DECC

SEVERN TIDAL POWER - SEA TOPIC PAPER

Freshwater Environment and Associated Interfaces

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

In association with
Black and Veatch Limited

Prepared for
DECC
3 Whitehall Place
London
SW1A 2HD

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Date		**March 2010**
Prepared by	**:**	**A C D Groves**
Checked by	**:**	**D. Toghill**
Approved by	**:**	**D. Keiller**

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ABBREVIATIONS

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The following abbreviations are used in this Topic Report:

AOD	Above Ordnance Datum (Newlyn)
AMP	Asset Management Plan
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
CAMS	Catchment Abstraction Management Strategy
CBB	Cardiff Bay Barrage
CCW	Countryside Council for Wales
CRoW	Countryside and Rights of Way Act 2000
cSAC	Candidate Special Area for Conservation
CSO	Combined Sewer Overflow
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
EIA	Environmental Impact Assessment
EPA	Environmental Protection Act 1990
EU	European Union
FR&LD	Flood Risk and Land Drainage
GCR	Geological Conservation Review
GIS	Geographical Information System
GQA	General Quality Assessment
H&G	Hydraulics and Geomorphology
LIDAR	Light Detection and Ranging
MAGIC	Multi-Agency Geographic Information for the Countryside
MSL	Mean Sea Level
MW	Meggawatts
MWQ	Marine Water Quality
NE	Natural England
NPS	National Policy Statement
ODPM	Office of the Deputy Prime Minister
PPS	Planning Policy Statement
PWS	Public Water Supply
PSU	Practical Salinity Unit
RBMP	River Basin Management Plan
RIGS	Regionally Important Geological and Geomorphological Site
SAC	Special Area for Conservation
SBDP	Severn Barrage Development Project
SEA	Strategic Environmental Assessment
SI	Statutory Instrument
SNCI	Sites of Nature Conservation Importance
SPZ	Groundwater Source Protection Zone
SSGB	Soil Survey of Great Britain
SSSI	Site of Special Scientific Interest
STP	Severn Tidal Power
SWRDA	South West Regional Development Authority
TAN	Technical Advice Note
TWh	Terrawatt Hours
UKCIP	United Kingdom Climate Impacts Programme
WAG	Welsh Assembly Government
WFD	Water Framework Directive
WRA	Water Resources Act 1991

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 Freshwater Environment & Associated Interfaces topic paper forms part of the reporting arising from Phase 2, the main assessment of short-listed options.

Consultation

The following consultation activities have been undertaken:

- Scoping consultation in January 2009;
- Technical Workshops held in June and November 2009; and
- Progress reporting and clarification undertaken by telephone with key Statutory Consultees.

SEA Objectives

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

- **Objective 1**: to avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality standards.
- **Objective 2**: to avoid adverse effects on water quality, which would affect human health, flora and fauna, recreation and other users.
- **Objective 3**: to avoid adverse effects on water abstractions (whether surface water of groundwater), particularly those utilised for the Public Water Supply (PWS).
- **Objective 4**: to avoid adverse effects to the water regime of designated water-dependent sites of nature conservation interest.
- **Objective 5**: to avoid adverse effects to buildings and infrastructure.
- **Objective 6**: to avoid adverse effects to the soil resource.
- **Objective 7**: to avoid adverse effects on agricultural land currently in use.
- Objective 8: to avoid adverse effects on geological and geomorphological sites of international and national importance.
- **Objective 9**: to conserve and enhance designated geological and geomorphological site features.

Baseline Environment

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

Baseline environment up to 2009

Surface and Groundwater Resources:

There are a large number of watercourses and ditches within the study area, however the main tributaries of the Severn estuary are: the Ely River and River Taff, which are impounded by Cardiff Bay, the River Rhymney, River Ebbw, River Usk, River Wye, the influent River Severn, the River Avon and River Parrett. The lowermost reaches of the Ely, Usk, Wye and Avon currently achieve the 'good' status for chemistry and biology required by the Water Framework Directive (WFD), although there are some issues with nutrients in these and other tributaries. The effects of contaminated land on regional water quality are therefore very small.

The rocks in the immediate vicinity of the Severn estuary are a complex series of folded and faulted strata of Cambrian to Jurassic age, which are covered with more recent deposits dating from the last glaciation. In general, however, the geology bordering the estuary can be considered as comprising low permeability bedrock overlain by low permeability soils, principally related to estuarine alluvium. The result is that surface water processes dominate the regional hydrology and hence there is little groundwater resource potential. The key exception to this general pattern is the presence of Carboniferous Limestone, an important aquifer, which is harnessed for the Public Water Supply (PWS); the fluvio-glacial deposits in Cardiff and, to a lesser extent, isolated deposits of River Terrace gravels and dune sands. Groundwater quality is generally good.

Abstractions:
There are a large number of abstractions within the study area and initial 'screening' has therefore concentrated on those within the Study Area within 2km of the coast or floodplain. These may be summarised as follows:

- Ten abstractions from surface water used for the PWS, of which only three occur upstream of a line from Lavernock to Hinkley, all associated with Bristol Water's Purton source form the Sharpness Canal;
- 128 licensed abstractions from surface water for other uses, of which 39 occur upstream of a line from Lavernock to Hinkley;
- Ten groundwater abstractions used for the PWS, of which three occur upstream of a line from Lavernock to Hinkley: Welsh Water's use of the 'Great Well', intercepted by the Severn Railway Tunnel; and Bristol Water's sources at Clevedon and Banwell.
- 103 licensed groundwater abstractions for other uses, of which 36 occur upstream of a line from Lavernock to Hinkley.

Sites of Geological and Geomorphological Interest:
There are a large number of SSSIs designated for their geological and / or geomorphological interest in the Study Area within 2km of the coast or floodplain, of which 14 occur east of a line between Lavernock to Hinkley:

- On the Welsh side: - Penarth Coast, Flat Holm, Rhymney River Section, Lower Wye, and Otter Hole within Pierce, Alcove and Piercefield Woods SSSI;
- On the English side - Lydney Cliff, Purton Passage, Aust Cliff, Avon Gorge, Portishead Pier to Black Nore, Clevedon Shore, Middle Hope, Spring Cove Cliffs and Brean Down.

The above are all geological SSSIs, with the exception of Clevedon Shore and the Lower Wye, which are geomorphological.

Soils:
The variation in soil type within the Study Area is vast and complex. As soil type is related to the underlying geology a *simplified* representation is that soils occurring above the estuarine alluvium and glacial till are generally heavy, clay-rich and poorly drained, whereas those overlying sand and gravel deposits are lighter, more sandy and better drained. Undisturbed peat also has poor drainage characteristics. This simplification makes no allowance for soil improvement that may have taken place as a result of agricultural practices but is sufficient for this SEA.

