would be for the lifetime of the plan alternative. The frequency of effect would be during each generation cycle. It is considered that the magnitude of effects upon the migratory fish species would be medium to high and upon the ecological guilds low to medium.

Habitat change and/or loss

3.5.303 The probability of habitat change and/or loss affecting the fish present in the Severn Estuary during the operational phase would be certain. The duration of effects would be for the entire period of operation over the lifetime of the plan alternative. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be negligible.

Changes to water quality

3.5.304 The probability of changes to water quality affecting the fish present in the Severn Estuary during the operational phase would be possible. The duration of effects would be for the entire period of operation over the lifetime of the alternative option. The frequency of effects would be constant although gradual long-term change in habitat distribution may also occur. The magnitude of potential effects is judged to be negligible.

Anthropogenic noise disturbance

3.5.305 The probability of anthropogenic noise disturbance affecting the fish present in the Severn Estuary during the operational phase is possible. The duration of effects would be for the entire period of operation over the lifetime of the proposed development. The frequency of effects would be variable over the period of operation depending on the programme of operation and maintenance. The severity of effects would depend upon the details of the structure. The magnitude of potential effects upon the receptor fish is judged to be medium for hearing specialists such as shad and herring and low for the other fish receptors categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the construction of this STP plan alternative.

Effects on freshwater, marine and estuarine fish species

3.5.306 The likelihood of the freshwater, marine and estuarine fish species being indirectly affected by a direct reduction in the numbers of fish as a result of this STP plan alternative is probable. The duration of effects would be for the lifetime of the plan alternative. It is considered that the magnitude of negative effects would be low.

Effects upon recreational and commercial fisheries

3.5.307 Based on the results of the life cycle models, commercial species that are most likely to be significantly, directly affected include eel and salmon. It is considered that a 90 % reduction in salmon egg deposition targets would likely result in the freshwater angling and commercial salmon fisheries becoming unviable on the River Wye. Reductions in eel of up to 99 % on all of the main rivers associated with the Severn Estuary, would make commercial eel fisheries unviable on this river. The indirect

effects for L3d that are discussed within this annex are not expected to be relevant for this option and would therefore not be expected to further effect the identified fisheries. The likelihood of the recreational and commercial fisheries being indirectly affected by a direct reduction in the numbers of fish as a result of the L3d STP plan alternative is certain. The duration of effects would be for the lifetime of the plan alternative. The magnitude of negative effects is considered to be low to medium.

Decommissioning Phase

Alterations to migratory cues

3.5.308 The likelihood of migratory cues and natal homing of migratory species being disrupted during decommissioning of this plan alternative would be possible. As with effects during the construction phase the duration of effects would be for the entire period of decommissioning. The magnitude of negative effects upon the migratory fish species is therefore considered to be negligible.

Disruptions to route of passage

3.5.309 It is considered that effects arising from decommissioning would be similar to construction. The likelihood of disruption occurring is considered to be highly probable. The duration of effect could potentially be for the entire period of the decommissioning phase. The potential frequency of effect could be continuous over the decommissioning period. The magnitude of effects is considered to be medium for the migratory fish species and low for the species contained within the ecological guilds.

Habitat change and/or loss

3.5.310 Decommissioning activities would likely be similar to those experienced during construction. The probability of habitat loss and/or change affecting the fish present in the Severn Estuary during decommissioning would be certain. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible.

Changes to water quality

3.5.311 The probability of changes to water quality affecting the fish present in the Severn Estuary during decommissioning activities would be possible. The duration of effects would be for the entire period of decommissioning. The frequency of effects would be variable over the length of the decommissioning period depending upon the various activities underway. The magnitude of potential effects upon the receptor fish is judged to be negligible – very low.

Anthropogenic noise disturbance

3.5.312 The likelihood of anthropogenic noise disturbance being generated during decommissioning is probable. The duration of effects would be for the entire period of decommissioning activity during which anthropogenic sound is being emitted into the aquatic environment. The frequency of effects would be variable over the length of the decommissioning period depending on the various decommissioning activities employed at any one time and the decommissioning method adopted. The severity of effects would depend upon the timing of the works. There is the potential for improvements to techniques for mitigation to have occurred, or for advances in construction technology that would reduce the noise generated during

decommissioning in the intervening years. The magnitude of potential effects upon the receptor fish is judged to be medium in the case of hearing specialists such as shad and herring and low for the remaining receptor fish species categorised as generalist or non-specialists. A number of nationally and internationally protected fish species have the potential to be affected by anthropogenic noise disturbance during the decommissioning of this STP plan alternative. Once decommissioning is complete it is anticipated that anthropogenic noise disturbance would cease.

Effects on freshwater, marine and estuarine fish species

3.5.313 Upon decommissioning of the STP plan alternative some of the effects on freshwater, marine and estuarine species could persist depending upon the potential recolonisation of the Estuary and rivers by migratory and marine/estuarine species. The likelihood of effects would be possible. The duration of effects would be for the entire period of decommissioning. It is considered that the magnitude of negative effects upon the fish species would be low.

Effects upon recreational and commercial fisheries

3.5.314 Upon decommissioning of the L3d STP plan alternative some of the effects upon the fisheries of the Severn Estuary and its tributary rivers could persist where direct and indirect effects upon the populations remain. The likelihood of effects is certain. The duration of effects would be for the period of decommissioning. The magnitude of negative effects upon the fisheries is considered to be low to medium.

Summary of Likely Magnitude of Effects on the Environment

3.5.315 The following summarises the likely magnitude of potential effects (direct, indirect, far field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases. The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

Alterations to migratory cues

3.5.316 Predicted magnitude of effects for each individual species and river system from alterations to migratory cues within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.86 and Table 3.87.

Table 3.86 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from alterations to migratory cues from the L3d option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Negligible	Negligible	Negligible
Sea trout	Negligible	Negligible	Negligible
Shad	Negligible	Negligible	Negligible
Sea lamprey	Negligible	Negligible	Negligible
River lamprey	Negligible	Negligible	Negligible
Eel	Negligible	Negligible	Negligible

Table 3.87 Magnitude of effects upon marine and estuarine fish species resulting from alterations to migratory cues from the L3d option

Functional group	Magnitude of effect
Marine migrants	Very low
Marine stragglers	Very low
Estuarine species	Very low
Freshwater stragglers	Very low

Disruptions to route of passage

3.5.317 Predicted magnitude of effects for each individual species and river system from disruption to migration or movement within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.88 and Table 3.89.

Table 3.88 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from disruption to route of passage from the L3d option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	High	High	High
Sea lamprey	High	High	High
River lamprey	Medium	Medium	Medium
Eel	Medium	Medium	Medium

Table 3.89 Magnitude of effects upon fish species within the ecological guilds resulting from disruption to route of passage from the L3d option

Guild	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine residents	Medium
Freshwater stragglers	Low

Habitat change and/or loss

3.5.318 Predicted magnitude of effects for each individual species and river system from habitat change and/or loss within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.90 and Table 3.91.

Table 3.90 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from habitat change and/or loss from the L3d option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Negligible	Negligible	Negligible
Sea trout	Negligible	Negligible	Negligible
Shad	Negligible	Negligible	Negligible
Sea lamprey	Negligible	Negligible	Negligible
River lamprey	Negligible	Negligible	Negligible
Eel	Negligible	Negligible	Negligible

Table 3.91 Magnitude of effects upon marine and estuarine fish species resulting from habitat change and/or loss from the L3d option

Functional group	Magnitude of effect
Marine migrants	Negligible
Marine stragglers	Negligible
Estuarine species	Negligible
Freshwater stragglers	Negligible

Changes to water quality

3.5.319 Predicted magnitude of effects for each individual species and river system from changes to water quality within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.92 and Table 3.93.

Table 3.92 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from changes to water quality from the L3d option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Negligible	Negligible	Negligible
Sea trout	Negligible	Negligible	Negligible
Shad	Negligible	Negligible	Negligible
Sea lamprey	Negligible	Negligible	Negligible
River lamprey	Negligible	Negligible	Negligible
Eel	Negligible	Negligible	Negligible

Table 3.93 Magnitude of effects upon marine and estuarine fish species resulting from changes to water quality from the L3d option

Functional group	Magnitude of effect
Marine migrants	Negligible
Marine stragglers	Negligible
Estuarine species	Negligible
Freshwater stragglers	Negligible

Anthropogenic noise disturbance

3.5.320 Predicted magnitude of effects for each individual species and river system from anthropogenic noise disturbance within the Estuary potentially resulting in direct and indirect effects upon the fish species residing within and migrating through the Severn Estuary are detailed within Table 3.94 and Table 3.95.

Table 3.94 Magnitude of effects upon migratory fish species from the Rivers Usk, Wye and Severn resulting from anthropogenic noise disturbance from the L3d option

Species	Magnitude of effect		
	Usk	Wye	Severn
Salmon	Medium	Medium	Medium
Sea trout	Medium	Medium	Medium
Shad	Medium	Medium	Medium
Sea lamprey	Low	Low	Low
River lamprey	Low	Low	Low
Eel	Low	Low	Low

Table 3.95 Magnitude of effects upon marine and estuarine fish species resulting from anthropogenic noise disturbance from the L3d option

Functional group	Magnitude of effect
Marine migrants	Medium
Marine stragglers	Low
Estuarine species	Medium
Freshwater stragglers	Low

Effects to freshwater, marine and estuarine fish species

3.5.321 Predicted magnitude of effects for each individual species and river system from effects to freshwater, marine and estuarine fish species are detailed within Table 3.96.

Table 3.96 Magnitude of effects upon freshwater, marine and estuarine fish species resulting from the L3d option

Functional group	Magnitude of effect
Marine migrants	Low
Marine stragglers	Low
Estuarine species	Low
Freshwater stragglers	Low
Freshwater species	Low

Effects upon recreational and commercial fisheries

3.5.322 A summary of the magnitude of effects upon recreational and commercial fisheries is given below in Table 3.97.

Table 3.97 Magnitude of effects upon recreational and commercial fisheries resulting from the L3d option

Fishery	Magnitude of effect
Recreational - salmonid	Medium
Recreational - sea	Low
Heritage	Medium
Commercial	Low

Compound effects on fish populations

3.5.323 The following assessments have focused upon the three primary Severn Estuary tributaries; the Usk, Wye and Severn. Although not individually assessed consideration has also been given to the coalfield rivers (Ebbw, Rhymney, Taff and Ely) with respect to in particular the salmon populations. It is considered that point source effects upon the Ebbw population would be the same as the Usk and also similar for the other rivers. Effects would also be anticipated upon the River Parrett migratory fish populations.

3.5.324 It has not been possible to quantify the future baselines for the following species and as such compound STP effects cannot be quantifiably predicted. The qualitative assessments detailed below are therefore considered to be applicable to all STP plan alternatives.

Sea trout

3.5.325 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the sea trout population due to the complexity of its life history within the freshwater environment. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of both reductions in population size and river specific stock collapse for the Rivers Wye, Severn and Usk.**

Allis shad

3.5.326 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the allis shad population due to the rarity of the species and paucity of available data regarding their presence within the study rivers. As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however that there is potential risk of both reductions in population size and river specific stock extinction for the Rivers Wye, Severn and Usk and to a lesser extent the Tywi which could put the UK stock at risk of extinction.**

Marine migrants

3.5.327 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine migrant species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Marine stragglers

3.5.328 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the marine straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Estuarine residents

3.5.329 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the estuarine resident species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Freshwater stragglers

3.5.330 As discussed within the future baseline sections of this topic paper it has not been possible to quantify the future baseline of the freshwater straggler species due to the number of species represented by this guild and a paucity of information regarding their current and likely future stocks As such it has not been possible at this stage to determine the effects upon the baseline of this species beyond the magnitude of effect classifications detailed within this document. **It is considered however, that there is potential risk of reductions in population size.**

Atlantic salmon

3.5.331 Although it has only been possible to quantify the effects associated with turbine passage, incorporation of these values into the life history models for Atlantic salmon demonstrate the potential minimum effects that could be sustained by the three main river populations. Against the future baseline between 2014 and 2020 under the assumption that all directive targets are met the inclusion of STP effects reduces the egg deposition to between approximately 77 and 99 % of the directive target depending upon rivers and confidence limit.

Table 3.98 L3d STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario

River	Parameter	Directive case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%	5%
SEVERN	Egg deposition (m)	16.59	15.14	16.37	13.45
	mean smolts	158,312	154,542	157,823	148,493
	mean spawners	4,862	4,440	4,798	3,947
	mean rod catch	676	618	667	549
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	39.63	35.48	39.01	30.63
	mean smolts	430,731	412,334	428,245	384,924
	mean spawners	11,438	10,243	11,258	8,847
	mean rod catch	2,142	1,919	2,108	1,658
	time to 5% EggDir	nr	nr	nr	nr
USK	Egg deposition (m)	19.41	18.23	19.23	16.84
	mean smolts	133,290	133,836	133,405	133,751
	mean spawners	7,465	7,012	7,396	6,484
	mean rod catch	1,128	1,060	1,118	981
	time to 5% EggDir	nr	nr	nr	nr

3.5.332 Under the future baseline between 2020 and 2140 represented by two climate change scenarios the egg deposition could be reduced by between 0 and 100% of the directive target. Furthermore, under climate change scenario B it is predicted that 5% of the egg directive target which is taken for the purpose of this assessment to represent population collapse could occur on the Rivers Severn and Wye under all confidence limits. Additionally, there is potential for collapse of the River Usk population under the 5% confidence limit. **It is therefore considered that there is potential for population collapse and effectively extinction of genetically distinct salmon populations within the Rivers Wye and Severn and to a lesser extent the Usk.**

Table 3.99 L3d STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario A

River	Parameter	Climate (A) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	7.37	5.93	7.16	4.26
	mean rod catch	410	330	398	237
	mean smolts	93,945	80,818	92,106	62,690
	mean spawners	3,284	2,644	3,188	1,898
	time to 5% EggDir	nr	nr	nr	nr
WYE	Egg deposition (m)	14.01	9.90	13.38	5.43
	mean rod catch	1,049	742	1,003	406
	mean smolts	200,386	151,418	193,428	89,471
	mean spawners	6,238	4,411	5,961	2,415
	time to 5% EggDir	nr	nr	nr	nr
USK	Egg deposition (m)	12.04	11.04	12.04	9.65
	mean rod catch	876	803	876	703
	mean smolts	109,239	105,983	109,239	100,256
	mean spawners	5,903	5,412	5,903	4,738
	time to 5% EggDir	nr	nr	nr	nr

Table 3.100 L3d STP effects upon the Atlantic salmon populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenario under climate change scenario B

River	Parameter	Climate (B) case baseline	2014 to 2020 future baseline with STP effects		
			Mean	95%(UCL)	5%(LCL)
SEVERN	Egg deposition (m)	0.13	0.03	0.11	0.01
	mean rod catch	7	2	6	0
	mean smolts	2,208	581	1,824	107
	mean spawners	59	15	49	3
	time to 5% EggDir	52	40	51	30
WYE	Egg deposition (m)	0.02	0.00	0.02	0.00
	mean rod catch	2	0	1	0
	mean smolts	371	80	295	13
	mean spawners	9	2	7	0
	time to 5% EggDir	34	28	30	19
USK	Egg deposition (m)	4.98	3.98	4.98	2.62
	mean rod catch	367	293	367	194
	mean smolts	58,629	49,566	58,629	35,302
	mean spawners	2,476	1,978	2,476	1,304
	time to 5% EggDir	nr	nr	nr	nr

Twaite shad

3.5.333 Table 3.101 and Table 3.102 demonstrate the potential effects upon the future baseline of the twaite shad populations from the Rivers Usk, Severn and Wye over the periods 2014 to 2020 and 2020 to 2140 respectively. Population collapse and effectively extinction is predicted for the River Severn, Wye and Usk populations under the base case scenarios. Under the climate case scenarios however, a loss of approximately 42% is estimated for each of the River populations. **The predicted effects associated with the L3d STP plan alternative upon twaite shad populations in the River Severn, Wye and Usk are considered to have the potential to result in population collapse and extinction. There is also potential for reductions in population size for the River Tywi, were significant population reductions to be seen on this river as well there is potential for whole UK stock extinction.**

Table 3.101 L3d STP effects upon the individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2014 to 2020 future baseline scenario (*indicates insufficient replacement to support population persistence over time i.e. extinction predicted, numbers in parenthesis identify the predicted number of years before population collapse)

	Baseline population		STP effects population	
River	Mean	SD	Mean	SD
Usk	18,421	15,130	5,102*(>100)	2,397
Severn	18,421	15,130	5,102*(>100)	2,397
Wye	46,052	37,826	12,754*(>100)	5,993

Table 3.102 L3d STP effects upon then individual adult twaite shad populations of the Rivers Severn, Wye and Usk under the 2020 to 2140 future baseline scenarios

	Climate change case (1°C)				Climate change case (2°C)			
	Baseline population		STP effects population		Baseline population		STP effects population	
River	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Usk	31,906	14,721	18,397	3,080	31,642	17,640	18,383	1,627
Severn	31,906	14,721	18,397	3,080	31,642	17,640	18,383	1,627
Wye	79,764	36,801	45,992	7,700	79,104	44,101	45,958	4,068