Subterranean Infrastructure and Assets:
The infrastructure considered in this report relates mainly to that which is underground and includes the following:

- Nationally important assets, comprising the Severn Railway Tunnel, the M4 and M48 road crossings and the high voltage cable tunnel operated by National Grid plc; and
- Locally important subterranean infrastructure within the urban centres, such as basements, sewers and other services. The extent of this is unknown.

Future baseline during construction: 2014-2020

The following are assumed:

- Regulation to align with the requirements of River Basin Management Plans (RBMPs) will be effective in achieving the Water Framework Directive (WFD) objectives of 'good' ecological status and 'good' chemical status for water bodies by 2015;
- Implementation of the national water resources strategies will maintain the number of licensed abstractions, although the licensed volumes at individual sources may be reduced in the second cycle of RBMPs due for publication in 2015;
- The rise in mean sea level, of between 0.075 - 0.097m above baseline, predicted by UKCP09 will have a negligible influence on all identified receptors.

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

The following are assumed:

- Subsequent cycles of the RBMPs will be effective in maintaining WFD objectives in the early stages of operation, however the predicted effects of climate change, will make it increasingly difficult for the *status quo* to be maintained;
- Available surface water and groundwater resources will reduce. Reductions in summer low flow predicted by the Environment Agency (EA) of between 50-80% by 2050 suggest that licensed abstractions will become increasingly limited in order to maintain PWS sources;
- Predicted sea level rise of between 0.1-0.63m, combined with lower summer river flows will result in increased saline intrusion up tributaries open to the Severn estuary, but will have a negligible effect on the accessibility to important coastal geological or geomorphoogical outcrops;
- The soil resource will come under increasing stress as a result of increased temperatures and lower summer soil moisture;
- Infrastructure will degrade, however known land contamination will gradually improve.

Key Environmental Issues and Problems

The most important environmental problems associated with this topic are the uncertainties associated with anticipated climate changes and the response to these over the operational life of a tidal power project. If the predictions are correct, significant changes will occur that will affect the availability and quality of water resources and the soil resource. Although linked, the comparative effects of predicted sea level rise on the current baseline environment over the same timeframe appear small. Regulatory mechanisms have been initiated by Government to manage these issues as they affect water resources and soils with what are, in effect, 5 year plans and reviews. It is uncertain, however, to what extent the predicted changes can be managed by intervention to maintain or improve the *status quo* (or a *quasi staus quo*) or at what point the degree of change or cost of intervention becomes so great that management of a degrading resource becomes accepted. These uncertainties are large and have an important influence on the trends in baseline conditions, summarised above.

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.

Most of the assessment undertaken in this topic has been desk-based and semi-quantitative. It has been informed by the output from the predictive modelling studies undertaken as part of the Hydrodynamics and Gemorphology (H&G), Flood Risk and Land Drainage (FR&LD) and the Marine Water Quality (MWQ) topics (STP, 2010b,c,d), supported by simple scoping calculations, as well as professional experience and judgement.

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 on the English side	2km	Ebb only	Straflo	50 (12.5MW)	1.4 to 1.6 TWh/year	31	1
L2: Welsh Grounds Lagoon	River Usk to Second Severn Crossing	28km	Ebb only	Bulb	40 (25MW)	2.6 to 2.8 TWh/year	32	1
L3d: Bridgwater Bay Lagoon	Brean Down to Hinkley 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

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

The likely significant effects of this alternative option are:
- Loss of soil resource, due to increased soil wetness over an approximate area of up to 360 km^2;
- Loss of access to 10 sites designated for important geological features, including direct loss of the southernmost portion of Penarth Coast SSSI during construction, and loss of safe access to the Otter Hole cave system and access at 8 others during operation; and
- Loss of local infrastructure through the effects of groundwater flooding, particularly in parts of Weston-super-Mare, although other low-lying urban areas could also be affected, including parts of Cardiff, Newport, Avonmouth and Clevedon.

Alternative Option B4: Shoots Barrage

The likely significant effects of this alternative option are:

- Loss of soil resource, due to increased soil wetness over an area of approximately 90 km^2 as a result of flooding; and
- Loss of access to one geological SSSI (Otter Hole) and partial access to up to 4 others during operation.

Alternative Option B5: Beachley Barrage

The likely significant effects of this alternative option are:
- The potential for direct loss of part of Aust Cliff SSSI during construction and reduced access at three others; and
- Loss of soil resource, due to increased soil wetness and potential waterlogging over an area of approximately 73km^2.

Alternative Option L2: Welsh Grounds Lagoon

The likely significant effects of this alternative option are:
- Loss of soil resource, due to waterlogging over an area of approximately 47km^2; and
- Potential impacts to subterranean infrastructure in Llanwern, eastern Caldicot and southern Newport, on the eastern side of the River Usk.

Alternative Option L3d: Bridgwater Bay Lagoon

The likely significant effects of this alternative option are:
- Loss of soil resource, due to increased wetness and potential waterlogging over an area of approximately 200km^2; and
- Potential impacts to subterranean infrastructure, most likely in southern parts of Bridgwater.

Assumptions, Limitations and Uncertainty

The assessment relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP, 2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):
- The value of the lowermost geological exposures at the geological SSSIs that may be covered by the increased sea levels;
- The importance of the extent of subterranean infrastructure and ground conditions in the areas identified potentially at risk; and
- The land quality where the soil resource will be depleted, which does not affect the assessment of effects but has implications for economic analysis.

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

Offsetting measures within this SEA are measures to as fully as possible offset any significant adverse effects on the environment. These measures therefore make good for loss or damage to an environmental receptor, without directly reducing that loss/damage. In this SEA 'compensation', a subset of offsetting, is only used in relation to those measures needed under the Habitats Directive.

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

Geological and Geomorphological SSSIs:

- During optimisation the land fall on the English side of the B3: Brean Down to Lavernock Point Barrage and the L3d: Bridgwater Bay Lagoon were adjusted to avoid direct loss to Brean Down SSSI.
- Direct loss of the southern part of Penarth Coast SSSI caused at the landfall on the Welsh side by the B3: Brean Down to Lavernock Point Barrage, and to the Aust Cliff SSSI by the land fall of the B5:Beachley Barrage on the English side could be offset by slight adjustments to the alignments of these alternative options.
- Provision of alternative access to the Otter Hole cave system could be considered to offset loss of safe access caused by the B3: Brean Down to Lavernock Point Barrage and the B4: Shoots Barrage.
- In all other cases, the indirect effects to SSSIs as a result of submergence of geological outcrop cannot be prevented and will need to be offset. It is possible that alternative GCR sites may offer opportunities for observation and study, in which case very little would be necessary other than provision of appropriate access. If the particular geological and geomorphological features were unique to the lost outcrop, however, no offsetting would be possible.