Sea lamprey

3.5.334 Table 3.103 demonstrates the potential minimum effect upon the baseline sea lamprey population that could occur as a result of the construction and operation (up to 2020) of the L3d STP plan alternative. The predicted reduction in adult population size is approximately 18% for both the River Wye and Usk. For transformers the population is predicted to reduce by approximately 19% on both Rivers. **It is considered that these losses would represent reductions in sea lamprey population size for both the Rivers Wye and Usk and the European population.**

Table 3.103 L3d STP effects upon the sea lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case		STP effects		Base case		STP effects	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	14,397,293	581,840	12,057,059	771,467	56,875,906	2,664,438	47,107,385	3,286,078
Transformers	2,245,978	90,767	1,829,741	117,075	8,937,418	417,532	7,201,058	501,743
Adults	3,069	455	2,531	375	12,200	1,836	10,060	1,514

River lamprey

3.5.335 Table 3.104 provides an indication of the potential minimum effect upon the baseline river lamprey population that could occur over the period 2014 to 2020 as a result of the construction and operation (up to 2020) of the L3d STP plan alternative. The predicted reduction in adult population size is approximately 11% for both the River Wye and Usk. For transformers the population is predicted to reduce by approximately 13% on both Rivers. **It is considered that these losses would represent reductions in river lamprey population size for both the River Wye and Usk and the UK population.**

Table 3.104 L3d STP effects upon the river lamprey populations of the Rivers Wye and Usk under the 2014 to 2020 future baseline scenario

	Usk				Wye			
	Base case		STP effects		Base case		STP effects	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Ammocoetes	21,952,630	1,985,605	19,387,649	948,959	71,158,380	15,598,596	62,898,380	3,083,692
Transformers	3,424,610	309,754	2,942,812	144,041	11,100,707	873,381	9,616,940	470,728
Adults	27,667	4,696	24,624	4,179	88,442	14,324	78,714	12,748

Eel

3.5.336 Table 3.105 provides an indication of the potential effects of the L3d STP plan alternative upon the silver eel biomass output for the Rivers Severn, Wye and Usk over the period 2014 to 2140. It is predicted that under the climate case scenario that the stock from all three rivers would be reduced by approximately 1% of the climate case population. **Although representing a reduction to the population size of this species with potential implications for compliance of the EU Eel Regulations for the Severn RBD it is considered very unlikely that the effects associated with the L3d plan alternative would affect the status of the European eel stock.**

Table 3.105 L3d STP effects upon the biomass output (Kg) of silver eel in the Rivers Severn, Usk and Wye under the 2014 to 2140 future baseline scenarios

River	Base case	Climate case	STP effects
Severn	26,865	124,134	122,359
Usk	497	3,146	3,101
Wye	5,861	37,330	36,796

Summary of Likely Significant Effects on the Environment

3.5.337 Based on the magnitude of potential effects calculated, and the compound effects upon fish populations and with consideration of the value and vulnerability of the individual fish receptors together with the reversibility and permanence of the effects, the likely significance of the effects of the L3d alternative option have been calculated and are shown in Table 3.106.

Table 3.106 Alternative Option L3d: Bridgwater Bay Lagoon

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Atlantic salmon *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea trout *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities			*biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Shad *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish*	*Negative*	*See text for details*	*N*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				Operation – L term, frequency continual Decommissioning – S/M term, frequency continual			*populations and wider biogeographic stocks.*			
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Sea lamprey *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*High*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
River lamprey	*Alterations to migratory*	*Indirect*	*High*	*Construction – S/M term,*	*Reversible*	*Negligible*	*Affecting only migratory*	*Negative*	*See text for details*	*N*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
Value = H Vulnerability = H	*cues*			*frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Temporary*		*fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*			
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Eel *Value = H Vulnerability = H*	*Alterations to migratory cues*	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities.*	*Reversible Temporary*	*Negligible*	*Affecting only migratory fish from rivers impounded by this plan alternative. Possible effects on wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Medium*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary.*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities			*See text for list of sites.*			
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon straying fish populations and wider biogeographic stocks.*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon straying fish populations, wider biogeographic stock and Natura 2000 sites outside of the Severn Estuary. See text for list of sites.*	*Negative*	*See text for details*	*Y*
Marine migrants *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Marine stragglers *Value = H Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency dependent upon activities						
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*
Estuarine residents *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Medium*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M*	*Reversible Permanent*	*Low*	*Potential far field effects upon wider biogeographic stocks*	*Negative / Positive*	*See text for details*	*Y*

Receptor (value (H/L)and vulnerability (H/M/L/None))	Description of effect	Direct or Indirect; Far-field effect; Cumulative effect; or effect resulting from Consequential Development	Probability (H/M/L/VL)	Duration (occurs during construction, operation or decommissioning phase and L/M/S/VS term) and frequency	Irreversible/ reversible; temporary/ permanent	Magnitude (H/M/L/VL)	Spatial extent & trans-boundary	Positive/ Negative	Assumptions, Limitations, Uncertainties	Significant (Y/N)
				term, frequency continual						
Freshwater stragglers *Value = L (H) Vulnerability = M*	*Alterations to migratory cues*	*Indirect*	*VL*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Very low*	*Severn Estuary population only.*	*Negative*	*See text for details*	*N*
	Disruptions to route of passage	*Direct*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Habitat change/loss	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Changes to water quality	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Negligible*	*No far field effects anticipated*	*Negative*	*See text for details*	*N*
	Anthropogenic noise disturbance	*Indirect*	*High*	*Construction – S/M term, frequency dependent upon construction activities Operation – L term, frequency continual Decommissioning – S/M term, frequency dependent upon activities*	*Reversible Temporary*	*Low*	*No far field effects anticipated*	*Negative*	*See text for details*	*Y*
	Effects to freshwater marine and estuarine fish species	*Indirect*	*High*	*Construction – S/M term, frequency continual Operation – L term, frequency continual Decommissioning – S/M term, frequency continual*	*Reversible Permanent*	*Low*	*No far field effects anticipated*	*Negative / Positive*	*See text for details*	*Y*

3.6 Measures to prevent, reduce, and as fully as possible, offset any significant adverse effects on the environment

3.6.1 The SEA Directive requires that information is provided on the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme (Annex I). These measures are considered within this topic, and would thereby inform an overall assessment of such measures within the SEA Environmental Report.

3.6.2 In this SEA, and in line with UK practice, these measures are split into those measures to prevent or reduce effects , and measures to as fully as possible offset any significant adverse effects on the environment.

3.6.3 A number of enhancement initiatives may already be planned or required to meet the conservation objectives under drivers such as Natura 2000 and the WFD. As such, the measures detailed in the following sections may in some instances not been seen as additional to measures already planned within conservation management plans. Measures that may not be additional to measures proposed elsewhere, have been included within this assessment however, a note has been added recommending that further consideration be given to this possible complication during any future STP assessment and before implementation of any measures.

3.6.4 A number of the measures detailed would be unprecedented at the scale likely to be required for an STP development and involve novel techniques. The potential application of the measures is therefore in the majority of cases likely to be limited and could offer only partial benefit. Although it has been noted for a number of the identified measures that they have potential to partially prevent/reduce STP plan alternative effects; it should be emphasised that there is no indication that the combination of such measures could result in complete prevention of effects. It is not considered possible at this time to accurately and completely quantify the potential extent, effectiveness or success of the measures identified and as such studies have been recommended to assist with this process during any future STP assessment. Where possible an assumption expert judgement based approach has been undertaken. It should be noted however, that it is considered unlikely that upon implementation, a combination of measures could completely prevent STP effects and as such there is potential for residual effects to remain.

3.6.5 SEA Directive terminology will be used throughout this topic paper however as all of the prevention, reduction and offsetting measures discussed concern SAC features it has been assumed that these are also applicable to measures to prevent or reduce adverse effects and compensation under the Habitats Directive.

Measures to prevent or reduce effects

3.6.6 The measures identified to prevent or reduce likely significant adverse environmental effects within this topic are described below.

3.6.7 Under SEA Directive terms the process of option optimisation is considered to be the consideration of measures to prevent and reduce the effects of an STP plan alternative.

3.6.8 Each of the indentified measures may, in isolation, not be sufficient to fully prevent or reduce a given effect, however, it is the cumulative effect of these measures (and

potentially in combination with offsetting measures) which is important when assessing their potential to prevent or reduce any negative effects of the proposed development. It is considered likely however, that even in combination that prevent/reduce measures would not be fully effective and that residual effects could remain that would need to be addressed with offsetting measures where possible. The potential to prevent potential effects and a confidence of effectiveness is given for each potential measure. This level of confidence represents the likelihood of the measure being successful in reducing potential effects. Confidence has been assigned based on expert judgement in line with the following categories:

- High
- Moderate
- Low
- Very low

3.6.9 For those options where measures could have some potential to offset effects of an STP plan alternative, an indication of whether the measure (at whatever scale or magnitude it its implemented) in question could entirely, or partially mitigate for the effect is also given.

3.6.10 It should be noted that the unprecedented scale of measures likely to be required for an STP plan alternative and the fact that many of them are novel is likely to result in the uncertainty of their success being high in a number of cases. To take into consideration the potential requirement for further investigations to reduce this uncertainty, assess the feasibility and determine potential extent, measures have been assessed on the basis of whether they could be implemented by 2020. Where it is considered that the required investigations would be of a level precluding their completion by 2020 the measure has either been excluded from further STP assessments or recommended for further consideration depending upon the level of investigations likely to be required and the extent of uncertainty surrounding it. An indication of the investigations likely to be required has been given where applicable for each measure.

3.6.11 Where possible the potential efficacy of individual measures has been estimated. Due to a paucity of detail, scientific knowledge and precedent on the scale likely to be required, a number of assumptions have been necessary during this assessment. Where necessary an expert judgement based best estimate approach has been adopted for the derivation of these assumptions. There is however, no inference that such assumptions would represent the actual circumstance and it is strongly recommended that the investigations identified be undertaken to improve potential efficacy ranges prior to design and implementation of prevent/reduce measures for an STP plan alternative. On the collection of this information it is considered likely that the assumptions made could change and with them the efficacy ratings. The assessment provided within this paper should therefore be considered as indicative only.

Option optimisation

3.6.12 One of the most significant potential effects upon estuarine and migratory fish receptors was identified within Phase 1 as the delay, injury and mortality resulting from fish passage past an STP plan alternative. It was recognised however that there may be potential option optimisation and modifications which could prevent and /or reduce these effects. As such during the Option Optimisation process, each of the five short-listed plan alternatives were reviewed by the fisheries and engineering topic

teams to determine their scope for optimisation. Such optimisations and modifications centred upon turbine and sluice design, the inclusion of fish passage mechanisms, the operational regime and fish deterrent/enticement schemes.

3.6.13 It should therefore be noted that the design and operational adaptations identified were specifically intended to reduce the effects associated with disruption to route of passage in particular passage through the structure. The measures identified and their relative potential efficacies should not therefore be applied to the compound effects of an STP plan alternative.

3.6.14 Early discussions were held between the fisheries specialists and engineers during the option optimisation stage to identify possible technological and operational modifications that could prevent or reduce effects upon the potentially at risk fish receptors. APEM in discussion with the engineers developed a list of measures which could go some way to reducing effects which where possible were incorporated into alternative option designs.

3.6.15 The following measures were identified by the fisheries team and where possible and appropriate were considered by the engineering team when selecting and specifying turbine design and operation:

- Mode of operation – it was considered by the fisheries team that ebb only generation would the preferable mode of operation for plan alternatives where possible.
- To reduce injury rates during turbine passage it was specified by the fisheries team that larger turbines with a slower rotation speed and fewer blades would be the most optimal design modifications to the types of turbine units being considered.
- Wherever possible it was advised that the efficiency of operation would be maximised including the use of double regulated turbine units and automated regulation to further minimise effects upon the fish populations of the Severn Estuary.
- It was further suggested that where possible the permeability of the structure should be increased to allow a greater proportion of water to pass through structures other than generating turbines to increase areas for free passage.
- Other operational regime modifications such as periods of generation cessation to avoid key sensitive periods were also discussed and are detailed further within the following sections.

3.6.16 A number of other significant effects upon migratory and estuarine fish species were identified during the Plan Alternatives Assessment which it could not be fully possible to eliminate through option optimisation. As such, it was deemed that adequate information on the potential feasibility of prevention and reduction measures was required.

3.6.17 A number of potential measures to prevent or reduce potential effects have been explored during Phase 2 and an in-depth assessment of the feasibility, confidence and likelihood of success of these measures has been undertaken (See Annex 2:

Measures to prevent and /or reduce STP plan alternative effects). The following measures have been considered:

- Construction prevention and reduction measures: the following potential construction effects have been identified: barrier effect, underwater noise, sediment movement/resuspension and accidental release of pollutants. The following potential measures to prevent or reduce effects have been investigated:
    - Timing of works: In general the potential effects of the proposed construction would vary according to the sensitive periods for the species and habitats within the Severn Estuary. Where possible, works would need to be undertaken outside of the key migratory periods for the designated species.
    - Noise effect: consisting of prevention, reduction and discouragement.
    - Methods to prevent or reduce effects of sediment movement/resuspension: including monitoring and sediment traps.
    - Methods to prevent or reduce risk of accidental release of pollutants: including prevention of contaminated run-off into the Estuary, strict controls for capture, storage and disposal of dewater and monitoring.
- Operation prevention and reduction measures – Operational regime;
- Operation prevention and reduction measures – Innovation and advancement in turbine design;
- Operation prevention and reduction measures – Noise minimisation;
- Operation prevention and reduction measures – Fish passage;
- Operation prevention and reduction measures – Fish exclusion and diversion;
- Operation prevention and reduction measures – Predator control;
- Operation prevention and reduction measures – Pheromone release;
- Operation prevention and reduction measures – Trap and transport;
- Operation prevention and reduction measures – Fish stocking;
- Operation prevention and reduction measures – Intertidal habitat creation and enhancement;
- Operation prevention and reduction measures – Addressing limiting factors in the freshwater environment.

Construction prevention and reduction measures

3.6.18 It should be noted that the measures detailed within this section are intended to prevent/reduce effects associated with construction activities only and as such identified efficacies should not be applied to compound STP plan alternative effects.

Timing of works

3.6.19 The feasibility of avoiding key at risk areas and individuals will differ between STP plan alternatives which is unlikely to prove feasible for all species and life stages due to differing key periods encompassing the majority of the year. Therefore, if this measure were to be taken forward it would be necessary to prioritise species on the basis of those likely to be at risk of greatest effect or the limited availability of other suitable measures to prevent or reduce the effects. This will have implications in terms of proposed measures to offset the effects of an STP plan alternative in that effects which can not be prevented or reduced would require offsetting. This would therefore require consideration early on in the process as offsetting measures could be required during the construction stage. The success of this measure would rely on the detailed knowledge of the key sensitive periods for the fish species within the Severn Estuary. The route of passage taken by migratory species through the Severn Estuary and information on the residence period is currently largely unknown. The confidence of potential success is therefore considered to be unknown at this stage as a result of requiring further study.

Noise effect prevention or reduction measures

3.6.20 It is considered that there are measures to reduce the effects of noise and vibration generated during construction activities which are established practice within the UK. It is acknowledged however, that their application within an environment such as the Severn Estuary is largely unprecedented and that further investigations are likely to be required regarding the feasibility of their application within this hostile working environment prior to implementation. It is considered unlikely however, that such investigations would preclude the implementation of identified suitable measures within the STP 2020 timeframe. It is not envisaged that there would be any significant adverse effects upon other environmental features or society and economy from the application of these measures. Although the measures would require intervention it would be restricted to the periods of construction and decommissioning activity and would not be required for the lifetime of the project. The potential efficacy of this measure depends upon the technique that is adopted and the specific construction activities employed. This level of information would only be finalised at the detailed design/EIA stage. In the absence of this information an accurate assessment of efficacy is not possible. It is considered however that there is potential that these measures could specifically reduce construction noise and vibration effects by between 10 and 90%. It is recommended that these measures be included within the suite of SEA prevent/reduce measures for all fish receptors.

Sediment movement/re-suspension prevention and reduction measures and measures to prevent or reduce the accidental release of pollutants

3.6.21 There are industry standard measures to reduce the effects of sediment disruption/displacement and accidental release of pollutants into the aquatic environment which have previously been successfully used within estuarine and marine environments in the UK. As measures are largely proven they would therefore require minimal development for specific application within the Severn Estuary and as such could be implemented within the STP 2020 timeframe. No major significant adverse effects are envisaged for other environmental features of society and

economy from application of the measures. Although the measures would require ongoing intervention during their deployment this would be restricted to periods of construction and decommissioning. The potential efficacy of these measures would depend upon the techniques employed and the specific construction activities. In the absence of this information which would not be defined until the detailed design/EIA stage an efficacy range of between 30 and 90% has been predicted. It is recommended that these measures be included within the suite of SEA prevent/reduce measures for all fish receptors.