Soils:
The drainage measures recommended by the FR&LD topic paper to prevent increased flooding risk to properties would reduce the effects to the soil resource but not prevent them entirely, as these are weighted towards urbanised areas. Provision of extra pumping above what is proposed by FR&LD would therefore be required to prevent significant effects to the soil resource. These could be incorporated into similar requirements to reduce and / or prevent significant effects to water-dependent sites of nature conservation importance (STP 2010e). Climate change effects are likely to mean that the amount of 'additional' drainage provision required to remove the significant effects to soils would be likely to reduce through the operational phase, particularly in summer periods.

Infrastructure:
No measures were taken during optimisation to prevent or minimise effects to subterranean infrastructure.

The likely significant effects to infrastructure result from raised water tables beneath buildings and urban areas and the increased dampness that could result in below ground structures, such as basements, and loss of capacity in sewers and other services. This could be reduced and, in many cases prevented, by provision of increased drainage in urban areas.

The drainage measures recommended by the FR&LD topic paper to prevent increased flooding risk to properties would reduce the effects to infrastructure in some areas. However, these would not prevent significant effects to infrastructure entirely, particularly where this is present in high permeability soils near the coastal fringe. Provision above what is proposed by FR&LD would therefore be required. The disruption associated with implementation of this could be large because of the constraints of working within urban areas.

Unlike the situation with soils, the additional pumping required in low-lying land near the coastal fringe would be likely to be necessary throughout the operational phase of an alternative option, particularly where there is good hydraulic connection with the impounded waters, e.g. through dune sands. In such cases, the amount of intercepted water could be large and therefore costly to maintain. Where the permeability of the ground is lower, e.g. in clay soils, the volume of water requiring pumping and its associated cost would be correspondingly smaller, however, the capital cost of installing effective drainage schemes could be higher in relative terms. It is possible that in some situations the local constraints were such that increased moisture within basements could not be prevented.

Assessment against SEA Objectives

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

The Options have been predicted to perform against the SEA Objectives as follows:

Alternative Option B3: Brean Down to Lavernock Point Barrage.

- A possible minor negative performance against Objective FE.1 in relation to groundwater because a potential adverse effect resulting from saline intrusion near Cardiff and Weston-super-Mare;
- A possible minor negative performance against Objective FE.3 in relation to Public Water Supply sources because a theoretical adverse effect upon Clevedon Pumping Station;
- A major negative performance in relation to Objective FE.5 because of the adverse effects to local infrastructure, particularly in Weston-super-Mare;
- A major negative performance in relation to Objective FE.8 because of adverse effects to geological / geomorphological SSSIs; and
- A major negative performance in relation to Objective FE.9 in relation to conserving and enhancing adverse geological / geomorphological SSSIs.

Alternative Option B4: Shoots Barrage.

- A slight negative performance in relation to Objective FE.8 because of adverse effects to geological / geomorphological SSSIs; and
- A slight negative performance in relation to Objective FE.9 in relation to conserving and enhancing adverse geological / geomorphological SSSIs.

Alternative Option B5: Beachley Barrage.

- A slight positive performance in relation to Objective FE.3 because of a slight improvement in the protection afforded to the security of Purton water treatment works, as a result of increased flood protection to the Sharpness Canal;
- A slight negative performance in relation to Objective FE.8 because of adverse effects to geological / geomorphological SSSIs; and
- A slight negative performance in relation to Objective FE.9 in relation to conserving and enhancing adverse geological / geomorphological SSSIs.

Alternative Option L2: Welsh Grounds Lagoon.
This alternative option has no effect (either positive or negative) in relation to the SEA Objectives.

Alternative Option L3d: Bridgwater Bay Lagoon.

- A possible minor negative performance against Objective FE.1 in relation to groundwater because a potential adverse effect resulting from saline intrusion near Bridgwater Bay.

Plan Implementation

Legislation and Policy Compliance

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

There are three main areas where there are potential issues relevant to this topic:

- All five alternative options would cause increased saline intrusion of the groundwater resource, which would be contrary to the Water Resources Act 1991 (WRA). It is uncertain how much this would be an issue at construction as some of the WRA is understood to be being replaced by proposed legislation as part of implementation of the Water Framework Directive.

- All three barrage options fail the requirements of the Countryside and Rights of Way Act 2000, in relation to conservation and enhancement of sites that are designated as geological and / or geomorphological SSSIs; and
- It is likely that the EA would object to any alternative option that increased the risk of flooding by raised groundwater levels under the WRA. This is a significant issue for the B3: Brean Down to Lavernock Point Barrage and could be for the two lagoon options L2: Welsh Grounds Lagoon and L3d: Bridgwater Bay Lagoon.

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.

1. Geological / Geomorphological SSSIs. More details are required for the geological / geomorphological SSSIs to allow the preliminary assessment presented herein to be revised on a more objective basis. Site-specific information is required from the tidal limit at Gloucester downstream as far as Bude on the English side and round the Welsh coast as far as the northern extremity of Cardigan Bay, particularly in relation to the value of exposures within the inter-tidal zone and immediately above it. Once obtained, ‘monitoring’ of the SSSIs *per se* would not be required, although confirmation of the sea level rise at those locations deemed likely to be affected would be necessary.
2. Subterranean Infrastructure / Assets. Monitoring of the water table elevation and its natural variation is required in order to assess the effect of an alternative option on subterranean assets, however before such information can be used effectively the following information will be required:
   - Details of the assets that might be affected, such as type, condition, elevation (including invert elevations); and
   - The type of ground within which they sit, including its physical, hydraulic and chemical characteristics and the vertical and lateral extent and variations of this material, including Made Ground, and its hydraulic connection to the surface water system.
3. Soils. The increased soil wetness that will result from each of the alternative options could be a positive or negative factor in the management of the soil resource. Before such information could be used effectively, however, a soil condition survey would need to be undertaken across the area potentially affected.

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 and social 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 with 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, as they are not at the stage currently 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 are aggregated into 'theme' papers to ensure that the inter-relationships between effects are considered and understood – see Section 1.2. The topic and theme papers provide supporting information to the Environmental Report that is needed to fulfil the requirements of the SEA Directive.

1.1.6 This is the Freshwater Environment and Associated Interfaces topic paper within the Physiochemical theme and considers the following:

- Surface water resources, particularly surface water quality;

- Groundwater resources, including groundwater levels and quality;

- Water abstractions from both surface water and groundwater, particularly those used for the Public Water Supply (PWS);
- Sites of geological and / or geomorphological interest, particularly SSSIs;
- The soil resource; and
- Assets not considered by other topic papers, particularly those below ground, such as the Severn Railway Tunnel and basements outside the designated floodplain.