Operation prevention and reduction measures – operational regime

3.6.22 It should be noted that it is intended that the measures identified and discussed within this section would be applicable to preventing/reducing the effects associated with disruption to route of passage in particular passage through the structure only. Identified efficacies for these measures should not therefore be applied to compound effects for the STP plan alternatives.

3.6.23 There are a number of potential operation regimes which could be altered to benefit fish passing the structure. These include timing of generation and the permeability of the structure in particular with regards to the ratio of water passing through generating turbines versus free wheeling turbines and sluices. The efficacy of these measures are both species and life stage specific and depend upon the percentage of time over which generation cessation could be operated and what percentage of flow could be lost to generation to increase permeability.

Cessation periods

3.6.24 It has been assumed for the purpose of this assessment that cessation periods over the course of the year of between 5 and 15% would be possible. The cessation period could be spread over the course of the year or clumped to a discrete high risk period. The scale of benefit would depend upon the extent of cessation, the period over which it was implemented and the behaviour of the at risk fish species it was designed to protect. There are many uncertainties within such an assessment of efficacy, necessitating a largely assumption based approach. The following efficacies have been predicted on the basis of this assumption and expert judgement based approach; salmon smolts – 15 to 75%, adult salmon – 0 to 40%, elver – 5 to 35%, silver eel – 15 to 75%, sea lamprey 15 to 75% and river lamprey – 5 to 35% (on the basis of a 50:50 resident:transit ratio). It is considered that this measure would be ineffective for shad and the marine/estuarine guilds due to their protracted residence time within the Estuary. Although there are some examples of where this measure has been employed for run-of-river hydro schemes, there is no precedent for its implementation within a tidal environment, on the required scale or for multiple species. Knowledge gaps in particular with respect to the behaviour of fish within the estuarine environment could preclude the optimal application of this measure. These knowledge gaps would need to be explored further prior to the detailed design and implementation of this measure. It is not envisaged that this measure would have any significant adverse effect upon other environmental features or society and economy. This measure would have energy penalties for the lifetime of the STP plan alternative. It is considered that there is potential that were knowledge gaps regarding fish behaviour within the Estuary to be investigated and the measure suitably designed that it could offer some reduction of effects upon salmon, eel and lamprey. On the basis of independent advice however, this measure has not been included within the suite of SEA prevent/reduce measures for these species. It is recommended however, that this measure be considered within future STP assessments. This measure is considered likely to be ineffective for shad and the marine/estuarine guilds

and as such it has not been recommended for inclusion within the measures for these species and should not be considered further within future STP assessments.

Increased permeability

3.6.25 As with generation cessation an energy loss of between 5 and 15% has been assumed for increased permeability in this case diverting this percentage volume of water through safer passage routes whether they be sluices, free-wheeling turbines or free gaps. It is considered that increasing the permeability of a structure to aid fish passage is an established practice and technique which would not require further technical development but would be dependent upon knowledge regarding fish behaviour. Were it possible to undertake investigations on the behaviour of the key fish species within the Estuary within the STP 2020 timeframe and the implementation of this measure be refined during the detailed design/EIA stage this measure could be incorporated into an STP plan alternative design. It is not envisaged that this measure would have any significant impact upon other environmental features or society and economy. It would however, have energy penalties for the lifetime of the STP plan alternative. Whilst it is clear that this measure could be effective at reducing STP plan alternative effects the scale of benefit would depend upon the volume of water that could be made available for it, the period of the generation time over which it was implemented and the behaviour of the at risk fish species. On the basis of an assumed increase in permeability of between 5 and 15% at varied generating periods it is predicted that the efficacy of this measure could be between 5 and 30%. It is recommended that this measure be included within the suite of STP prevent/reduce measures for all of the fish receptors.

Operation prevention and reduction measures – innovation and advancement in turbine design

3.6.26 It should be noted that the measures identified and discussed in this section would be applicable to preventing/reducing the effects associated with disruption to route of passage in particular passage through the turbines only. Identified efficacies for these measures should not therefore be applied to compound effects for the STP plan alternatives.

3.6.27 All of the five short listed STP plan alternatives under consideration within this assessment include Kaplan type turbines within their design. There have however been a number of innovations and advances in turbine design made within recent years (particularly from the US) with the intention of reducing effects upon fish during passage. Few of these have undergone full trials to date and are predominantly currently intended for freshwater applications and therefore great uncertainty remains as to their potential success within the Severn Estuary.

3.6.28 In the absence of robust data to demonstrate the benefits of the installation of an advanced or innovative turbine unit over more traditional units it is not considered possible to recommend the inclusion of this measure within the suite of SEA measures for any of the fish receptors. Moreover, a feasibility study would be required prior to inclusion within an STP plan alternative. It is recommended that were an STP development intended to be developed later than the 2020 timeframe that consideration be given to undertaking studies to determine the efficacy of the promising technology types for the fish receptors of the Severn Estuary.

Operation prevention and reduction measures – noise minimisation

3.6.29 It should be noted that the measures identified within this section are specifically intended to prevent/reduce effects associated with noise generated during operation. Any identified efficacies should not therefore be applied to the compound effects estimated for the STP plan alternatives.

3.6.30 The potential effects of noise during STP operation are uncertain. The extent of potential habituation of fish to these noise levels is also currently unknown, which precludes a full assessment of a need for measures to prevent/reduce potential effects.

3.6.31 Insufficient information and an absence of existing available precedents preclude the inclusion of this concept within the suite of STP prevent/reduce measures. More routine and practical measures such as regular maintenance should however, be adopted as a potential reduction solution.

Operation prevention and reduction measures – Fish passage

3.6.32 It should be noted that the measures identified and discussed within this section are specifically intended to prevent/reduce effects associated with disruption to route of passage in particular passage through the structure. Identified efficacies should not therefore be applied to compound effects estimated for the STP plan alternatives.

3.6.33 Purposely designed fish passage mechanisms are regularly used on run of river hydropower schemes to aid fish passage past the structure through a 'safer' route than the turbines. Estuary equivalent examples are limited to the Annapolis Royal Scheme; the experiences from which have been applied within an STP context. Potential passage solutions for STP effects can be broadly categorised by the direction of travel by fish to include both landward and seaward (bi-directional) or seaward only (seaward - which has greatest risk of mortality as a result of greater flow passing through generating turbines).

3.6.34 There are three main fish passage mechanisms which could offer some potential for reducing STP plan alternative effects associated with disruption to route of passage through providing a 'safer' passage route; altering the type, size, number and position of sluices, including fish bypasses within the plan alternative designs and the inclusion of fish lifts and locks. The inclusion of traditional fish passage mechanisms have been ruled out for all species as in their current design forms and within the constraints of energy penalty limits it would not be feasible to effectively implement them within the Severn Estuary.

3.6.35 Altering the type, size, number and position of sluices is considered to offer the greatest potential for reducing STP plan alternative effects. It has been assumed for the purpose of this assessment that where an increase in sluice number has been proposed that it would enable between an additional 5 and 15% of permeability. The measure would however, likely require further technical and fish behavioural investigations before they could be designed and implemented which could preclude their implementation within the STP 2020 timeframe. Furthermore, they would result in a continual energy penalty for the lifetime of the plan alternative. They would however, pose no significant adverse effect upon other environmental features or society and economy. The efficacy of this measure would depend upon the exact implementation at detailed design stage. For this assessment it has been assumed that they would be designed for all species in combination and as such would have an efficacy of between 5 and 30%. Were they to be designed for individual species or life

stages however, they could afford them a higher efficacy rate. This measure has been recommended for inclusion within the suite of STP prevent/reduce measures for all fish species.

3.6.36 Although having similar efficacy ratings, effects to other environmental features and society and economy, energy penalties and development timeframes as sluices, there is less confidence that fish bypasses, lifts and locks could successfully be operated within the environment of the Severn Estuary at the scale required for an STP plan alternative. As such on the basis of independent advice these measures have not been included within the suite of STP prevent/reduce measures for any of the fish receptors. It is considered however, that the measures could offer some potential for reducing STP plan alternative effects and it is recommended that they not be excluded from future STP assessments.

3.6.37 It is strongly recommended that a joint engineer and fisheries specialist feasibility study be undertaken to investigate potentially feasible fish passage solutions for an STP plan alternative to reduce effects associated with disruption to route of passage in particular from turbine passage.

Operation prevention and reduction measures – fish exclusion and diversion

3.6.38 It should be noted that the measures identified and discussed within this section are intended to apply specifically to disruption to route of passage in particular passage through the structure. Identified efficacies should not therefore be applied to compound effects estimated for the STP plan alternatives.

3.6.39 Fish exclusion and diversion would prevent/reduce STP effects by deterring fish from passing through turbines and directing them to an alternative passage route. This measure could be achieved via a number of mechanisms. Physical screens have been considered; however the high flow velocities that are experienced within the Severn Estuary preclude their use. Fish behaviour deterrents/attractants could also prevent/reduce STP effects, but would also be limited by flow velocities. Such methods utilise a number of behavioural stimuli such as sound, vibration, temperature, taste, odour, pressure change, touch, hydraulic sear, light, and some species can also detect electrical and possibly magnetic fields to elicit a reaction.

3.6.40 The efficacy of behavioural fish exclusion and diversion systems would vary depending upon the target species and conditions within the Estuary. Although systems have proved effective not only within freshwater environments but also estuarine and marine their use is unprecedented on the scale required for an STP plan alternative and within the hostile environment of the Severn Estuary. Due to differing sensory abilities, thresholds and behavioural responses crucially there is potential for measures to have contradictory effects upon different species. It is considered that these measures would require considerable further research and feasibility study before they could be implemented within the Severn Estuary for the range of target species and on the scale required for an STP plan alternative which would likely preclude their inclusion within the STP 2020 timeframe. As such this measure has not been recommended for inclusion within the suite of STP prevent/reduce measures for nay of the fish receptors. Furthermore, it has not been recommended for consideration within future STP assessments.

Operation prevention and reduction measures – predator control

3.6.41 It should be noted that the measures identified and discussed within this section are intended to apply specifically to effects associated with increased predation events.

Identified efficacies should not therefore be applied to compound effects estimated for the STP plan alternatives.

3.6.42 Were migratory fish to be delayed by an STP plan alternative there is the potential for the pooling of migrants up or seaward of the structure which may increase predation rates through predator attraction. Predator control for piscivorous birds and fish could potentially prevent/reduce increased predation events resulting from an STP plan alternative. Examples of auditory and visual scarers that could be used to deter birds include gas bangers/cannons, predator distress calls, pyrotechnics, electronic noise makers, lights and effigies. However, there is evidence to suggest that habituation could occur, which could render avian control a short term prevent/reduce method only. Shooting birds is another option, which could also be used in combination with other deterrents. Physical exclusion techniques include perimeter fencing or netting, water spray devices, overhead wires, electric wires and floats or roping. Wire has been used successfully in a number of cases to reduce predation by cormorants and other piscivorous bird species; and it is considered that it would likely be most applicable at an STP plan alternative. Potential methods for piscivorous fish control could include targeting fish that are likely to cause significant reductions (by predation) in other fish populations (e.g. bass); this has been implemented in the US at dams by means of a bounty reward scheme financed by the power company. Bypass design could also provide passageways for fish to reduce the risk of predation.

3.6.43 There are very few if any suitable effective controls for piscivorous fish to prevent or reduce increased predation events potentially resulting from an STP plan alternative. This measure has not therefore been recommended for inclusion within the suite of STP prevent/reduce measures for any of the fish receptors.

3.6.44 There is however, greater precedent and established techniques and methods for the control of piscivorous bird predation. It is considered that there is potential for this measure to have an efficacy of between 10 and 80%. Although the measure would not require substantial further investigations it would likely require regular maintenance and could have significant adverse effects upon other environmental features. Despite these limitations it is recommended that this measure be included within the suite of STP prevent/reduce measures for all of the fish receptors.

Operation prevention and reduction measures – pheromone release

3.6.45 It should be noted the measures identified and discussed within this section are intended to apply specifically to effects associated with disruption to route of passage. Identified efficacies should not therefore be applied to the compound effects estimated for STP plan alternatives.

3.6.46 Pheromones are chemical substances (or odours) that are passed between organisms (including fish) and act as a signal for individuals of the same species to communicate. Pheromone release could prevent/reduce the effects of an STP plan alternative by deterring or attracting fish from passing through turbines and directing them to an alternative passage route.

3.6.47 There is limited evidence that pheromones would prove effective for controlling the behaviour of the fish receptors with restricted supporting evidence limited to lamprey specie only. Furthermore, the development of the measure in particular with respect to the production of a synthetic chemical cue is many years from fruition which would preclude its implementation within the STP 2020 timeframe. Due to the restricted confidence in the likely success of the application of this measure alongside the

limitations detailed above among others this measure has not been recommended for inclusion within the suite of STP prevent/reduce measures for any of the fish receptors. Furthermore, it has not been recommended that it be considered during future STP assessments.

Operation prevention and reduction measures – trap and transport and herding

3.6.48 It should be noted that it would be intended that these measures be applied specifically to effects associated with disruption to route of passage. Identified efficacies should not therefore be applied to the compound effects estimated for STP plan alternatives.

3.6.49 Trap and transport of fish would involve their interception at a given point, their transport landward or seaward from the capture site to circumvent the obstacle, and their subsequent release.

3.6.50 Trap and transport is not an established practice or technique within an estuarine environment such as the Severn Estuary, on the scale likely to be required for an STP plan alternative or for the range of species to which it would need to be applied. It is considered that complications with capture, osmoregulation and handling sensitivity would make the measure ineffective. On this basis it has therefore been recommended that this measure not be included within the suite of STP prevent/reduce measures for any of the fish receptors. Furthermore, it has not been recommended that this measure be considered within future STP assessments.

3.6.51 Herding is a related technique which involves the spatial manipulation of fish within the aquatic environment by anthropogenic means such that fish are aggregated at a particular point or caused to avoid a certain area; and is considered to be a prevention and reduction measure.

3.6.52 Fish herding is not an established practice or technique for the protection of fish and has no real precedent for application as a prevent/reduce measure. Extensive further research would be required before the measure could be implemented and the efficacy is currently unknown due to a lack of knowledge and evidence. The lack of confidence in the feasibility and efficacy of the implementation of this measure for an STP plan alternative has precluded the suggestion for its inclusion within the suite of STP prevent/reduce measures. Furthermore, it is not recommended that consideration be given to this measure during future STP assessments.

Operation prevention and reduction measures – fish stocking

3.6.53 It should be noted that this measure would be intended to boost the overall populations of the fish receptors. Identified efficacies for these measures could therefore be applied to the compound effects estimated for the STP plan alternatives.

3.6.54 Fish stocking could involve the placement of fish or fish eggs into a waterbody that has been affected by an STP plan alternative to prevent/reduce effects upon the population status or integrity. Stocking in this context addresses stocking within the rivers (Wye, Usk, Severn and other tributaries of the Severn Estuary affected by a plan alternative) and Estuary to directly support the populations which could be affected by an STP plan alternative.

3.6.55 Stock enhancement is an established method for some of the fish receptors in particular salmon and has precedent as a prevent/reduce measure including for tributaries of the Severn Estuary. The measure and the associated rearing

requirements are however, not established methods or techniques for other species such as shad and lamprey for example. Furthermore, the scale likely to be required for an STP plan alternative is unprecedented for all species. As such, this measure has not been recommended for inclusion within the suite of STP prevent/reduce measures for any of the fish receptors.

Operation prevention and reduction measures – intertidal habitat creation and enhancement

3.6.56 It should be noted that the measures identified and discussed within this section are specifically intended to prevent/reduce effects associated with intertidal habitat loss/change. Identified efficacies should not therefore be applied to overall compound effects estimated for STP plan alternatives.

3.6.57 Potential habitat creation and enhancement measures in freshwater and intertidal areas could be implemented to prevent /reduce the loss of individual fish and/or intertidal habitats in the Severn Estuary. There is a large quantity of intertidal habitat within the Severn Estuary (approximately 100 km^2), a portion of which are protected under the EU Habitats Directive. These areas provide rich habitats for fish that utilise the Estuary. The employment of methods to create intertidal habitats is becoming more widespread within the UK and Europe as a whole. The main techniques for intertidal habitat creation involve the application of soft engineering approaches such as managed realignments, the re-use of dredged material, enhanced sedimentation and creation of islands with intertidal habitats. In addition, certain methods may be applicable to specific habitat types such as transplantation of eelgrass beds. It should be noted that in the context of this assessment managed realignment is considered to be an offsetting measure under the SEA Directive as it would entail intervention outside the existing Estuary. All other measures have been grouped within the scope of 'topographic modification'.

3.6.58 Knowledge regarding the use of intertidal habitat in particular by the migratory fish species is largely unknown and requires further study. Although intertidal habitat enhancement/creation is therefore in principle an established practice and technique it does not have precedent for these species. Considerable further investigation would therefore likely be required before this measure could be implemented as a prevent/reduce option for the migratory fish species. Although it could afford some benefits to migratory species such as shad, eel and river lamprey which are believed to spend a protracted period within the estuarine environment due to current knowledge gaps it has not been recommended as a measure specifically targeted at these species. It is however recommended for inclusion within the suite of STP prevent/reduce measures for the marine and estuarine fish guilds which could if implemented also offer some benefit to the other species utilising this habitat for limited or protracted periods.

3.6.59 It is not considered possible at this time to quantify the potential extent of intertidal habitat enhancement/creation required or indeed the resulting efficacy of the measure. Quantification is predominantly limited by knowledge gaps regarding habitat utilisation, area and density dependent functions.

Operation prevention and reduction measures – addressing limiting factors in the freshwater environment

3.6.60 It should be noted that the measures identified and discussed within this section are intended to boost the overall populations of the fish receptors. Identified efficacies for

these measures could therefore be applied to the compound effects estimated for the STP plan alternatives.

3.6.61 A further measure that could be implemented would be to address the factors potentially currently limiting populations of migratory fish within freshwaters and thereby potentially boosting the overall production of the population. The methods that could be implemented include various habitat enhancement (e.g. gravel cleaning and loosening) and creation (addition of boulders/gravel) techniques, increasing access to habitat through obstruction removal, and implementation of measures to improve water quality.

3.6.62 Addressing limiting factors in the freshwater environment are established practices and techniques for all of the migratory fish species and are regularly included within management plans for their protection. Although demonstrating the precedent for this measure, this does however also potentially raise the question of whether such a measure would be additional to current conservation management actions ('additionality'). Techniques included within this measure have also not previously been undertaken on the scale likely to be required for an STP plan alternative and opportunities for application may be restricted. Although this measure therefore shows potential for all of the migratory fish species, on the basis of independent advice this measure has not been included at this stage within the suite of STP prevent/reduce measures. It is however, recommended that it be considered within any future STP assessments.

3.6.63 Were this measure to be considered within future STP assessments there would be a requirement to investigate the potential extent to which the measure could be applied and the issues surrounding 'additionality'.

3.6.64 This measure is not applicable to the marine and estuarine fish guilds and has not therefore been recommended for them.

3.6.65 The main purpose of enhancement/creation measures within freshwater habitats would be to reduce the effects of a loss of individuals. As such, a key requirement would be to identify the numbers of individuals of protected species likely to be lost due to construction and operation of the proposed STP plan alternative. Only then could effective options for reducing the effects of an STP plan alternative be assessed. In addition, the habitat enhancement/restoration and creation projects currently implemented by the regulatory bodies to meet conservation objectives need to be fully understood and dialogue with those bodies would be required to ensure that proposed measures are additional and provide further benefits to fish populations than the measures currently in place and those planned to be introduced in the future.

Measures to prevent or reduce effects proposed by other topics

3.6.66 As with this topic a number of prevention and reduction measures have been proposed by the other STP SEA topics suitable for the requirements of their receptors. Each of these measures could have an effect upon the migratory and estuarine fish receptors with either negative or positive consequences. A brief overview of the identified measures which could affect the migratory and estuarine fish topic is given below.

Operational management of barrage/lagoon regime

3.6.67 A number of different measures regarding the operational regime of the STP plan alternatives have been proposed by other topics within the SEA STP including; the

operation of plan alternatives in ebb and flood mode, sluicing after the generation period, altering turbine generation time and additional sluicing. Some of these measures such as sluicing after the generation period and additional sluicing are complementary with the measures proposed for the migratory and estuarine fish topic and it is considered that they would have a reduced adverse effect upon the fish receptors via increasing non-generating fish passage routes. The adaptation of the generating mode of the STP plan alternatives however, to ebb and flood mode would be contradictory to the aims of the measures identified within this topic and would have a significant negative effect upon the fish receptors.

Topographic modification

3.6.68 The creation of intertidal habitat to prevent or reduce effects from its change or loss has been proposed by both the marine ecology and waterbirds topics of the STP SEA. It is considered that this measure would complement those identified by this topic under the habitat enhancement/creation measure detailed above. This measure would have a significant reduced adverse effect upon the fish receptors. There is evidence that managed realignments are used by adult and juvenile fishes and that these created habitats can rapidly form environments which are successfully colonised by a number of different species (Colclough *et al*., 2005). Creation of intertidal habitats would likely be beneficial for a wide range of fish species, including UK BAP species and protected diadromous species such as shad, salmon and lamprey. Further detail is available in the SEA Migratory and Estuarine Fish Annex 3: Measures to offset plan alternative effects.

Increase sluice numbers

3.6.69 Increasing the number of sluices and effectively the volume of water passing through them to reduce the high water stand and maximise the gap between low water spring tides and high water neap tides is considered complimentary with the measures identified by this topic to increase the permeability of the STP structures. This measure would therefore have a significant reduced adverse effect upon the fish receptors.

Alter construction timings or methods

3.6.70 Altering the timing or methods of proposed construction works is considered complimentary with those measures identified by this topic and could have a significant reduced adverse effect upon the fish receptors.

Inclusion of locks and modification to sizing/position

3.6.71 A greater number of locks could be beneficial both for fish passage and the passage of small commercial and recreational fisheries crafts. It is considered that this measure if designed appropriately could have a significant reduced adverse effect upon the fish receptors.

Training walls

3.6.72 The installation of training walls to keep channels clear and reduce the requirement for dredging could have a positive significant effect upon the fish receptors via reducing the effects upon fish associated with the activity of dredging.

Dredging

3.6.73 Local dredging has been proposed by the navigation topic to counteract sedimentation. This measure could have negative effects upon the fish receptors.

Increasing water exchange through the structure

3.6.74 Increasing the volume of water through the structure to promote water exchange has been proposed by the marine water quality topic and is considered complimentary with measures identified by this topic. This measure could have significant reduced adverse effects upon the fish receptors.

Reconfiguration of intakes/outfalls at Hinkley Point

3.6.75 It has been identified by the marine water quality topic that intakes and outfalls at Hinkley Point could be reconfigured to reduce the effects of increased water temperature within localised areas of the Estuary in particular within impoundments. Measures to control changes to water quality could be considered positive within the migratory and estuarine fish topic.

Time project construction period to avoid other large construction projects

3.6.76 Avoiding timing project construction with known periods planned for major works for other large construction projects within the area has been proposed as a measure by the communities topic. Preventing cumulative effects of projects upon the aquatic environment and the fish community supported by it could be considered a reduced adverse effect for the migratory and estuarine fish topic.

Measures to preserve the historic environment resource (in situ)

3.6.77 Topographic modification has been identified by the historic environment topic as a possible measure to preserve the historic environment receptors. It is unclear what modifications this measure would involve and depending upon their nature they could represent either a positive or negative effect upon the fish receptors. More information would be needed before a full assessment of the potential implications of this proposed measure could be made.

Minimising the extent of lighting, particularly in night-time landscape/seascape

3.6.78 Minimising lighting has been proposed as a measure by the landscape and seascape topic. Where such lighting is over the Estuary it could represent a potential barrier to the migration and movement of fish in transit through and residing within the Estuary. As such it is considered that this measure could have reduced adverse effects upon the fish receptors.

Measures needed to offset effects

3.6.79 The identification of offsetting measures is a requirement of the SEA Directive. For the purposes of the STP SEA, these are measures which as fully as possible make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA, 'compensation', a subset of offsetting, is only used in relation to those measures needed under Directive 92/43/EEC (the Habitats Directive).

3.6.80 The need for offsetting measures would be identified within this topic. However, it would not be possible to describe full details of offsetting measures, such as geographic locations, at this strategic level. Therefore, generic suggestions would be made. Compensation measures are even more indefinite in scope, being dependent on preceding tests within the Habitats Directive. Thus it would only be possible to describe the need for such measures under the Habitats Directive, rather than scope them in any detail.

3.6.81 It is considered likely that when combined the proposed measures to prevent or reduce the effects of an STP plan alternative could be only partially effective. As such offsetting measures may be required. It should be noted that some of the potential offsetting measures detailed below would require more detailed study to evaluate their potential effectiveness and as such the potential extent cannot be quantified at this time. Nonetheless it is fully understood that the task of offsetting potential effects at the scale that may be required would be an extensive and serious undertaking and is unprecedented. Each of the identified offsetting measures may, in isolation, not be sufficient to fully offset against a given effect, however, it is the cumulative effect of these measures (and in combination with prevent and reduce measures) which is important when assessing their potential to minimise any adverse effects of an STP plan alternative. It is considered likely however, that even in combination that offsetting measures would not be fully effective and that residual effects could remain .The confidence of effectiveness is given for each potential offsetting measure discussed. Confidence has been assigned based on expert judgement in line with the following categories:

- High
- Moderate
- Low
- Very low

3.6.82 Detailed discussion of potential offsetting and compensation measures are contained within Annex 3: Measures to offset STP plan alternative effects. The identified offsetting measures within the migratory and estuarine fish topic paper (that may also qualify as compensation measures under the Habitats Directive as they concern SAC features) are:

- Operation offsetting measures – fish stocking and translocation;
- Operation offsetting measures – intertidal habitat enhancement/creation;
- Operation offsetting measures – addressing limiting factors in the freshwater environment;
- Operation offsetting measures – fisheries buyout
- Operation offsetting measures – pheromone release

3.6.83 The following potential compensation measure under the Habitats Directive has also been considered as part of this Topic Paper:

- Additional sites for inclusion in the SAC list: the potential for new SAC designation as part of the compensatory measures.

Operation offsetting measures – fish stocking and translocation

3.6.84 Stocking in this context involves the placement of fish or fish eggs into a water body other than those affected (i.e. outwith the Severn Estuary and its tributaries), or with a different genetic stock. Translocation of fish involves the introduction of fish from a discrete location in the wild to a separate location in the wild. This would generally involve the placement of fish within a site where it is not currently present with the intention of creating an alternative, additional population to safeguard the biological and genetic resource. This could involve the direct transfer of fish or eggs and might involve a period of hatchery residence where the fish are held, and juveniles produced for subsequent stocking. These two measures are considered to offset population declines in the Severn Estuary and its tributaries by increasing populations elsewhere.

3.6.85 It is not considered possible with the current available information to assess the potential extent at which stocking or translocation could be employed for each of the fish receptors. Further study would be required to identify receiver sites and their carrying capacity before any assessment of potential extent could be made. To determine the carrying capacity of each river system an assessment of the extent of the existing populations would be required alongside quantifying the area of suitable habitat and the species and river specific density dependent functions. Upon estimation of the potential population that each river could support an assessment of the required infrastructure to rear the number of individuals to maintain this population (which would be far greater than the actual population size) would be required.

Operation offsetting measures – intertidal habitat enhancement/creation

3.6.86 Specifically, intertidal habitat creation and enhancement measures undertaken outside the Severn Estuary are considered here to attempt to offset the loss of intertidal habitat resulting from an STP plan alternative by creating, restoring or enhancing the same type of habitat within other UK estuaries. Such measures could however be utilised to meet targets set out in European legislation such as the Habitats Directive and the WFD. Therefore measures proposed under the SEA may present an 'additionality' issue. Whilst a variety of methods are available managed realignment was identified as one of the key techniques which could potentially be employed; with recent experience improving the effectiveness of such plan alternatives and evidence to suggest that managed realignment are rapidly colonised by adult and juvenile fishes. The minimum area which may need to be created would be determined by the amount of habitat predicted to be lost due to an STP plan alternative.

3.6.87 It is recommended predominantly in light of the knowledge gaps regarding the utilisation of intertidal habitat by in particular the migratory fish species that intertidal habitat enhancement/creation be included within the suite of SEA STP offsetting measures for eel, marine migrants, marine stragglers and estuarine residents. It should be noted however, that although not recommended for inclusion for other species that if implemented it could offer them some offsetting potential.

3.6.88 It is not considered possible at this time to quantify the potential extent of intertidal habitat enhancement/creation required or indeed the resulting efficacy of the measure. Quantification is predominantly limited by knowledge gaps regarding habitat utilisation, area and density dependent functions.

3.6.89 As part of the consideration of the potential for intertidal habitat creation/restoration outside of the Severn Estuary a thorough assessment would be required regarding the fish assemblages currently present within the intertidal areas to ascertain their importance. Information would also be required on the extent to which these areas are also used by diadromous fish species. Without this baseline information it is difficult to design habitat restoration/creation programmes to maximise the likelihood of recreating an environment which supports a similar fish community to the habitat which may be potentially lost within the Severn Estuary. For example, if it is known that juvenile sea bass are commonly found in high abundances within a particular habitat which could be lost then certain measures could be deployed to optimise the likelihood of sea bass utilising the man-made habitat (e.g. Colclough *et al*. 2005). Although it is clearly likely to be more beneficial creating or restoring new intertidal habitats for fish than taking a 'do nothing' approach, without basic baseline data these benefits cannot be quantified. Similarly, unless detailed information relating to intertidal fish communities within the Estuary is gathered before construction of a proposed STP plan alternative then the performance of any habitat creation/restoration projects could not be assessed effectively in the future.

Operation offsetting measures – addressing limiting factors in the freshwater environment

3.6.90 Addressing limiting factors in freshwater areas outside the Severn Estuary tributaries has the potential, in conjunction with other measures, to offset some of the effects of an STP plan alternative by providing greater resource availability and thus increasing the overall production of either the UK population as a whole or populations within other UK rivers; as well as supporting translocation efforts. Specific methods include in-stream habitat restoration to increase the availability of key habitats, riparian restoration to improve bank stability and instream conditions, habitat creation, increased access through the removal of barriers to migration and improvements to water quality. The overall effect of such work would depend upon the scale at which it was required and this is likely to be at an unprecedented scale for an STP Plan Alternative. The acceptance of these methods as offsetting measures under the SEA may be subject to ‘additionality’ conflict.

3.6.91 Measures to address limiting factors upon freshwater life stages have been recommended for inclusion within the suite of SEA offsetting measures for salmon, allis and twaite shad, river and sea lamprey and eel. It is not applicable for marine and estuarine fish species.

3.6.92 The main purpose of enhancement/creation measures within freshwater habitats would be to offset loss of individuals. As such, a key requirement would be to identify the numbers of individuals of protected species likely to be lost due to construction and operation of the proposed STP plan alternative. Only then could effective options for offsetting the effects of an STP plan alternative be assessed. In addition, the habitat enhancement/restoration and creation projects currently implemented by the regulatory bodies to meet conservation objectives need to be fully understood and dialogue with those bodies would be required to ensure that proposed measures are additional and provide further benefits to fish populations than the measures currently in place and those planned to be introduced in the future.

Operation offsetting measures – fisheries buyout

3.6.93 The buyout of fisheries is an established practice and has precedent for the conservation of salmon populations. Through buying out distinct salmon (including trout) fisheries, a certain number of fish could be retained within the system that

would otherwise have been removed. Fisheries catch data can provide estimates of the number of fish which could potentially be offset. For example, based on 5-year average catch rates, the number of fish that could be offset as a result of a fisheries buyout would be ~1,200 salmon and trout for the main freshwater fisheries reliant upon the Estuary and ~950 salmon and trout and ~11,000 eels (adults and elvers) for migratory net fisheries remaining within the estuary. Providing an estimate for the number of marine and estuarine species that could be retained from buyout of commercial fisheries within the Severn Estuary is more difficult due to catch data limitations. Estimates of individuals per species however, range between ~10 to ~2,000. A rigorous economic valuation of the indentified fisheries would be necessary as well as extensive stakeholder consultation and changes to legislative and regulatory instruments.

3.6.94 A fishery buyout could only be effective for species that are already subject to fisheries (primarily salmon). It is considered that a fisheries buyout would potentially partially offset effects from an STP plan alternative upon a range of species. The extent of this offset would vary between individual fisheries and, in the case of recreational angling, between rivers but it is considered extremely unlikely any of the cases to be able to offset at the unprecedented scale potentially required for an STP plan alternative.

3.6.95 Once implemented, the exclusion of fisheries could lead to an increase in poaching which would reduce the effectiveness of fisheries buyout as an offsetting measure. Ongoing intervention in the form of bailiff patrols may therefore be required. In the case of commercial fisheries, buyouts for select species could be limited by a potential loss of fish to bycatch during remaining fisheries operations. It is considered that fisheries buy-out could be implemented within the 2020 STP timeframe.

3.6.96 It has been recommended that fisheries buy-out be included within the suite of SEA offsetting measures for the migratory salmonids, eel and the marine migrants and stragglers. Although no specific fishery exists for the shad species it is considered that the buy-out of the salmonid fisheries could offer them some offsetting benefits due to the occasional accidental catch of shad within these fisheries whether recreational or heritage.

Operation offsetting measures - pheromone release

3.6.97 Fish (in particular lamprey) are known to respond to pheromone releases, which could be used as an attractant to guide fish away or to direct fish to other rivers and thus avoid an STP plan alternative. This offsetting measure is primarily untested and synthetic chemicals cues are not currently commercially available.

3.6.98 Due to several knowledge gaps and no existing commercially available chemicals for application it is considered extremely unlikely that this measure could be implemented within the STP 2020 timeframe for any of the fish receptors. In addition due to an unknown effectiveness and a requirement for more detail on application it is not considered possible at this time to determine its potential extent.