1.1.7 Reference is also made to contaminated land because of its relationship to water quality.

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; Terrestrial & Freshwater 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 below for this topic.

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 Several common concerns were raised by consultees during this process. The Environment Agency (EA), Countryside Council for Wales (CCW) and Natural England (NE) each commented that the Study Area should be sufficiently large, particularly downstream of the shortlisted options, to consider all potential effects and that uncertainties within the assessment process should be properly considered. The EA further recommended that the SEA should consider the potential impacts and benefits of the proposals on the water resources of the River Severn and associated catchments, including those related to:

- Licensed and un-licensed surface water and groundwater abstractions;
- Future water resource availability, including the implications of altered residual flow requirements;
- Water dependent conservation sites and general ecology; and
- The use of the catchment as a source of drinking water and recipient of consented discharges.

Technical Workshops

1.3.4 A series of 'Technical Workshops' was convened during Phases 1 and 2 of the Feasibility Study, principally to provide the opportunity for technical specialists across many organisations to input to the developing SEA. Table 1.2 below summarises the workshops held in support of this topic.

Table 1.2 SEA Technical Workshops for Freshwater Environment and Associated Interfaces SEA Topic

Phase, date	Workshop Purpose
Phase 2, 1 June 2009	To confirm the scope of SEA work planned in Phase 2 and review key aspects of the assessment methodology.
Phase 2, 30 November 2009	To review preliminary findings and approaches to identifying measures to prevent, reduce and as fully as possible offset significant environmental effects.

1.3.5 During the workshop held in June 2009 the EA and CCW reinforced the comments made above regarding the downstream extent of the Study Area (paragraph 1.3.3) and also suggested that contaminated land be included within the topic because of its potential influence on surface and groundwater quality. Both of these suggestions were subsequently incorporated (see paragraphs 1.1.7 and 2.1.6).

Other Consultation

1.3.6 A series of update telephone conferences was held following the first Technical Workshop to inform the statutory consultees and DECC workstreams of progress. These were held on 10 August, 15 September and 18 November 2009.

1.3.7 Informal consultation was also held with the EA, CCW, local water undertakers and local councils as part of the supplementary baseline data gathering and verification undertaken during Phase 2.

1.4 SEA Objectives

1.4.1 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.

1.4.2 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 measure of a variable over time, often used to measure achievement of objectives.

1.4.3 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).

1.4.4 The SEA Objectives for this topic are summarised below in Table 1.3. These remained relatively unchanged throughout Phase 1, although Objective FE.4 was reworded following the Phase 1 public consultation.

Table 1.3 SEA Objectives, Assessment Criteria and Indicators for Freshwater Environment and Associated Interfaces SEA topic

<table>
<tr><th colspan="2">SEA Objective</th><th>Assessment Criteria</th><th>Indicators</th></tr>
<tr><td>FE.1</td><td>To avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality standards.</td><td>Will option cause deterioration in water quality such that RQO or requirements of WFD are not attained / maintained?

Will option allow improvements in water quality to be maintained?</td><td rowspan="2">Estimate changes in physical, chemical and biological water quality (further details to be collated at nominated site stage where applicable)

Changes to water, sediment and biota samples at key sites. Water quality standards, plus WFD priority substances, where applicable</td></tr>
<tr><td>FE.2</td><td>To avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users.</td><td>Will option cause potential negative effects to human health?</td></tr>
</table>

SEA Objective		Assessment Criteria	Indicators
FE.3	To avoid adverse effects on water abstractions (whether surface water of groundwater), particularly those utilised for the PWS.	Will option reduce available fresh water resources in terms of quantity or quality? Will option negatively affect PWS or other licensed or unlicensed sources in terms of quantity of quality?	Estimate potential changes in availability and water quality at surface and groundwater abstractions. Indicators as above plus SPZ configurations in the case of groundwater abstractions
FE.4	To avoid adverse effects to the water regime of designated water-dependent sites of nature conservation interest.	Will option affect sites of nature conservation importance or protected areas, including freshwater fisheries, by changes in water levels, flows or quality?	Estimate changes in stress on land drainage and associated infrastructure Assess changes in integrity of nature conservation sites due to changes in groundwater levels, and/or surface water flows and/or quality
FE.5	To avoid adverse effects to buildings and infrastructure.	Will option negatively affect the Severn railway tunnel or other important transportation infrastructure? Will option negatively affect buildings?	Assess changes in hydrology of Severn Estuary on Severn Tunnel and implications for tunnel integrity Assess changes in groundwater elevations and chemistry caused by impoundment schemes on buildings, sewers, CSOs etc.
FE.6	To avoid adverse effects to the soil resource.	Will option lead to loss of terrestrial soil resource or cause increased coastal erosion?	Diversity, quality and coverage of soil resource
FE.7	To avoid adverse effects on agricultural land currently in use.	Will changes to groundwater elevations so impair land drainage so as to reduce the fertility and/or usefulness of agricultural land?	Agricultural land quality, accessibility to machinery
FE.8	To avoid adverse effects on geological and geomorphological sites of international and national importance.	Will the option lead to reduced accessibility to designated geological / or geomorphological sites?	Estimate altered accessibility to geological and geomorphological SSSIs
FE.9	To conserve and enhance designated geological and geomorphological site features.	Will the option lead to an increased rate of deterioration?	Estimate rate of increased deterioration by physical or chemical processes

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 within 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.

<u>Study Area</u>

2.1.6 In response to the comments received at Scoping and the first Technical Workshop held in early June 2009, the preliminary Study Area was enlarged to cover the extent of LIDAR data obtained for the Flood Risk and Land Drainage topic, shown on the receptor plans presented as Figures 1-13. This ensured consistency with other topics within the SEA and accommodated the comments made by CCW at Scoping that the study area extend sufficiently far enough to incorporate the large number of geological SSSIs on the South Wales coast (see paragraph 1.3.3).

2.1.7 Within this large area, particular attention was given to receptors within a buffer 2km inland from the coast, and 2km upstream of the tidal limit on the main tributaries and the 200 year floodplain. The rationale for the width of the buffer zone was explained within the paper on receptor value and vulnerability (STP, 2009c), which is included in Appendix A.

<u>Receptors</u>

2.1.8 The individual receptors within this topic are shown on the series of baseline maps, which are presented as Figures 1-13. Because of the large number of individual receptors, these have been summarised into various receptor groups in the discussion which follows and in Tables 2.1 and 2.2.

<u>Water Resources</u>

2.1.9 The water environment is protected under the Water Resources Act 1991 (WRA), which uses the term 'controlled waters.' Controlled waters correspond to all rivers, canals, lakes, groundwaters, estuaries and coastal waters up to three nautical miles from shore. All controlled waters have therefore been regarded as potential receptors within the SEA, however this topic has concentrated on those controlled waters that represent freshwater resources, upstream of seawater influence. For clarity and in line with current convention, these have been divided between surface waters and groundwater, which are considered in terms of quantity and quality.

2.1.10 There are acknowledged interfaces between this topic and the other topics within the Physio-chemical Theme, which are summarised in Table 1.1.

Surface Water

2.1.11 A simplified representation of the surface water network, showing the main tributaries to the Severn estuary, as well as the designated 200 year tidal and fluvial floodplain, is shown in Figure 1. There are a large number of smaller watercourses and ditches within the study area, which cannot be shown because of scale, particularly on the low-lying ground adjacent to both sides of the estuary. The main tributaries of the Severn estuary are: the Ely River, River Taff, River Rhymney, River Ebbw, River Usk, River Wye, the influent River Severn, the River Avon and River Parrett. The water quality within these rivers is discussed in paragraph 2.4.8.

Groundwater

2.1.12 The rocks in the immediate vicinity of the Severn estuary are a complex series of folded and faulted strata of Cambrian to Jurassic age, which are covered with more recent deposits dating from the last glaciation (drift). The variation in strata is shown on the published geological mapping and described in the respective memoirs (BGS 1962, 1996a,b, 2004; Whittaker *et a*l 1983, Kellaway and Welch 1993). In general, however, the geology bordering the estuary can be considered as comprising low permeability bedrock overlain by low permeability soils. The result is that surface water processes dominate the regional hydrology and hence there is little groundwater resource potential.

2.1.13 A simplified representation of the solid geology is provided in Figure 2. This indicates that the majority of the bedrock bordering the coast upstream of a line between Lavernock to Hinkley comprises sediments of the Mercia Mudstone Group (Triassic) and Lias (Jurassic), both of which can be considered to have little water resource potential. (A small sliver of Cambrian rocks outcrops immediately to the east of Sharpness, which are also of little importance in water resource terms.) The key exception to this general pattern is the presence of Carboniferous Limestone, an important aquifer, which is harnessed for the Public Water Supply (PWS). A large block of Carboniferous Limestone occurs immediately inland of Chepstow, with smaller coastal outcrops occurring on the ridge between Portishead and Clevedon, as well as the coastal outliers at Worlebury Hill, Middle Hope and Brean Down, near

Weston-super-Mare. These outcrops are more resistant to erosion than the surrounding country rocks and therefore tend to form the topographic highs above the more eroded Triassic and Lias sediments.

2.1.14 A simplified representation of the drift geology is shown in Figure 3. This indicates six main types of material adjacent to the Severn estuary, discussed as follows:

- Estuarine and fluvial alluvium. This represents, by far, the most important deposit, covering an extensive area adjacent to and inland from the coast, the distribution of which coincides very closely with the extent of the 200 year floodplain, shown in Figure 1. The estuarine alluvium is typically present as an organic-rich silty clay.

- River Terrace deposits. These are present as much smaller, isolated outcrops of mainly sand and gravel that occur at the inland edge and topographically slightly above the floodplain. These deposits form a line on the Welsh side upstream of Caldicot.

- Peat occurs above the alluvium, extensive deposits occurring within the Somerset Levels, in the valleys of the River Brue and River Cary inland of Bridgwater, but also inland of Weston, Clevedon and in the Gordano Valley.

- Fluvio-glacial gravels are present above the bedrock on the Welsh side of the estuary, particularly within and to the east of Cardiff. In Cardiff, these deposits become covered by the estuarine alluvium adjacent to the coast.

- Glacial till (formerly boulder clay) is present over extensive areas in South Wales and typically occurs inland and at a higher elevation than the fluvio-glacial gravels. It borders the floodplain between Cardiff and Newport.

- Dune sands border the coast is a line between Weston-super-Mare and Bridgwater and on the Welsh coast to the west of Bridgend.

2.1.15 In addition to the above, Made Ground is present beneath urban areas, particularly where these are located on naturally low-lying and/or poorly draining ground. Made Ground is present beneath large areas of coastal Cardiff, Newport, Avonmouth, Weston-super-Mare and Bridgwater.

2.1.16 Water is present in each of the solid and drift materials described above and, with the exception of that within Made Ground, is considered as a receptor in this assessment (see paragraph 2.3.5). In most cases, however, this water is unavailable for exploitation because of the low permeability of the geological materials. The main exceptions to this are the Carboniferous Limestone, the fluvio-glacial deposits in Cardiff and, to a lesser extent, the isolated deposits of River Terrace gravels and dune sands.

Contaminated Land

2.1.17 At the first technical workshop, held on 1 June 2009, there was consensus from the statutory consultees present that the SEA should include an assessment of the effect(s) of contaminated land under Part 2a of the Environmental Protection Act 1990 (EPA) because of the potential link with surface water and groundwater quality. As a result, those sites that are registered as contaminated land are shown on Figure 4, with further information included in Appendix B.

Abstractions

2.1.18 There are a large number of abstractions within the study area, which are shown on Figures 5-9, with further details provided in Appendices C and D. Each of the figures shows a 2km envelope around the coast and tidal tributaries, to assist with screening and the assessment of receptor vulnerability and magnitude of effects.

Abstractions for the Public Water Supply

2.1.19 The PWS abstractions within the study area from surface waters are shown in Figure 5. Each abstraction is shown with a unique reference, which corresponds to that used for the supporting information provided in Appendix C.

2.1.20 Figure 5 indicates that there are 10 surface water sources for the PWS within 2km of the coast or floodplain, which are summarised in Appendix C. The only PWS abstractions within the 2km envelope upstream of the line between Lavernock to Hinkley, however, are those associated with Bristol Water's Purton abstraction from the Sharpness Canal, which supplies north Bristol, shown as references 42, 43 and 44 on Figure 5.

2.1.21 The PWS abstractions within the study area sourced from groundwater are shown in Figure 6. This indicates that there are 10 groundwater sources for the PWS within 2km of the coast or floodplain, which are summarised in Appendix D. Of these, only three sources are upstream of a line between Lavernock to Hinkley, as follows:

- Banwell Spring, harnessed by Bristol Water (Reference 9), which is located on the edge of the floodplain and over 5km inland;
- Clevedon PS, operated by Bristol Water (Reference 11); and
- The well shaft to the Great Spring, operated by Welsh Water (Reference 36).

2.1.22 The groundwater source protection zones associated with these sources are shown in Figure 7.

Other Licensed Abstractions

2.1.23 Licensed abstractions from surface water for uses other than the PWS are shown in Figure 8, with further details provided in Appendix C. As of 2009, there were a total of 128 licensed surface water abstractions within 2km of the coast or floodplain, of which 39 were located east of the line between Lavernock to Hinkley.