3.6.99 The use of pheromones as an offsetting measure has not been recommended for inclusion within the suite of SEA offsetting measures for any of the fish receptors nor is it recommended for consideration within any future STP assessment. As this measure is not recommended for further consideration there is no requirement for further study.

Compensation need - additional sites for inclusion in the SAC list

3.6.100 The potential for the creation of a new Special Area of Conservation (SAC) designation could also be implemented. However, as this is concerned with measures such as a Habitat Regulations Assessment (HRA) under the EC Habitats Directive (92/43/EEC) this is considered a compensation measure and not SEA offsetting. Proposed species for which this measure would afford protection include sea lamprey, river lamprey, allis shad, twaite shad and Atlantic salmon which are protected as Annex II species of the Habitats Directive, and sea trout and eel which are features of the SPA and Ramsar designations. Due to a lack in records on up to date species distribution and population data, it is not currently possible to ascertain if the level of compensation would be sufficient.

3.6.101 The notification of additional SAC sites has not been included within the suite of SEA offsetting or Habitats Directive compensation measures for any of the fish receptors. It could however, have some compensation benefit for the SAC designated fish features and as such it has been recommended that it continue to be considered within any future STP assessment.

Offsetting measures proposed by other topics

3.6.102 A number of measures have been proposed by the other STP SEA topics to offset effects identified within the plan alternatives assessment. Some or all of these measures could have implications for the migratory and estuarine fish topic whether resulting in a positive or negative effect. Those which are considered to potentially affect the migratory and estuarine fish topic are detailed and briefly discussed below.

Regulated tidal exchange (RTE)

3.6.103 Regulating the tidal exchange or artificially irrigating areas using saline water to create or maintain estuarine habitat has been proposed by the marine ecology topic. Effectively this is another form of intertidal habitat creation, discussed above. It is considered that any measures to maintain important estuarine habitat would be complementary to the measures identified by the migratory and estuarine fish topic and would have reduced adverse effects upon the fish receptors.

Controls of inputs of contaminants from other sources in the Estuary

3.6.104 Measures to improve or maintain the water quality of the Estuary as proposed by the marine water quality topic such as reducing diffuse inputs and implementing tighter discharge consents would be considered a reduced adverse effect for the fish receptors within the migratory and estuarine fish topic.

Assumptions, Limitations and Uncertainty

3.6.105 In identifying measures to prevent or reduce adverse effects and off-setting measures and making suggestions, there are some limitations, and assumptions have been made. Furthermore, in assessing the effects of measures to prevent or reduce adverse effects and off-setting needs, particularly because the suggestions made are high level, uncertainty is inherently associated with this assessment. These issues are discussed for this topic below.

Construction prevention and reduction measures – timing of works

3.6.106 Uncertainty exists due to gaps in the detailed scientific knowledge of the key sensitive periods for fish receptor species within the Severn Estuary, the route of passage taken by migratory species through the Estuary and the residence period of the various species. Such information would be required to successfully time works to prevent and reduce effects to the greatest extent possible.

Construction prevention and reduction measures – noise effect reduction

3.6.107 There is uncertainty associated with the implementation of measures to prevent noise effect on sensitive areas (e.g. nursery or rearing grounds) due to a lack of information regarding the location of these areas within the Severn Estuary. Similarly a lack of detailed knowledge regarding the route of passage taken by migratory species leads to uncertainty in preventing or reducing noise effect to these key areas.

3.6.108 Implementation of noise reduction techniques have associated uncertainties due to the lack of knowledge regarding the feasibility of their application in as extreme an environment in the Severn Estuary. Noise levels could be reduced by utilisation of particular construction equipment and materials. A lack of knowledge regarding specific construction techniques likely to be utilised leads to uncertainty in the implementation of these prevention and reduction measures.

3.6.109 The uncertainty associated with the phasing of intensive construction work to prevent key nursery and migration periods is due to a lack of knowledge regarding the migratory movement and residence period within the Estuary for many of receptor fish species.

3.6.110 Discouraging fish from entering an area of effect during operations, by either physical or behavioural deterrents is possible. The lack of information on proposed construction techniques adds to current uncertainty as adopted methods are likely to be specific to the construction method undertaken.

Construction prevention and reduction measures – sediment movement/resuspension

3.6.111 Uncertainty remains with regard to these measures due to the extreme physical nature of the Severn Estuary. Silt curtains, for example, could be rendered ineffective should the strong currents deform their structure. Field trials would be required to assess their effectiveness.

Construction prevention and reduction methods – accidental release of pollutants

3.6.112 Detailed knowledge of the construction process is required to fully assess levels of uncertainty associated with methods to reduced or prevent the accidental release of pollutants during construction.

Operation prevention and reduction measures – operational regime

3.6.113 Uncertainty remains in particular regarding the behaviour of the migratory and estuarine /marine fish species within the Estuary with regards to timing and periods of transit and residence which precludes the full assessment of the potential prevent/reduce measures discussed above. The provision of more detailed

information regarding the behaviour of key fish species within the Severn Estuary would likely improve the confidence of success of these measures.

Operation prevention and reduction measures – innovation and advancement in turbine design

3.6.114 As a result of the embryonic nature of the majority of these technology types, great uncertainty remains regarding both the potential feasibility of their operation in the context of STP and the benefits which may be gained for fish populations within the Severn Estuary.

Operation prevention and reduction measures – noise minimisation

3.6.115 Uncertainty remains regarding the potential frequencies and levels of noise generated during operation of an STP plan alternative in particular from turbines. The extent of potential habituation of fish to these noise levels is also currently unknown which precludes a full assessment of a need for measures to prevent/reduce and offset effects.

Operation Measures to Prevent or Reduce Adverse Effects – Fish passage

3.6.116 The uncertainty regarding fish behaviour within the Estuary currently limits the potential success of the inclusion of fish passageways within an STP plan alternative design. In the absence of an understanding of the movement of the migratory fish species it would not be possible to design the vertical and horizontal positioning of fish passageways or select the optimum operation regime to maximise their potential for successful fish passage. There is also some uncertainty regarding the technical feasibility of some of the more conventional fish passage technologies within a tidal environment as well as uncertainty with respect to novel approaches.

Operation Measures to Prevent or Reduce Adverse Effects – Fish exclusion and diversion

3.6.117 Uncertainty in relation to the use of an AFD in general as a fish avoidance measure is considered to be low. There are uncertainties regarding potential difficulties involved in producing a reliable stimulus as well as difficulties with predicting sound propagation and fish response within the environment of the Severn Estuary. There could also be difficulties in terms of the habituation of fish to the sound generated. As mentioned previously there is no precedent for the use of a system of this type at this scale in an environment such as the Severn Estuary. It is therefore considered that uncertainty of the operation of an AFD within the environment of the Severn Estuary would be high.

Operation Measures to Prevent or Reduce Adverse Effects – Predator control

3.6.118 Uncertainty in the predator control of piscivorous birds as a measure to reduce effects is considered as high because of uncertainties associated with the available options. Netting off a structure on the scale of an STP plan alternative is unprecedented, and may not be practicable due to durability of netting material and required maintenance levels. The placement of wires in conjunction with bird scaring devices, while probably more feasible, has high uncertainty due to the knowledge that birds can become habituated to the scaring devices, and that some species can adapt hunting methods to operate between the wires (NE, 2007). The configuration applied may need to change seasonally to defend against seasonal predators, and this would require

further research to determine the bird species present and appropriate defences to their hunting methods.

3.6.119 With regard to piscivorous fish, no information was found in the literature regarding their control, and accordingly uncertainty associated with this method must be stated as unknown. Given the uncertainties associated with other methods of fish control in natural environments it is considered probable that the associated uncertainty with this approach would be high.

Operation prevention and reduction measures – pheromone release

3.6.120 Uncertainty in relation to the use of pheromones as a measure to reduce effects must remain high as this is primarily an untested technique, in the early stages of research for a single key species. Despite the potential advantages of applying pheromone-based techniques, the lack of firm scientific knowledge, or previous examples of application to natural systems from which to draw conclusions, means that uncertainty of development, production, application and effects on target and non-target species must all be stated as high.

Operation prevention and reduction measures – trap and transport and herding

3.6.121 Trap and transport has been demonstrated as a practically employable measure for a small number of species (most notably salmonids and seaward relocation of seaward migrating eel), in truly riverine environments, and is a straightforward concept, although by no means totally effective in practice. However, no examples of using the technique in relation to complex movements of a wide range of fish species exists, and neither has trap and transport been applied across a wide interface (structure) which an STP plan alternative is likely to comprise. Limitations also exist regarding lack of knowledge of the movement patterns and biology of many of the species for which trap and transport would be required. A further unknown factor is the ability to trap fish which may be dispersed over a wide area, in a manner which does not harm individual fish. Taking these factors together the uncertainty associated with success of trap and transport as a measure to prevent or reduce adverse effects for fish populations potentially affected by an STP plan alternative is regarded as being high.

3.6.122 Herding has been demonstrated largely only at an experimental level, thus, whilst it is conceivable that it could play a role as part of an overall measures to prevent or reduce adverse effects package, this is highly speculative at this stage. Uncertainties relate to deploying an operating herding mechanism in the challenging environment of the Severn Estuary, and more fundamentally, identifying suitable stimuli for the range of species for which herding would be required – each species may differ in its response and stimuli for one species may have an undesirable effect on another. Taking these factors together the uncertainty associated with success of herding as a measure to prevent or reduce adverse effects for fish populations potentially affected by an STP plan alternative is regarded as being very high.

Operation prevention and reduction measures – fish stocking

3.6.123 The actual proportion of each species and life stage that would need to be stocked would be determined by the modelling exercise. The extent of either of these is however, likely to be beyond that undertaken in previous stocking exercises in the UK and internationally. Whilst some species have well established approaches to husbandry and stocking, many others have not been subject to culture or stocking, at least on the scale which may be required as part of an STP plan alternative. The lack of knowledge extends not only to husbandry and stocking, but for some species to

basic biological and habitat requirements (particularly regarding the non-commercial marine species), making stocking objectives and requirements difficult to define. The long term fate of populations subject to stocking introduces an additional element of uncertainty, and in the case of marine and estuarine populations, stocking may not be a valid concept at all. Taken collectively, the uncertainty associated with a stocking prevention/reduction approach is regarded as being high. However, the nature of the uncertainty varies significantly according to species, as discussed in terms of each species in Annex 2.

Operation prevention and reduction measures – intertidal habitat creation and enhancement

3.6.124 Where there is uncertainty in predicting effects and determining significance for an aspect of the SEA then this should be stated where appropriate. With regards to loss of intertidal habitat/loss of individuals, uncertainty could be related to the area of habitat/numbers of individuals expected to be lost, interpretation of legislation such as the EC Directive and the measures to prevent or reduce adverse effects/compensation packages required to satisfy such legislation. Further sources of uncertainty are associated with the types of habitat which would need to be replaced/enhanced and the confidence that the schemes implemented would have a similar ecological function to the habitat lost, or that they would adequately compensate for loss of a specified number of individuals.

3.6.125 It is considered that there is currently a high level of uncertainty associated with the degree to which creation/restoration would provide an effective measure for reducing the effects of the potential loss of intertidal habitats and the subsequent effect on fish communities within the Severn Estuary.

3.6.126 There is limited information available regarding fish assemblages within intertidal areas of the Severn Estuary and Bristol Channel with the exception of data derived from intertidal fish surveys conducted by the EA as part of a WFD monitoring programme However, these data indicate that a wide range of fish species utilise the intertidal zone and in common with studies conducted in other locations there is evidence to suggest that the intertidal zone is likely to be of high importance to a number of species. In particular, the extent to which diadromous fish utilise these habitats is unclear from sampling conducted in these areas due to the low numbers recorded. The general consensus based on our current understanding of diadromous fish is that most of these species would be expected to exploit the intertidal zone during passage although further information is required to clarify this.

3.6.127 Without more baseline information it is difficult to design habitat restoration/creation programmes to maximise the likelihood of recreating an environment which supports a similar fish community to the habitat which may be potentially lost. For example, if it is known that juvenile sea bass are commonly found in high abundances within a particular habitat which could be lost then certain measures could be deployed to optimise the likelihood of sea bass utilising the man-made habitat (e.g. Colclough *et al*. 2005). Although it is clearly likely to be more beneficial creating or restoring new intertidal habitats for fish than taking a 'do nothing' approach, without basic baseline data these benefits cannot be quantified. Similarly, unless detailed information relating to intertidal fish communities within the Severn Estuary is gathered before construction of a proposed STP plan alternative then the performance of any habitat creation/restoration projects could not be assessed effectively in the future.

Operation prevention and reduction measures – addressing limiting factors in the freshwater environment

3.6.128 It is considered that there is currently a high level of uncertainty associated with the degree to which the enhancement/creation of freshwater habitats would provide an effective measure to prevent/reduce the effects of a potential loss of fish and the subsequent effect on fish communities in the Severn Estuary.

3.6.129 The main purpose of enhancement/creation measures within freshwater habitats would be to reduce the loss of individuals by boosting the overall population. As such, a key requirement would be to identify the numbers of individuals likely to be lost due to construction and operation of the proposed STP plan alternative. Only then can effective options for reducing the effects of an STP plan alternative be assessed. In addition, the habitat enhancement/restoration and creation projects currently implemented by the regulatory bodies to meet conservation objectives need to be fully understood and dialogue with those bodies would be required to ensure that proposed measures are additional and provide further benefits to fish populations than the measures currently in place and those planned to be introduced in the future.

Operation offsetting measures – fish stocking and translocation

3.6.130 The actual proportion of each species and life stage that would need to be stocked / replaced by translocation would need to be determined for each STP plan alternative. However, the extent of either is likely to be on an unprecedented scale than any undertaken in previous stocking and translocation exercises in the UK and internationally. Whilst some species have well established approaches to husbandry and stocking, many others have not been subject to culture or stocking, at least on the scale which may be required as part of an offsetting programme. The lack of knowledge extends not only to husbandry and stocking, but for some species to basic biological and habitat requirements (particularly regarding the non-commercial marine species), making stocking and translocation objectives and requirements difficult to define. The long term fate of populations translocated or subject to stocking introduces an additional element of uncertainty, and in the case of marine and estuarine populations, translocation and stocking may not be a valid concept at all (primarily due to the presence of currently vacant habitat). Lastly, translocation requires an acceptable recipient site (s), which at this stage has not been secured. Taken collectively, the uncertainty associated with a stocking or translocation offsetting approach is regarded as being high. However, the nature of the uncertainty varies significantly according to species, as discussed in terms of each species in the previous sections.

Operation offsetting measures – intertidal habitat enhancement/creation

3.6.131 With regards to loss of intertidal habitat/loss of individuals, uncertainty could be related to the area of habitat/numbers of individuals expected to be lost, interpretation of legislation such as the EC Directive and the measures to prevent or reduce adverse effects/compensation packages required to satisfy such legislation. The primary uncertainty regarding the development of intertidal habitat enhancement/creation as an offsetting measure for an STP development is the paucity of knowledge regarding the utilisation of intertidal habitat of in particular the migratory fish species within the Estuary. This presents a fundamental knowledge gap which necessitates a high level of uncertainty to be indicated for this measure for these species. Further sources of uncertainty are associated with the types of habitat which would need to be replaced/enhanced and the confidence that the plan alternatives implemented would have a similar ecological function to the habitat lost,

or that they would adequately compensate for loss of a specified number of individuals.

3.6.132 It is considered that there is currently a high level of uncertainty associated with the degree to which intertidal habitat creation/restoration outside of the Severn Estuary would provide an effective offsetting measure for the potential loss of intertidal habitats and the subsequent effect on fish communities within the Severn Estuary.

Operation offsetting measures – addressing limiting factors in the freshwater environment

3.6.133 It is considered that there is currently a high level of uncertainty associated with the degree to which the enhancement/creation of freshwater habitats would provide an effective offsetting measure for the potential loss of fish and the subsequent effect on fish communities in the Severn Estuary.

3.6.134 The main purpose of these measures would be to offset loss of individuals as opposed to loss of intertidal habitats. As such, a key requirement is to identify the numbers of individuals of protected species likely to be lost due to construction and operation of the proposed STP plan alternative. Only then can effective options available for appropriate offsetting be assessed. In addition, the habitat enhancement/restoration and creation projects currently implemented by the regulatory bodies to meet conservation objectives need to be fully understood and dialogue with those bodies would be required to ensure that proposed measures are additional and provide further benefits to fish populations than the measures currently in place and those planned to be introduced in the future.

Operation offsetting measures – fisheries buyout

3.6.135 There is relatively low uncertainty associated with this offsetting measure. Indeed, where adequate data exists, it has been possible to estimate numbers of fish that may be retained following a fisheries buyout. There is however, a certain amount of uncertainty associated with enforcing a buyout with the potential for continued fishing via poaching.

Operation offsetting measure - pheromone release

3.6.136 Uncertainty in relation to the use of pheromones as a measure to offset potential effects must remain high as this is primarily an untested technique, in the early stages of research for a single key species. Despite the potential advantages of applying pheromone-based techniques, the lack of firm scientific knowledge, or previous examples of application to natural systems from which to draw conclusions, means that uncertainty of development, production, application and impacts to target and non-target species must all be stated as high.

Compensation need - additional sites for inclusion in the SAC list

3.6.137 The scale of measures required is unprecedented (ABPmer 2008b) and the integrity of the affected Natura 2000 sites may not be maintained. A governmental decision would likely have to be taken to determine if this approach would actually compensate for lost habitat. Even with other sites designated, while the area of protected habitat may remain the same, the loss of the ecological functioning provided by the Severn Estuary and associated tributaries for many of the migratory species could mean that favourable conservation status for these species is reduced for the UK as a whole.

Considerable research and investigation of possible sites would need to be undertaken, and for some species habitat restoration and translocation of populations may be required. The total of the potential effects cannot be quantified at this stage, and accordingly the compensation need cannot be defined. As a result the uncertainty associated with this compensatory measure must be classed as high.

SECTION 4

ASSESSMENT AGAINST SEA OBJECTIVES

4 ASSESSMENT AGAINST SEA OBJECTIVES

4.1 Introduction

4.1.1 While not specifically required by the SEA Directive, the Practical Guide (ODPM *et al*., 2005) recommends that SEA Objectives are used to compare the effects of alternative options. The SEA Objectives, assessment criteria and indicators were drafted and consulted upon as part of the Phase 1 SEA scoping stage.

4.1.2 SEA Objectives reflect a desired direction of change. It therefore follows that these objectives may not necessarily be met in full by a given alternative option, but the degree to which they do would provide a way of identifying preferences when comparing alternative options.

4.1.3 This topic paper informs the Environmental Report and its assessment of alternative options against SEA Objectives. This is by providing an assessment specifically in relation to the topic's SEA Objectives. The Environmental Report would then consolidate each topic assessment to provide a description of the assessment in relation to all SEA Objectives.

4.2 Assessment Methodology

4.2.1 An SEA Objective compliance methodology requires judgements to be made on the performance of alternative options against each SEA Objective. The 'assessment criteria' and 'indicators' which accompany the SEA Objectives aid these judgements. The effects on receptors presented in section 3 are aggregated and related back to the SEA Objectives so that the environmental performance of each alternative option can be compared.

4.2.2 The SEA Objectives assessment summary table (Table 4.1) shows how each alternative option performs over its entire life-cycle against each SEA Objective, and whether this is major or minor, positive or negative or a combination of the two. For instance, some receptors covered by an SEA Objective may benefit from an alternative option, whereas others would be adversely affected. Furthermore, the judgement of whether the alternative option performance is minor or major depends on the number or proportion of receptors for each objective that are significantly affected, and their value. In addition to the SEA Objectives assessment summary table, the SEA Objectives are also discussed in relation to assessment criteria and indicators.

4.2.3 It recognised that there is a degree of judgement related to alternative option performance, and the assessment criteria are intended as an aid to these judgements. This activity has also been informed by inputs from the Technical Workshops and the Environment and Regional Workstreams.

4.3 Objectives-led Assessment Summary

4.3.1 Table 4.1 sets out the summary of the SEA Objectives assessment which is described in detail below. Note that in formulating this table major negative effects have been deemed likely to result where the magnitude of effect is 'high' and 'medium' where it has been judged that the effect will be adverse.

4.3.2 The measures to prevent or reduce effects considered in assessing the effect of the alternative options against the following SEA objectives are: the operational management of barrage/lagoon regime to change water levels to prevent or reduce the effect of tidal range reduction through ebb and flood generation; the operational management of barrage/lagoon regime to change water levels to prevent or reduce the effect of tidal range reduction through sluice management; the operational management of barrage/lagoon regime to change water levels to prevent or reduce the effect of tidal range reduction through turbine management; the operational management of barrage/lagoon regime to increase permeability of the barrage/lagoon by operating fewer turbines during low efficiency periods; the inclusion of locks and modification to sizing positions; topographic modification; inclusion of fish passage management options within or near the barrage/lagoon through use of fish bypasses; inclusion of fish passage management options within or near the barrage/lagoon through use of fish lifts and locks; fish exclusion and diversion; pheromone release; local dredging; reconfiguration of intakes/outfalls at Hinkley Point (L3d only); pumping of outfalls; increase of fluvial storage, and improvements to tidal or sea defences (B3, B4, B5 only).

4.3.3 It is noted that the inclusion of ebb and flood generation is considered likely to result in a negative effect on the fish receptors via disruption to route of passage. The inclusion of local dredging could have a negative effect on water quality for the fish receptors. The remaining measures are considered likely to result in reduced adverse effects upon the fish receptors. The effect of topographic modification on fish receptors is unclear and this measure has not been taken into account during the following assessment.

SEA Objective 1: To avoid adverse effects on designated wildlife sites for fish of international and national importance.

4.3.4 The designated wildlife sites considered in relation to this objective are the Severn Estuary/Môr Hafren, River Usk/ Afon Wysg and River Wye/ Afon Gwy SACs and the Severn Estuary Ramsar site. The protected fish species in these locations are sea lamprey, river lamprey, twaite shad, Atlantic salmon, sea trout, allis shad and European eel. The diversity of the fish community associated with the River Severn and the Severn Estuary is noted in the Severn Estuary Ramsar designation, as is the value of the Estuary as a migration route to the spawning grounds used by these species in the many tributaries that flow into the Estuary. The wider fish community (marine residents, marine stragglers, freshwater stragglers) are also part of the conservation objectives for the Severn Estuary/Môr Hafren SAC and their status therefore contributes to the determination of favourable conservation status. This wider fish community is also a notable feature of the Ramsar designation. Accordingly adverse effects upon these species would contribute to an adverse effect on any designated wildlife site. There is also the possibility of far field effects upon sites within the Natura 2000 network.

4.3.5 As a result of alterations to migratory cues options B3, B4, and B5 are considered likely to result in major negative effects on the protected fish species, and therefore on the designated wildlife sites, with the B3 option potentially effecting fish from all of the designated sites listed above. All of the alternative options are considered likely to result in a major negative effect as a result of the magnitude of effect resulting from disruption to route of passage. The magnitude of effect resulting from habitat loss and/or change is considered likely to result in a major negative effect for shad, river lamprey and eel, and potentially a minor negative effect for Atlantic salmon and sea

trout for all designated wildlife sites for the B3 option; while B4, B5, and L2 could result in a minor negative effect for the species, but not at all designated sites. L3d is not considered likely to result in a noticeable magnitude of effect with regard to habitat change and/or loss. It is considered likely that changes to water quality could result in a major negative effect for Atlantic salmon, sea trout and shad as a result of the B3, B4, B5, and L2 options. L3d is not considered likely to result in a noticeable magnitude of effect with regard to changes in water quality. All of the alternative options are considered likely to result in a major negative effect on Atlantic salmon, sea trout and shad as a result of the magnitude of effects associated with anthropogenic noise disturbance. Overall, it is considered that there is a risk of adverse effects upon all of the designated sites from all of the alternative options predominantly as a result of disruption to route of passage in particular turbine passage.

4.3.6 Some of the measures to prevent/reduce effects could have a bearing upon their magnitude and significance which could influence the level of effect. For example management of operation regime and the implementation of fish passage mechanisms could reduce effects associated with alterations to migratory cues and disruption to route of passage. It is considered unlikely however, that such measures would prevent any adverse effects upon the fish receptors and as such there is a risk that this SEA objective may not be met. It should be noted that under the Habitats Directive it would be necessary to demonstrate that there was no adverse effect upon site integrity and that if this could not be demonstrated without scientific doubt it would pose an infraction risk.

SEA Objective 2: To avoid adverse effects on the populations of other protected fish species and habitats.

4.3.7 The receptor fish species considered in relation to this objective are Atlantic salmon, sea trout, allis and twaite shad, river and sea lamprey and European eel, and the wider fish community present in the Severn Estuary/Môr Hafren SAC and Severn Estuary Ramsar site

4.3.8 It is considered that the same effects as discussed in relation to SEA Objective 1 would remain the same for the assessment of SEA Objective 2 for each of the plan alternatives.

4.3.9 As discussed above for objective 1 it is considered likely that some adverse effects to the fish receptors would remain after implementation of the measures to prevent/reduce effects, and accordingly it is considered that there is a risk that SEA Objective 2 would not be met.

SEA Objective 3: To avoid adverse effects on national and local biodiversity target features that include fish habitats and species.

4.3.10 The receptor species under consideration in relation to this objective are the UK BAP features within the marine migrant and marine straggler guilds.

4.3.11 All of the alternative options are considered likely to result in a major negative effect as a result of the magnitude of effect resulting from disruption to route of passage. The magnitude of effects associated with habitat change and/or loss are considered likely to result in a minor negative effect for marine migrant UK BAP features for the B3 option. A major negative effect as a result of the magnitude of effect resulting

from changes to water quality is considered likely as a result of the B3, B4, B5 and L2 options. A major negative effect as a result of the magnitude of effect resulting from anthropogenic noise disturbance is considered likely as a result of all the alternative options. A minor negative effect as a result of the magnitude of effects predicted from effects to freshwater, estuarine and marine fish species is considered likely in relation to all alternative options. Overall, it is considered that there is a risk of adverse effects upon all of the UK BAP fish features from all of the alternative options predominantly as a result of disruption to route of passage in particular turbine passage.

4.3.12 As discussed above for objective 1 it is considered likely that some adverse effects to the fish receptors would remain after implementation of the measures to prevent/reduce effects, and accordingly it is considered that there is a risk that SEA Objective 3 would not be met.

SEA Objective 4: To avoid adverse effects on recreational and migratory commercial fishing.

4.3.13 This objective considers recreational and heritage fisheries and the species which support them, in particular Atlantic salmon.

4.3.14 All of the alternative options are considered likely to result in a major negative effect on recreational and heritage fishing due to the high magnitude of effects associated with these options. The L3d option may result in a slightly lower level of negative effect upon recreational and migratory commercial fisheries than the other options.

4.3.15 As discussed above it is considered likely that adverse effects upon the fish receptors would remain after implementation of the measures to prevent or reduce effects, and accordingly it is considered that there is a risk that SEA Objective 4 would not be met.

SEA Objective 5: To avoid adverse effects on marine commercial fish resources.

4.3.16 All commercially targeted marine migrant and marine straggler fish receptors are considered under this objective.

4.3.17 The B3, B4, B5 and L2 options are considered likely to result in a major negative effect on commercial fish resources. The L3d alternative option is considered likely to result in a minor negative effect upon marine commercial fish resources.

4.3.18 As discussed above it is considered likely that some adverse effects to the fish receptors would remain after implementation of the measures to prevent or reduce effects, and accordingly it is considered that there is a risk that SEA Objective 5 would not be met.

SEA Objective 6: To minimise the risk of introduction of non-native invasive fish species.

4.3.19 This objective considers all the fish receptors.

4.3.20 The introduction of non-native invasive fish species is not considered to be an issue associated with any of the alternative options and as such this objective would be met.

Assumptions, Limitations and Uncertainty

4.3.21 In undertaking the assessment of the alternative options against the SEA objectives, there are assumptions, limitations and uncertainties, particularly as there is a degree of judgement related to option performance. These issues are discussed for this topic below.

4.3.22 The assessment of the alternative options against the SEA objectives has the same level of assumption, limitation and uncertainty as the assessment of the individual options for the plan alternatives assessment. This is because the SEA objectives assessment is dependent upon the individual evaluations of the likely magnitude and significance of effects associated with the alternative options. SEA requirements are for a high level assessment which limits the level of detail available, and accordingly judgements are made at a lower level of knowledge than ideal. In relation to this assessment of objective compliance, uncertainty is present as that associated with the prior judgements made as to magnitude and significance of effect, and also in terms of the uncertainty associated with the implementation of measures to prevent/reduce and offset effects. Many of the measures considered for this topic have high levels of associated uncertainty that can only be reduced upon further study.

Table 4.1 SEA Objective Assessment Summary Table

Key

Performance is based on number or proportion of receptors linked to each SEA Objective for which significant effects have been predicted, and informed by consideration of SEA Assessment Criteria.			
Major negative performance against SEA Objective	--	Major positive performance against SEA Objective	++
Minor negative performance against SEA Objective	-	Minor positive performance against SEA Objective	+
No Effects	0	Uncertain	?

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		Alternative Option B3: Brean Down to Lavernock Point Barrage	**Alternative Option B4: Shoots Barrage**	**Alternative Option B5: Beachley Barrage**	**Alternative Option L2: Welsh Grounds Lagoon**	**Alternative Option L3d: Bridgwater Bay Lagoon**
SEA Objective 1 – to avoid adverse effects on designated wildlife sites for fish of international and national importance	Severn Estuary/Môr Hafren SAC River Wye/ Afon Gwy SAC River Usk/ Afon Wysg SAC Severn Estuary Ramsar Potentially some far field Natura 2000 sites	--	--	--	--	--
		Significant negative effects associated with alteration to migratory cues, disruption to route of passage, habitat change and/or loss, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with alteration to migratory cues, disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with alteration to migratory cues, disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with disruption to route of passage and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.
SEA Objective 2 – to avoid adverse effects on the populations of other protected fish species and habitats	Atlantic salmon Sea trout Allis and twaite shad River and sea lamprey Eel	--	--	--	--	--
		Significant negative effects associated with alteration to migratory cues, disruption to route of passage, habitat change and/or loss, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with alteration to migratory cues, disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with alteration to migratory cues, disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with disruption to route of passage, change to water quality (salmon, sea trout and shad only) and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.	Significant negative effects associated with disruption to route of passage and anthropogenic noise disturbance (salmon, sea trout and shad only). Objective not met.
SEA Objective 3 –	UK BAP features	--	--	--	--	--

SEA Objective	Relevant Receptors	Alternatives Performance against SEA Objectives over entire life-cycle				
		Alternative Option B3: Brean Down to Lavernock Point Barrage	**Alternative Option B4: Shoots Barrage**	**Alternative Option B5: Beachley Barrage**	**Alternative Option L2: Welsh Grounds Lagoon**	**Alternative Option L3d: Bridgwater Bay Lagoon**
to avoid adverse effects on national and local biodiversity target features that include fish habitats and species	within the marine migrant and marine straggler ecological guilds					
		Significant negative effects associated with disruption to route of passage, change to water quality and anthropogenic noise disturbance. Minor negative effect associated with habitat change and/or loss (marine migrant guild only). Objective not met.	Significant negative effects associated with disruption to route of passage, change to water quality and anthropogenic noise disturbance. Objective not met.	Significant negative effects associated with disruption to route of passage, change to water quality and anthropogenic noise disturbance. Objective not met.	Significant negative effects associated with disruption to route of passage, change to water quality and anthropogenic noise disturbance. Objective not met.	Significant negative effects associated with disruption to route of passage and anthropogenic noise disturbance. Objective not met.
SEA Objective 4 – to avoid adverse effects on recreational and heritage fishing	Recreational and heritage fishing and the species which support them in particular Atlantic salmon	--	--	--	--	--
		Significant negative effects on recreational (particularly salmonid) and heritage fishing are considered likely. Objective not met.	Significant negative effects on recreational (particularly salmonid) and heritage fishing are considered likely. Objective not met.	Significant negative effects on recreational (particularly salmonid) and heritage fishing are considered likely. Objective not met.	Significant negative effects on recreational (particularly salmonid) and heritage fishing are considered likely. Objective not met.	Significant negative effects on recreational (particularly salmonid) and heritage fishing are considered likely. Objective not met.
SEA Objective 5 – to avoid adverse effects on commercial fish resources	All commercially targeted marine migrant and marine straggler fish receptors	--	--	--	--	-
		Significant negative effects on commercial fish resources are considered likely. Objective not met.	Significant negative effects on commercial fish resources are considered likely. Objective not met.	Significant negative effects on commercial fish resources are considered likely. Objective not met.	Significant negative effects on commercial fish resources are considered likely. Objective not met.	Significant negative effects on commercial fish resources are considered likely. Objective not met.
SEA Objective 6 – to minimise the risk of introduction of non-native invasive fish species	All fish receptors	This is not considered to be an issue.	This is not considered to be an issue.	This is not considered to be an issue.	This is not considered to be an issue.	This is not considered to be an issue.

SECTION 5

PLAN IMPLEMENTATION

5 PLAN IMPLEMENTATION

5.1 Introduction

5.1.1 This section assesses whether each alternative may be compliant with existing legislation and policy relevant to this topic as set out in section 2.3. This section also sets out suggestions for the framework for the monitoring of the plan against the predicted effects within this topic. It would thereby inform the development of the overall monitoring suggestions contained within the SEA Environmental Report.

5.2 Legislation and policy compliance

5.2.1 Identification of compliance with existing legislation and policy is not a requirement of the SEA Directive but would assist with suggestions to Government by DECC. The assessment considers legislation and policy relevant to this topic; and does not consider the overall consenting route that would apply to alternative options. Consenting is the subject of a separate Feasibility Study workstream.