2.1.24 Licensed groundwater abstractions for uses other than the PWS are shown in Figure 9, with further details provided in Appendix D. As of 2009, there were a total of 103 licensed surface water abstractions within 2km of the coast or floodplain, of which 36 were located east of the line between Lavernock to Hinkley.

Unlicensed Abstractions

2.1.25 Unlicensed abstractions from either surface of groundwater are likely to be present within the Study Area, however these are not considered in this SEA because of their size (less than 20 m^3/day).

Sites of Geological and Geomorphological Interest

2.1.26 There are a large number of coastal sites of geological or geomorphological interest, which are shown on Figures 10 and 11. Additional information on SSSIs is provided in Appendix E.

Sites of Special Scientific Interest

2.1.27 The geological and geomorphological SSSIs within 2km of the coast or floodplain within the study area are shown in Figure 10, with further details provided within Appendix E. There are 14 SSSIs east of a line between Lavernock to Hinkley, five on the Welsh side and nine on the English, as follows:

- On the Welsh side: - Penarth Coast, Flat Holm, Rhymney River Section, Lower Wye, and Otter Hole within Pierce, Alcove and Piercefield Woods SSSI.
- On the English side - Lydney Cliff, Purton Passage, Aust Cliff, Avon Gorge, Portishead Pier to Black Nore, Clevedon Shore, Middle Hope, Spring Cove Cliffs and Brean Down.

2.1.28 The above are all geological SSSIs, with the exception of the Lower Wye, which is geomorphological, designated because of the river morphology within the tidal range and Clevedon Shore. Otter Hole represents the cave system within Pierce, Alcove and Piercefield Woods SSSI, the entrance to which is within the tidal range. Formalisation of the designation of both Otter Hole and River Wye at Launcaut has not currently been finalised (as at 01/10).

2.1.29 To the west of the line between Lavernock to Hinkley there are 24 coastal SSSIs within the study area, 18 on the Welsh side (12 of which occur on and to the west of the Gower) and six on the English coast. Of these, at least seven SSSIs contain features of recent geological (Quaternary) or geomorphological interest, such as saltmarsh, coastal soft cliffs, raised beaches, dune systems, and caves with important soft sediment infil. Six of these are on or west of the Gower (Pwll-Du Head and Bishopston Valley, Oxwich Bay, Gower Coast Rhosili to Porteynon, Rhosili Down, Burry Inlet and Loughor Estuary, and Morfa a Chraig Cwm Ivy), with one on the English side (Porlock Ridge and Saltmarsh).

Regionally Important Geological and Geomorphological Sites

2.1.30 RIGS are shown in Figure 11, however the process of identifying RIGS in South Wales is not yet complete and so those sites identified on the Welsh side should be considered as ‘potential’ RIGS. This accounts for the large number of sites identified within 2km of the Welsh coast or floodplain (404 as at September 2009), compared with that on the English side (43).

2.1.31 Because of the current difference in classification on either side of the Estuary, RIGS have not been included in the assessment of likely significant effects, described in Section 3 and are not considered further in this paper.

Soils

2.1.32 The variation in soil type within the Study Area is vast and cannot be represented meaningfully in a graphical format at the small scales used in this report. As soil type is related to the underlying geology, however, a *simplified* understanding of soil type can be obtained by reference to Figure 3. Soils occurring above the estuarine alluvium and glacial till are generally heavy, clay-rich and poorly drained, whereas those overlying sand and gravel deposits are lighter, more sandy and better drained. Undisturbed peat also has poor drainage characteristics.

2.1.33 This simplified division of soil types makes no provision for soil improvement that may have taken place through agricultural practices (such as improved land drainage or fertilisation) or land classification or value, but is sufficient for the assessment presented here.

Infrastructure

2.1.34 The infrastructure considered here is the (mainly) subterranean infrastructure not included within other topics. This includes the following:

- The Severn Railway Tunnel;
- The M4 and M48 road crossings;
- The small (3m diameter) cable tunnel beneath the estuary operated by National Grid plc (Haswell, 1973); and
- Locally important subterranean infrastructure within the urban centres, such as basements, sewers and other services.

2.1.35 The definition of the receptors included within the last bullet changed during Phase 2 of the SEA to include all those that could potentially be affected by increased groundwater levels; surface water effects being covered in the Flood Risk and Land Drainage topic paper (STP, 2010b).

2.2 Methodologies Used to Develop the Baseline

Sources of Data

2.2.2 The baseline was developed from a detailed desk-based review of readily available data in the public domain, which was supplemented and clarified, where necessary, by consultation with key stakeholders. The sources of data included:

- Published mapping, undertaken by Ordnance Survey, Soil Survey of England and Wales and British Geological Survey (BGS);
- Direct information requests to Statutory Consultees, including EA, CCW, NE and Local Authorities;
- Websites for EA www.environment-agency.gov.uk; CCW www.ccw.gov.uk; NE www.**naturalengland**.org.uk.
- Local record offices and interest groups.

2.2.3 The process of data collection yielded a large volume of information, in both electronic and 'hard' format, which was collated, reviewed and interpreted using a Geographical Information System (GIS). This allowed for a certain amount of data verification, for example, by checking for consistency between datasets where these were available in both electronic and paper formats, or where GIS layers included sensitive receptors known to the project team. This process identified some errors and omissions, which were clarified, where possible, by consultation with the statutory consultees.

Assumptions, Limitations and Uncertainty

2.2.4 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 Climate Change Assumptions

2.2.5 In developing the future baseline projections, assumptions are made about environmental trends, and policy responses to these trends. It has been assumed that UK Climate Projections (UKCP09) central estimate projections for the medium emissions scenario apply for most topics (UKCP, 2009).

General Assumptions Concerning Application of Government Policy

2.2.6 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

2.2.7 The key assumption that underlies the baseline, is that the information obtained from published and other public sources, including that obtained in electronic format, is correct and has been transferred correctly into the GIS without distortion. Although a certain amount of quality control was undertaken on the baseline datasets, as outlined in paragraph 2.2.3, verification of all data was not possible during the SEA process. It is possible, therefore, that not all receptors have been ‘captured’ correctly within the GIS.

2.2.8 A limitation of this topic is the treatment given to locally important underground infrastructure. Whilst it is known, for example, that there are areas of Cardiff and Weston-super-Mare that have properties with basements, it has not been possible with the resources available to quantify the number or details of these in any meaningful manner; nor has it been possible to ascertain the extent and condition of important underground services, such as sewers and communication infrastructure, for example. Even if this information were available, however, simplifying assumptions and professional judgement, such as used within this assessment, would still be required because of the large variations that exist within local ground conditions, which are fundamental to understanding the future condition of such assets. In most cases, ground conditions cannot be ascertained by reference to published information but only by local ground investigation and, whilst a large amount of such information has been undertaken within the study area, much of this is contained within the ‘grey’ literature, which was not obtained by this topic.