5.2.2 The legislation relevant to the Migratory and Estuarine Fish topic and considered within the assessment below are:

- EC Habitats Directive (92/43/EC)
- EC Water Framework Directive (2000/60/EC)
- All PPP's listed within Section 2.3 of this document

Alternative Option B3: Brean Down to Lavernock Point Barrage

5.2.3 Effects associated with the B3 plan alternative upon the migratory and estuarine fish receptors are considered to be significant which could potentially result in fish losses with the potential to affect the sustainability or integrity of designated fish features. As such these effects are considered likely to put B3 at high risk of not complying with key directives including international drivers such as the EC Directives detailed above.

5.2.4 Additionally the B3 STP plan alternative is considered at high risk of not complying with both international and national legislation including SAFFA, eel management plans and proposed passage of fish regulations relating to the free or safe passage and escapement of fish. Although the efficacy of the use of fish passage mechanisms for this plan alternative remains largely unknown and requires further study there is potential that effects could be reduced but are unlikely to be prevented, compliance would therefore remain at risk.

5.2.5 Predicted reductions in the egg deposition of Atlantic salmon resulting in potential effects upon the integrity or sustainability of the populations within systems covered by a Salmon Action Plan including the Severn Estuary itself as well as the Rivers Usk, Wye, Taff and Ely are likely to result in a high risk of non-compliance of the Conservation Limit targets set out within the plans. It should be noted however, that future baseline population predictions for these rivers have the potential to result in a high risk of non-compliance of the conservation limit targets when the potential effects of climate change are also considered.

5.2.6 Although the assessment of compliance of the 40% escapement target of silver eel within the Severn River Basin District is complex it is largely considered that the population is currently failing (34% compliance) (Aprahamian & Walker, 2008). Any further effect upon this species, as is predicted to be the case for the B3 STP plan alternative, is therefore likely to augment the risk of failure of complying with this target.

5.2.7 Many of the key themes of the UK Marine and Coastal Access Act relate to the management and protection of marine, estuarine and migratory fish populations and their associated fisheries. Any significant effects upon the fish receptors and their fisheries, as are predicted for this plan alternative may therefore result in a high risk of non-compliance of this Bill.

5.2.8 The vision of the Wales Fishery Strategy is to 'support the development of viable and sustainable fisheries in Wales as an integral part of coherent policies for safeguarding the environment'. Any significant effects upon the target fish species and subsequently their fisheries as a result of the construction, operation and decommissioning of a B3 plan alternative may therefore result in a high risk of non-compliance of this strategy.

Alternative Option B4: Shoots Barrage

5.2.9 As with the B3 plan alternative there is potential that the significant effects associated with B4 could result in a high risk of the non-compliance of a number of key national and international legislative drivers. Disruption to route of passage, among other effects, has been identified as potentially having a significant effect upon the majority of fish species and ecological guilds potentially resulting in losses to the populations and subsequently effecting their sustainability or integrity. Where an effect such as this places a potential threat on meeting directive targets and goes against key objectives, in particular in this case providing safe passage, it is likely that there is a high risk of the above mentioned legislation and policies from not being complied with.

Alternative Option B5: Beachley Barrage

5.2.10 As with B4, effects potentially posed by B5, such as disruption to route of passage, which has the potential to pose a significant effect upon the fish receptors may result in losses to populations and subsequently effect their sustainability or integrity. Where this is the case there is the potential for the compliance of key national and international legislative drivers, within which the fish populations of the Severn Estuary are protected as detailed above, to be at high risk of failure.

Alternative Option L2: Welsh Grounds Lagoon

5.2.11 There is potential that effects arising from the construction, operation and decommissioning of the L2 plan alternative could have significant effects upon the fish receptors of the Severn Estuary. Effects contributing to this major negative classification include disruption to route of passage which has the potential to result in losses to fish as well as threatening the sustainability and integrity of key fish species. As such there is a high risk that the effects posed by the L2 plan alternative could result in the non-compliance of the national and international legislations and policies detailed above.

Alternative Option L3d: Bridgwater Bay Lagoon

5.2.12 Although effects upon the protected fish receptors are on the whole of a lower magnitude for the L3d plan alternative than other options, a risk of a significant effect remains in particular for rare and distribution restricted species such as shad. Disruption to route of passage in particular has the potential to affect the integrity or sustainability of this and other protected species which could put the compliance of the national and international legislations and policies, as detailed above, at high risk.

5.3 Monitoring of significant environmental effects

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

5.3.2 The Severn Tidal Power Feasibility Study SEA alone does not identify a preferred alternative option, but supports the wider decision making framework. Thus the monitoring is not prejudicial on the implementation of any alternative option. Below is a high level framework for monitoring, which can be applied to all of the Severn Tidal Power Schemes under consideration. The framework for this topic includes a brief description of monitoring proposed and the relationship between proposed monitoring, predicted likely significant environmental effects and receptors affected.

5.3.3 Any pre and post monitoring investigations would be designed and undertaken on consideration of legislative requirements and common standard monitoring protocols such as the Habitats Directive and WFD. It is recommended that agreement be sought with the statutory authorities regarding any investigation designs prior to implementation. Any dissemination of data collected would need to be at the agreement of the funding party and project proponents and would be determined upon implementation.

Measures suggested pre plan implementation to aid in assessment of effects and option development

5.3.4 To underpin the more detailed assessment that would be required for implementation of a plan alternative, suggestions have been provided on the nature, type and frequency of monitoring that might be required. It should be noted that a significant monitoring programme would be required covering all receptors and for an extended period of time, at least five years pre-construction as a minimum. This is necessary to provide a sufficient and robust understanding of seasonal and annual variation to support future assessment predictions.

5.3.5 In addition to monitoring to determine the accuracy of predicted effects it is recommended that further work be undertaken to enhance knowledge in a number of key areas which at present are limiting the complete assessment of effects. It is considered that any future assessment of the potential environmental effects associated with an STP option would be significantly limited in the absence of information which could be gathered from the monitoring outlined. Furthermore, the confidence which could be applied to both the environmental assessment and the confidence in the efficacy of identified prevention, reduction and offsetting measures could be greatly enhanced.

5.3.6 It has been identified within this document that information regarding the baseline situation of a number of the fish receptors is currently unknown which has significantly

limited the assessment of the implications of potential effects associated with an STP alternative option upon their populations. Any future STP assessment would be greatly assisted were this data to be collected. Life cycle models have been developed within this study for a number of the key fish receptors. It has been acknowledged throughout their development however, that there are a number of knowledge gaps which restricts the certainty that can be applied to them. Furthermore, due to a paucity of information it has not been possible to attempt to develop models for a number of the species and guilds. It is therefore recommended that studies be designed and undertaken to quantify the baseline population of the fish receptors including investigations to assist with parameters to be included within life cycle models.

5.3.7 Studies which could enhance the assessment of effects of an STP option which are recommended for consideration for any future phase of an STP SEA are summarised below:

5.3.8 A number of assumptions, limitations and uncertainties have been identified throughout the plan alternatives assessment which through further study and data collection could be removed or improved;

- **Provision of detailed option design** - Provision of more detailed information regarding the design of proposed options as well as the intended construction and decommissioning activities and programme would assist in eliminating a number of these uncertainties. It is recommended that any future STP assessment include more detailed design of these key elements.

- **Study to investigate the response of key fish receptors to changes to water quality and the presentation of anthropogenic noise** - There is a general paucity of available information regarding the response of key fish receptors to changes to water quality and to the presentation of anthropogenic noise associated with the activities proposed for the construction, operation and decommissioning of an STP option. Although studies to investigate the response of key fish receptors to these potential effects would increase the confidence in assessment, the possible significance of these effects may not warrant such a large scale study over other more limiting data gaps. An understanding of the use of at risk habitat by key fish receptors in particular the migratory species however would undoubtedly benefit the assessment of an STP option and is recommended for any future study.

- **Study of the behaviour of migratory, estuarine and marine fish species within the Severn Estuary** - An understanding of the behaviour of migratory, estuarine and marine fish species within the Severn Estuary is a key element to the assessment of the majority of potential effects upon these species from an STP option. The behaviour of the fish receptors including their distribution within the Estuary is a key limiting factor in the assessment of potential effects. It is therefore recommended that a sampling programme to include tagging and tracking and trawls be implemented to gain valuable information with respect to a number of the current knowledge gaps limiting this assessment.

- **Valuation of the fisheries of the Severn Estuary and its tributary rivers** - Although a review and limited data collection exercise has been undertaken as part of this assessment to value the fisheries of the

Severn Estuary and its tributary rivers, available data are currently lacking or are dated. It is recommended that to fully assess the potential economic effects upon the fisheries resulting from the construction, operation and decommissioning of an STP option that an extensive assessment be undertaken with the inclusion of detailed up to date data collection for all fisheries.

5.3.9 Measures suggested to assist in the determination of effects posed by fish passage through a tidal turbine and allow better fish passage design are as follows (See Annex 5: Fish passage through tidal power schemes for more detail);

- **Determination of detailed turbine specifications** - Engage manufacturers for provision of more detailed turbine specifications following which modelling of effects upon the fish populations of the Severn Estuary should be re-run;
- **Study of observations of fish passage through tidal turbines** - Carry out observational studies of fish behaviour during passage through a tidal power turbine at an existing site such as Annapolis Royal and/or La Rance;
- **Study of the behaviour of migratory, estuarine and marine fish species within the Severn Estuary** - Increase knowledge regarding some of the fundamental gaps in information of fish behaviour within the Severn Estuary in particular with respect to their vertical/horizontal distribution, diel/seasonal movement and transit/residence time and habitat use. It is recommended that this be undertaken through tagging and tracking studies of key fish species (See Annex 8: Assessment of current telemetry technologies for the tracking of fish in the Severn Estuary of this topic for further information) as well as netting and trawling programmes;
- **Study of turbine fluid dynamics** - Determine STP turbine specific fluid dynamic information to be obtained either from manufacturers where available or from CFD analysis or similar;
- **Assess applicability of experimental and laboratory fish injury/mortality data -** Upon determination of fluid dynamic turbine specific information assess the applicability of experimental and laboratory fish injury/mortality data and identify further study requirement where necessary.
- **Assessment of risk of multiple passage through turbines** - Develop a better understanding of the risk of fish making multiple passes through STP turbines. It is recommended that knowledge gaps be filled where possible through behavioural studies of key fish species within the Estuary as discussed above. Upon attainment of this information calibration and refinement should be undertaken of the indicative fish movement model developed by HR Wallingford for this phase of the STP SEA study.

- **Study of effects of turbine passage** - Undertake field based assessments of effects upon fish resulting from turbine passage were an STP plan alternative to become operational.

5.3.10 Uncertainty remains regarding the potential efficacy and confidence of success of a number of the identified prevention and reduction and offsetting measures for this topic. Where it is considered that the success of a measure could significantly reduce the magnitude of effect of an STP option and assist with the compliance of national and international legislation and policies it is recommended that further study be undertaken to investigate the potential of the identified measures. Studies which could increase the confidence in the success of prevention, reduction and offsetting measures which are recommended for consideration for any future phase of an STP SEA are summarised below:

- **Efficacy of operational and management refinement** - It is recommended that consideration of operational management refinement of an STP option be considered in more detail as a measure for this topic.

- **Fish passage feasibility study** - It is recommended that a detailed feasibility study be undertaken by a joint team of engineers and fisheries specialists to design and determine the efficacy of the inclusion of fish passage mechanisms within an STP option structure. This measure has the potential to significantly reduce effects relating in particular to disruption to route of passage and with appropriate design and installation could have a high certainty of success.

- **Feasibility of proven measures** – Where measures are largely proven but on a smaller scale such as habitat enhancement, stocking and translocation the assessment of the feasibility of their application at a larger scale would improve the confidence of success.

- **Efficacy of novel techniques** – The confidence of success of some of the more novel prevent/reduce and offsetting techniques could be enhanced through further investigations.

Measures suggested post implementation to monitor potential effects

5.3.11 The outline monitoring measures that have emerged during scoping and feasibility are summarised below.

5.3.12 Further discussion of the practical difficulties, risk and technical aspects of this monitoring is detailed within Annex 8: Assessment of current telemetry technologies for the tracking of fish in the Severn Estuary.

5.3.13 To assess changes in fish populations and identify appropriate levels of measures to prevent or reduce adverse effects and compensation from the installation of an STP scheme it would be necessary to monitor both migratory and estuarine fish populations pre and post construction. Sufficient post construction monitoring would be required to distinguish between temporary construction and longer term operation effects and assess the effectiveness of measures to prevent or reduce adverse effects and compensation measures.

5.3.14 Where historical monitoring of a sufficient nature to determine a significant change exists, it is suggested that this monitoring be continued. For example, this may include for migratory fish species, a continuation of condition assessment monitoring within the riverine SACs and other major river systems such as the River Severn and Avon. However it is likely that this would need to be conducted on a more regular basis than the current 6 year cycle. Annual sampling would be suggested. Methods of sampling may also need to be adapted to enable, where feasible, a quantitative assessment of stocks and integrity of all species and utilised habitats. This is particularly pertinent for the two shad species for which, at present, the Common Standards Monitoring technique is considered to not lend itself to a quantitative assessment of stocks or densities. Estuarine fish sampling is currently undertaken on the Severn Estuary as part of the WFD monitoring programme. These surveys employ a multi-method approach utilising seine nets, otter and beam trawls to examine fish assemblages within the estuary (Coates *et al.,* 2007). A number of ecological measures are then assessed for fish caught and analysed to give an indication of the status of assemblages within the Estuary (Coates *et al.,* 2007). The number and location of sites sampled for the WFD programme, however, may not be sufficient in isolation to record fish communities within all key areas and habitats and include all fish species of interest. It may therefore be necessary to supplement this sampling with additional techniques, sites and where necessary, frequency. In addition to those sites where effects may be felt it would also be necessary to monitor sites at which compensation measures were intended to be implemented.

5.3.15 It is suggested that statistical tools such as Bohlin and Power Analysis are used to determine an appropriate number of sites to be monitored in order to detect as a minimum, a change equivalent to a halving or doubling of the population. A more robust approach could also be followed although understandably the more robust the approach the more resources would be required.

5.3.16 Although there are a number of limitations to the analysis and interpretation of the data sets in terms of identification of change and bias, due to the length of the data set it is suggested that power station entrainment monitoring be continued and data acquired for use within the suite of monitoring for the STP option.

5.3.17 For those measures to prevent, reduce or offset effects for which confidence is currently unknown or a level of confidence has been applied in a precautionary way, it is suggested that trials and monitoring programmes be initiated before STP implementation.

5.3.18 It should be stressed that the competent authorities involved would want to see all possible measures taken to ensure the protection of internationally and nationally designated species and habitats and all efforts undertaken to avoid any additional anthropogenic change and indeed a robust monitoring programme to confirm that measures to prevent, reduce or offset effects were indeed effective.

Table 5.1 Monitoring of significant environmental effects

Significant effect	Relevant receptor	Description of monitoring
Alterations to migratory cues	All diadromous fish receptors	Monitor fish migration to identify any increased straying or delay.
Disruption to route of passage	All fish receptors	Monitor fish losses, population sustainability, delay to passage, effects upon reproductive success etc.
Habitat change and/or loss	All fish receptors	Monitor species distribution and abundance within key habitats.
Changes to water quality	All fish receptors	Monitor water quality parameters and assess against key fish receptor thresholds. Monitor fish behaviour and distribution.
Anthropogenic noise disturbance	All fish receptors	Monitor background, construction, operation and decommissioning noise levels and assess potential effects upon the thresholds of key fish receptors. Monitor distribution of key fish receptors during noise generating activities.
Effects upon freshwater, estuarine and marine fish species	Freshwater, estuarine and marine fish species	Assess and monitor potential effects resulting from those identified above.
Effects upon recreational, commercial and shell fisheries	Target fish species	Monitor rod catches and landings. Liaise with fishery owners and commercial crafts.

SECTION 6

GLOSSARY

6 GLOSSARY

Term	Definition
Appropriate Assessment	A process required by the Habitats Regulations (SI 1994/ 2716) to avoid adverse effects of plans, programmes and projects on Natura 2000 sites and thereby maintain the coherence of the Natura 2000 network and its features.
Ancillary development	Other works beyond a Severn Tidal Power scheme but are needed to build or operate the scheme, including measures to prevent, reduce or as fully as possible offset significant environmental effects, e.g. dredging, bypasses etc.
Barrage	A manmade obstruction across a watercourse to retain a head of water on the rising tide, and then run the water through turbines when the tide level drops.
Bristol Channel	The area seaward of the headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast (see Severn Estuary and also Inner Bristol Channel and Outer Bristol Channel)
Bulb Kapeller type turbines	The Kapeller Bulb turbine is a turbine regulated only by its adjustable runner blades (single regulation). It has fixed wicket gates. It is adaptable to pumping as well as generation but only suited to one way generation. Kapeller Bulb turbine technology has largely been superseded by Bulb Kaplan turbines.
Bulb Kaplan turbines	The Kaplan turbine is a propeller-type water turbine that has adjustable blades and adjustable wicket gates (double regulation). It is adaptable to pumping as well as generation. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. The Kaplan turbine is an inward flow reaction turbine, which means that the working fluid changes pressure as it moves through the turbine and gives up its energy. The Kaplan turbine is suited to one or two way generation.
Bulb turbines	The generator is mounted in a bulb on the main turbine axis upstream of the runner blades for one way generation. Bulb turbines can be used for one or two way generation depending on the type (see above).
Caissons	Prefabricated concrete units used to construct parts of a barrage, lagoon or other offshore structures. Caissons can be used to house turbines, sluices or to construct navigation locks, or they may just be plain units used for impoundment construction.
Coalfield river	A river draining a coalfield valley
Coastal Squeeze	Process whereby the coastal margin is squeezed between a fixed landward boundary and the rising sea level.
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage . Only used in relation to the Habitats Directive (see offsetting, below).
Consequential development	It is conceivable that a major tidal power scheme would facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as ‘consequential developments’.

Term	Definition
Cumulative effects	Effects arise, for instance, where several developments each have insignificant effects but together have a significant effect, or where several individual effects of the plan have a combined effect.
Direct effects	The original effect as a result of an option (see indirect effects)
Ebb	When the sea or tide ebbs, it moves away from the coast and falls to a lower level.
Ebb mode	One way generation on ebb tides only i.e. during the period between high tide and the next low tide in which the sea is receding.
Ebb and flood mode	Two way generation during the ebb and flood tides
Effect	Used to describe changes to the environment as a result of an option (see also direct effects, indirect effects, far field effects and cumulative effects)
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorus). This in turn can lead to 'eutrophication effects' – an increase in an ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
Far field effects	Effects that are felt outside the Severn Estuary study area.
Favourable condition	A result of characterising the condition of a Special Area of Conservation feature where the aspirations for its condition, as expressed in its conservation objective, are being met.
Flood	The inward flow of the tide - This is the opposite of ebb. This refers to a mode of operation for a STP alternative option.
Future baseline	Baseline during construction (2014-2020) and operation (2020-2140), decommissioning and longer term trends.
Geomorphology	The study of the changing form of the estuarine environment and its components in relation to physical forcing.
Heritage fishing	Commercial fishing within the estuary by traditional techniques including the use of gill nets, sweep/encircling nets, fixed engines and hand held nets.
Hydrodynamics / hydraulics	The science of physical forces acting on the water.
Impoundment	A body of water, such as a reservoir, made by impounding
Indicator	A measure of variables over time, often used to measure achievement of objectives.
Indirect effects	Those effects which occur away from the original effect or as a result of a complex pathway.

Term	Definition
Inner Bristol Channel	The downstream limit extends from Nash Point in Wales to the west of Minehead along the English coast. The upper limit extends from Swanbridge on the Welsh coast to Brean Down along the English coast.
Irreversible	Effect that cannot be reversed. If the timescale for a receptor's return to baseline condition is greater than 50 years then it would be considered irreversible.
Lagoon(s)/ Land-connected lagoons	A man-made enclosed body of water that retains a head of water on the rising tide and then runs the water through turbines when the tide level drops. A land connected lagoon uses the shoreline to make the enclosure.
Long-listed options	All options identified in the SDC report, Call for Proposals and other strategically selected proposals as well as the Interim Options Analysis Report.
Measures to prevent or reduce effects	Measures to prevent or reduce any significant adverse effects on the environment.
Natura 2000	Natura 2000 is the European Union-wide network of protected areas, recognised as 'sites of Community importance' under the EC Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). The Natura 2000 network includes two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Negative effects	Changes which are unfavourable for a receptor. Can sometimes be referred to as 'adverse'.
Offsetting	Measures to as fully as possible offset any significant adverse effects on the environment. Such measures will aim to make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. Not used in relation to the Habitats Directive (see compensation, above).
One way generation	The operating mode whereby power is generated on only one phase of the tidal cycle. For Severn tidal power, one way generation is typically ebb mode.
Original scheme	The form of the scheme when it was shortlisted at the end of phase 1.
Outer Bristol Channel	The outer limit extends from St. Govans Head in Pembrokeshire to Hartland Point in Devon, which traditionally defines the lower limit of the Bristol Channel. The upper limit extends from Nash Point in Wales to the west of Minehead along the English coast.
Permanent effect	An effect which would last at least for 50 years.
Phase 1	The current stage of the STP Feasibility Study - i.e. the Decision Making Assessment Framework (to develop a short-list of options) and SEA Scoping.
Phase 2	The second stage of the STP Feasibility Study - i.e. short-listed options appraisal and main assessment stage of the SEA.
The Policy; Plan and Programme	Sets out which international, national, regional and local policies, plans and objectives must be taken into account in the SEA.

Term	Definition
Review (PPP)	
Positive effects	Changes which are favourable for a receptor. Can sometimes be referred to as 'beneficial'.
Pumping	Operating turbines in reverse to pump water from lower to higher levels. Pumping can be used during one way generation to raise impounded water levels so that more energy can be generated when the ebb tide is receding.
Ramsar site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Reversible	Effect that can be reversed. If the timescale for a receptor's return to baseline condition is less than 50 years then it would be considered reversible.
Scoping	The process of deciding the scope and level of detail of an SEA, including the environmental effects and alternatives which need to be considered, the assessment methods to be used, and the structure and contents of the Environmental Report.
SEA objective	A statement of what is intended, specifying the desired direction of change in trends.
Seabed	The areas permanently covered by the sea, i.e. Lowest Astronomical Tide. Sometimes referred to as sub-tidal.
Severn Estuary	This is the physical extent of the Estuary and does not reflect the Study Area (see below) or nature conservation designations. Downstream limit - headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast passing through the small island features of Flat Holm and Steep Holm. Upstream limit – Haw Bridge, upstream of Gloucester on the River Severn (based on 1 in 100 year flood risk area and also used by Shoreline Management Plan (SMP) (Gifford, 1998) and Coastal Habitat Management Plan (CHaMP) (ABPmer 2006)). N.B. The tidal limit, which for the Severn is at Maisemore (West Parting) and Llanthony (East Parting) weirs, near Gloucester.
Severn Tidal Power Study Area	The general study area used for the project broadly extends downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and the River Usk. Study areas for individual topics for Phase 2 may extend beyond this area and these are defined separately according to topic.
Short-listed options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.

Term	Definition
Significant environmental effects	Effects on the environment which are significant in the context of a plan or programme. Criteria for assessing significance are set out in Annex II of the SEA Directive (2001/42/EC).
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Sluice caissons	Prefabricated concrete structures placed into the water to house a sluice.
Special Area of Conservation (SAC)	Strictly protected site designated under the EC Habitats Directive 92/43/EEC. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that would make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).
Special Protection Area (SPA)	Strictly protected site classified in accordance with Article 4 of the EC Directive on the Conservation of Wild Birds (79/409/EEC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.
Straflo type turbines	A more compact turbine compared to Bulb turbine technology. Instead of containing the generator in a bulb, it is located and designed for ebb only operation and not suited to pumping.
Strategic Environmental Assessment (SEA)	Term used to describe environmental assessment as applied to policies, plans and programmes. 'SEA' is used to refer to the type of environmental assessment required under the SEA Directive.
Sub tidal	Areas (particularly with reference to habitats) that lie below the level of the lowest astronomical tide.
Temporary effects	An effects which only lasts part of the project lifetime, e.g. is confined to the construction period.
The Shoots	The downstream boundary extends from Undy along the Welsh coast to Severn Beach along the English coast, just to the south of the M4 motorway crossing. The upstream limit extends just to the north of the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary.
Transboundary effects	An environmental effect upon another EU Member State.

Term	Definition
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
TWh/year	A unit used to describe how much energy generated, sold, consumed, etc. A terawatt-hour refers to generating or using power at a capacity of 1 terawatt (1012 watts) for one hour. A terawatt-hour per year means the equivalent amount of power sometime within the period of a year.
Two way generation	The operating mode whereby power is generated on both phases of the tidal cycle (ebb and flood)
Unfavourable condition	A result of characterising the condition of a Special Area of Conservation feature where the aspirations for its condition, as expressed in its conservation objective, are not being met.
Upper Severn Estuary	Upstream from the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast, to the tidal limit along the River Severn at Maisemere, Gloucestershire.
Variant	A modified version of the original shortlisted scheme.

SECTION 7

REFERENCES

ABPmer. 2008a. Severn Tidal Power – Scoping Topic Paper: Marine and Estuarine Water Quality. Report for Parsons Brinkerhoff.

ABPmer. 2008b. Severn Tidal Power – Scoping Topic Paper: Geomorphology. Report for Parsons Brinkerhoff.

Alexandrino. P., Faria, R., Linhares, D., Castro, F., Le Corre, M., Sabatié, Bagliniére and Weiss, S. 2006. Interspecific differentiation and intraspecific substructure in two closely related clupeids with extensive hybridization, *Alosa alosa* and *Alosa fallax. Journal of Fish Biology,* 69: 242-259.

APEM, 2007. River Dee Fish Entrainment Study. APEM Scientific Report 886

Aprahamian, M.W., Walker, A.M., Wouldiams, B., Bark, A. and Knights, B. 2007. On the application of models of European eel (*Anguilla anguilla*) production and escapement to the development of Eel Management Plans: the River Severn – ICES Journal of Marine Science, 64: 1472-1482.

Aprahamian, M. & Walker, A. 2008. Status of eel fisheries, stocks and management in England and Wales. Knowledge and Management of Aquatic Ecosystems. 390-391, 07.

Battersby J, Morris R, Cole-King A. 2009. Severn Tidal Power Feasibility Study Working Paper New Site Designation as a Compensatory Measure under Article 6

Burnard D, Gozlan RE, Griffiths SW. 2008. The role of pheromones in freshwater fishes. Journal of Fish Biology 73: 1-16.

Countryside Council for Wales CCW. 2008a. Core Management Plan including conservation objectives for River Usk Special Area of Conservation, March 2008.

Countryside Council for Wales CCW. 2008b. Core Management Plan including conservation objectives for River Wye Special Area of Conservation, March 2008.

Coates, S., Waugh, A., Anwar, A., Robson, M. 2007. Efficacy of a multi-metric fish index as an analysis tool for the transitional fish component of the Water Framework Directive. Marine Pollution Bulletin 55, 225-240.

Colcough S., Fonseca L., Astley T., Thomas K. and Watts W. 2005. Fish utilisation of managed realignments. *Fisheries Management and Ecology* 12: 351-360

Davidson, I.C. and Hazlewood, M.S. 2005. Climate change and fisheries: Use of scale material to examine spatial and temporal trends in the freshwater and marine growth of Atlantic salmon in England and Wales. Environment Agency Science Report W2-047/SR.

Department of Energy and Climate Change. 2009a. Severn Tidal Power: Strategic Environmental Assessment Scoping Report, January 2009.

Department of Energy and Climate Change. 2009b. Severn Tidal Power Phase One Consultation Government Response, July 2009.
Environment Agency, 2008. River Severn Salmon Action Plan.

Environment Agency. 2003a. River Usk Salmon Action Plan, October 2003.

Environment Agency. 2003b. River Wye Salmon Action Plan, October 2003.

Environment Agency, 2009. Eel Management Plans for the United Kingdom, October 2009. 33 pp.

Friedland, K.D., Reddin, D.G., McMenemy, J.R. and Drinkwater, K.F. 2003. Multidecadal trends in North American Atlantic salmon (*Salmo salar*) stocks and climate trends relative to juvenile survival. *Canadian Journal of Fisheries and Aquatic Sciences*, 60, 563-583.

Ferguson, A. 2006. Genetics of sea trout with particular reference to Britain and Ireland. *In* G.S. Harris and N.J. Milner. *Sea Trout: Biology, Conservation and Management*. Proceedings of First International Sea Trout Symposium, Cardiff, July 2004. Blackwell Scientific Publications, Oxford, 157-182.

Franco, A., Elliott, M., Franzoi, P., Torricelli, P., 2008. Life strategies of fishes in European estuaries : the functional guild approach. Marine Ecology Progress Series 354, 219-228

Harvey, J.P; Nunn, A.D. and Cowx, I. (2006) Survey of larval lamprey (ammocoetes and transformers) in the Yorkshire Ouse and Derwent catchments, 2004. Report to the Environment Agency (Dales Area).

Henderson, P.A. (2007) Discrete and continuous change in the fish community of the Bristol Channel in response to climate change. *Journal of the Marine Biological Association of the United Kingdom*, 87, 589-598.

Henderson, P.A. and Seaby, R.M. (2005) The role of climate in determining the temporal variation in abundance, recruitment and growth of sole *Solea solea* in the Bristol Channel. *Journal of the Marine Biological Association of the United Kingdom*. 85, 197-204

Henderson, P.A. and Holmes, R.H.A (1990) High fish recruitment in the Severn Estuary: the effect of a warm year? (Brief Communication). *Journal of Fish Biology,* 36, 961-963.

ICES. 2007. Report of the ICES Advisory Committee on Fishery Management, Advisory Committee on the Marine Environment and Advisory Committee on Ecosystems, 2007. ICES Advice. Book 9. 129 pp.

Jensen, L.F., Hansen, M.M., Pertoldi, C., Holdensgaard, G., Dons Mensberg, K-L., and Loeschke, V. 2008. Local adaptation in brown trout early life history traits: implications for climate change adaptability. Proceedings of the Royal Society, Series B 275, 2859-2868.

Li W, Twohey M, Jones M, Wagner M (2006) Research to guide use of pheromones to control sea lamprey. *Journal of Great Lakes Research* **33** (Special Issue 2): 70-86.

Maitland P.S. 2003. *Ecology of the River, Brook and Sea Lamprey*. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough.

Natural England. 2007. Reducing the impacts of fish-eating birds: the use of nets and wires. Natural England Technical Information Note TIN029.

Office of the Deputy Prime Minister (2008) A Practical Guide to the Strategic Environmental Assessment Directive. ISBN 1 85 112788 7, August 2006.

OSPAR (2009) Draft OSPAR Background information document for Sea lamprey *Petromyzon marinus*. 24 pp.

Polkinghorne, C. N., Olson, J. M., Gallaher, D. D., and Sorensen, P. W. 2001. Larval sea lamprey release two unique bile acids to the water at a sufficient rate to produce a detectable pheromonal plume. Fish Physiology and Biochemistry 24,15–30.

Potter, I. C., Bird, D. J., Claridge, P.N, Clarke, K. R., Hyndes G. A., and Newton, L. C. (2001) Fish fauna of the Severn Estuary. Are there long-term changes in abundance and species composition and are the recruitment patterns of the main marine species correlated? *Journal of Experimental Marine Biology and Ecology*, 258:1, 15-37.

Potter I. C., Claridge P. N. & Warwick R. M. (1986). Consistency of seasonal changes in an estuarine fish assemblage. MEPS 32: 217-228

Sorensen PW, Stacey NE (2004) Brief review of fish pheromones and discussion of their possible uses in the control of non-indigenous teleost fishes. *New Zealand Journal of Marine and Freshwater Research* **38**: 399-417

Sorensen PW, Scott AP, Kihslinger RL (2000) How common hormonal metabolites function as specific pheromones in the goldfish. In, *Proceedings of the Sixth International Symposium on the Reproductive Physiology of Fish*, eds. Norberg B, Kjesbu OS, Taranger GL, Andersson E, Stefansson SO. Bergen, Norway, 125-129

Severn Tidal Power (2009a) Severn Tidal Power SEA: Policy, Plan and Programme. September 2009. 219pp.

Severn Tidal Power (2009b) Cumulative effects and consequential developments. September 2009. 18pp.

Swain, A. 1982. The migrations of salmon (*Salmo salar* L.) from three rivers entering the Severn Estuary. *Journal du Conseil International Pour L'Exploration de la Mer* 40: 76-80.

Tierney KB, Sampson JL, Ross PS, Sekela MA, Kennedy CJ (2008) Salmon olfaction is impaired by an environmentally realistic pesticide mixture. *Environmental Science & Technology* **42**: 4996-5001

Turnpenny, A.W.H., Thatcher, K.P., Wood, R. and Nedwell, J. 1994. Fish deterrent field trials at Hinkley point power station, Somerset, 1993-4. Fawley Aquatic Research Laboratories Ltd, Report to Nuclear Electric plc, No. FRR 132/94.

Wagner CM, Jones ML, Twohey MB, Sorensen PW (2006) A field test verifies that pheromones can be useful for sea lamprey (*Petromyzon marinus*) control in the Great Lakes. *Can. J. Fish. Aquat. Sci.* **63**: 475-479

Wagner, C.M., Twohey, M.B. and Fine, J.M. 2009. Conspecific cueing in the sea lamprey: do reproductive migrations consistently follow the most intense larval odor? *Animal Behaviour* **78**(3): 593-599

Webb, B. W. and Walsh, A. J. 2004. Changing UK river temperatures and their impact on fish populations. Hydrology: Science and Practice for the 21st Century 2, 177-191.