2.2.9 Future trends within the water environment represent the other important component of uncertainty within this topic. These are heavily dependent on the degree of climate change that occurs and the consequential alterations to rainfall, infiltration and surface flow patterns, not solely the aspect of sea level rise (se Section 2.5).

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.

Water Resources

2.3.2 Regulation of the water environment in England & Wales is undertaken by the EA through the WRA and a large amount of associated legislation. The EA's approach to water resource management over the next 40 years is described within The Water Resources Strategy for England and Wales, which provides a framework for managing water resources in the context of the impacts of climate change, demographic changes and population increase (EA, 2009a). The themes of the strategy are developed in regional action plans, including those developed for Wales and South-West England (EA, 2009b,c).

2.3.3 The EU Water Framework Directive (WFD) has the objective of protecting and enhancing the water environment and ensuring the sustainable use and development of water resources for economic and social development. It establishes a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, and has the objective of achieving good ecological status and good chemical status for surface waters by 2015.

2.3.4 The EA's approach to meeting the WFD objectives at the river basin scale is described in river basin management plans (RBMPs), which will be updated and reissued every six years. Those of most relevance to this study are those for the River Severn and Western Wales, which were published on 22 December 2009 (EA, 2009d,e).

2.3.5 The EA's approach to protecting groundwater resources in the context of the WFD is described within their Groundwater Protection Policy, also known as GP3 (EA, undated, 2008).

Abstractions

2.3.6 Abstractions from surface water or groundwater for industrial and domestic purposes and of more than 20 cubic metres per day (m^3/day) are licensed by the EA through the WRA (as amended). Management of the amount of abstraction that takes place within a given catchment is undertaken through Catchment Abstraction Management Studies (CAMS), which form part of the EA's management of water resources at the local, river catchment scale. The first CAMS cycle was completed in March 2008. CAMS are due to be revised every six years and will feed into the draft RBMPs.

Geological and Geomorphological Sites of Nature Conservation Interest

2.3.7 Important geological and / or geomorphological sites may be designated as SSSIs under the Wildlife and Countryside Act 1981, as amended by the Countryside and Rights of Way Act 2000 (CRoW). Under the latter legislation, relevant authorities, which are defined within CRoW, have a responsibility to "take reasonable steps to further the conservation and enhancement of …..geological or physiographical features by reason of which the site is a SSSI." Geological conservation is also included in Planning Policy Statement 9 (DCLG, 2005).

Soils

2.3.8 The Soil Strategy for England (Defra 2009a) sets out the Government's approach to safeguarding the soil resource and provides a framework for policy development to provide better protection and management of the soil resource over the next 20 years. It has four main themes: the sustainable use of agricultural soils; the role of soils in mitigating and adapting to climate change; protecting soil functions during construction; and preventing pollution and dealing with contamination. The Strategy supports the aims of the EU Thematic Strategy on Soil Protection but differs in approach to that outlined within the draft EU Soil Framework Directive.

Infrastructure

2.3.9 The infrastructure considered within this topic is either underground or those underground parts to above ground structures that could be influenced by water table rise. The most appropriate legislative context is therefore that related to groundwater flooding, which is covered in England by PPS25 (DCLG, 2006). The corresponding Welsh guidance is contained within TAN 15, which makes no specific mention of groundwater flooding (WAG, 2004).

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.

Water Resources

2.4.3 Water resources are separated between surface waters and groundwater (see paragraph 2.1.9).

Surface Waters

2.4.4 This topic concentrates on surface water quality upstream of marine influence. For those watercourses that are open to the Severn estuary, however (as opposed to closed, as a result of tidal flaps or impoundment), the extent of marine influence is not 'fixed' but varies with the state and height of the tide, as well as the flow conditions within the particular watercourse. As a result, there is an important interface between this topic paper and that on Marine Water Quality (MWQ) (STP, 2010d). The latter provides a detailed consideration of water quality within the Severn estuary and tidal tributaries, and the predictive modelling that has been undertaken to assess the changes that are likely to occur as a result of the alternative options under consideration. This topic paper summarises the results obtained from this modelling work within the tidal tributaries, and reference should be made to the MWQ topic paper for the details of the work undertaken.

2.4.5 This assessment has concentrated on assessing the effects to the following tributaries, principally because of the amount of data available to the modelling studies (STP, 2010d):

- The Ely River and River Taff, which are both impounded by the Cardiff Bay Barrage (CBB), which has a retained water level of 4.5m AOD;
- The River Usk;
- The River Wye;
- The influent River Severn;
- The River Avon; and
- The River Parrett.

2.4.6 The details of the flow regimes within the main watercourses are described within the Flood Risk and Land Drainage topic paper (STP, 2010b).

Baseline Environment (up to 2009)

2.4.7 The main tributaries to the Severn estuary are shown in Figure 1, which also shows the most downstream EA water quality monitoring stations upstream of the tidal limits and the most recent General Quality Assessment (GQA) classifications for which data are available (2008).

2.4.8 The GQA classifications for chemistry and biology are both graded from A (very good), to F (bad), with B indicative of good quality. Nitrates and phosphates are graded from 1 (very low) to 6 (very high for nitrates; excessively high for phosphates). It can be seen from the data summarised in Figure 1 that the lowermost reaches of the main tributaries of the Ely, Usk, Wye and Avon currently achieve the 'good' status for chemistry and biology required by the WFD, although there are some issues with nutrients in these and other tributaries.

Baseline During Construction (2014 – 2020)

2.4.9 It is assumed that regulation to align with the requirements of RBMPswill be effective in achieving the WFD objectives of 'good' ecological status and 'good' chemical status for surface waters by 2015. The current baseline will therefore be maintained or improved. The rise in mean sea level, of between 0.075 - 0.097m above baseline, predicted by UKCP09 during this period is assumed to have a negligible influence on available resources, in terms of quality.

Baseline During Operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.10 It has been assumed that subsequent cycles of the RBMPs and asset management plans (AMPs) for the water industry will be effective in maintaining WFD objectives in the early stages of operation. The expected effects of climate change, however, are anticipated to result in marked changes to the surface water regimes of the influent tributaries, including the River Severn.

2.4.11 Climate changes are anticipated to result in hotter mean annual temperatures, with wetter winters and drier summers, and higher rainfall intensity overall. By 2050, winter surface water flows are predicted to increase by between 10-15% above baseline but summer flows to decrease by over 50% and as much as 80% in places. It is estimated that these patterns could result in a reduction in total annual average river flow by up to 15% (EA, 2009a).

2.4.12 During this period mean sea level is predicted to rise from 0.097 – 0.63m above baseline (UKCP09a). With the predicted changes in river flow, described above, this will result in modifications to the freshwater-seawater transition in estuaries: a general seaward movement of the interface is anticipated in winter due to the slightly larger predicted winter flows, with a general and slightly greater movement inland in summer.

2.4.13 Higher mean temperatures will result in reduced dissolved oxygen concentrations, whilst lower summer flows will reduce the potential for dilution of effluents. Without regulation, nutrient concentrations can be expected to increase and turbidity to reduce, particularly in summer. The potential for the occurrence of algal blooms on inland surface waters will therefore become increasingly likely.

Groundwater

Baseline Environment (up to 2009)

2.4.14 The baseline groundwater environment of the coastal fringe of the Severn estuary was described in paragraphs 2.1.12 - 2.1.16. It mainly comprises low permeability surface soils and superficial drift geology, overlying low permeability bedrock. Water is present within these deposits and is important for maintaining soil moisture, however in most cases it can neither infiltrate easily from rainfall nor be readily extracted. As a consequence, the hydrology of the coastal fringe is dominated by surface flow processes.

2.4.15 The main exception to this is the presence of substantial blocks of Carboniferous Limestone, which is classified as a Principal (formerly Major) aquifer by the EA (EA undated). The Carboniferous Limestone stores and transmits large volumes of water, which mainly moves through fractures and solution-enhanced joints. Springs are a feature of this geology, often emerging on land at the boundary with adjacent, low permeability material. However, they are also known to emerge within the Severn estuary itself, at the elevation of historic sea levels associated with the last glaciation, which were much lower than at present (Whittaker *et al* 1983, Allen *et al* 1996). At a regional scale the water quality is assumed to be good, as it is often harnessed for the PWS.

2.4.16 The fluvio-glacial gravels that occur in the Cardiff area, the isolated deposits of River Terrace gravels and dune sands are also assumed to be hydraulically linked to the Severn estuary. These deposits can transmit water relatively easily, through porous (laminar) flow, but are only locally important in water resource terms because they do not cover large areas. As with the Carboniferous Limestone, however, water quality is assumed to be generally good.

2.4.17 Locally, however, groundwater quality has been impacted (by anthropogenic activities, particularly in urban areas (Figure 4). A total of 124 sites of contaminated land have been designated within the Study Area under the EPA, most of which are in Cardiff (see Figure 4 and Appendix B). An assumption made is that this only causes localised effects, being limited by the general low permeability of the ground.

Baseline During Construction (2014 – 2020)

2.4.18 It is assumed that implementation of the RBMPs will be effective in achieving the WFD objectives of 'good' ecological status and 'good' chemical status for 'water bodies' by 2015. The current baseline will therefore be maintained or improved. The rise in mean sea level, of between 0.01 - 0.02m above baseline, predicted by UKCP09 during this period is assumed to have a negligible influence on available resources, in terms of quantity or quality.

Baseline During Operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.19 Anticipated climate changes, with higher mean annual temperatures, wetter winters, drier summers, and higher rainfall intensity overall, will result in a gradual reduction in available groundwater resources as a result of reduced infiltration, with greater evapotranspiration generally and surface runoff in winter. This will be witnessed as lower baseflow contributions to summer river flows of over 50% and as much as 80% in places by 2050 (EA, 2009a). Without intervention, therefore, sustainable groundwater resources are expected to reduce appreciably during the operational period. In the Study Area, this will be witnessed as reduced water tables, water levels in watercourses and groundwater flux to the Severn estuary, particularly from subterranean springs emanating from the Carboniferous Limestone.

2.4.20 Over the same period mean sea level is predicted to rise from 0.02 to 0.26m above baseline (UKCP09a). With the predicted changes in groundwater flux, described above, this will result in higher water tables adjacent to the coast, together with modifications to the freshwater-seawater transition within the ground, resulting in a general movement of the saline interface inland. It is anticipated that this will be greatest within the more permeable strata, particularly the Carboniferous Limestone, dune sand deposits, and fluvio-glacial gravels and terrace deposits.

2.4.21 In contrast, the localised effects of historic contamination can be expected to reduce through natural attenuation and breakdown processes.

Abstractions

Baseline Environment (up to 2009)

2.4.22 There are a very large number of licensed abstractions within the Study Area, which were described in general terms in paragraphs 2.1.19 – 2.1.24 and shown on Figures 5-9.

Baseline During Construction (2014 – 2020)

2.4.23 The rise in mean sea level, of between 0.01 - 0.02m above baseline predicted by UKCP09 is assumed to have a negligible influence on water resources. Predicted climate changes, however, are likely to reduce available water resources, particularly in summer periods. Implementation of the water resources strategies for England and Wales is assumed to be effective in managing water resources efficiently. As a result, it is assumed that the current baseline, in terms of the number of abstractions, will be maintained, although the reliability of licensed abstractions may change as "hands-off" flow conditions are likely to be exceeded more frequently.

Baseline During Operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.24 Anticipated climate changes are likely to result in a gradual reduction in available water resources throughout the operational period, particularly in summer periods, with lower infiltration resulting in lower water tables, aquifer storage and river baseflows. The anticipated reductions in summer river flows, of between 50-80% of current baseline by 2050 (EA, 2009a) imply reductions in available surface and groundwater resources of a similar order. At the same time, population growth and demographic changes are likely to increase water demands from the PWS. As a result, it seems likely that successive RBMPs will take an increasingly stringent position favouring PWS sources over less important uses. It seems likely that new abstraction licences will become increasingly difficult to obtain and existing licences will become increasingly restricted in terms of abstraction volume and/or timing. Overall licensed volume from catchments will reduce throughout the operational phase and, ultimately, it seems likely that the most sensitive time-limited surface and groundwater abstractions will not be renewed.

Sites of Geological and Geomorphological Interest

Baseline Environment (up to 2009)

2.4.25 The locations of the geological and geomorphological SSSIs within 2km of the coast were summarised in paragraphs 2.1.27-2.1.29 inclusive and the locations shown in Figure 10, whilst Figures 12 and 13 show the locations of those closest in proximity to the alternative options under consideration in greater detail. At the time of writing (01/10), important details for many of these designations, particularly the importance of coastal geological exposures within the tidal range, in relation to the whole of the designation, remain unknown (see paragraph 2.3.7).

Baseline During Construction (2014 – 2020)

2.4.26 It is assumed that the sites for which formal designation was not complete at baseline, including Otter Hole, River Wye at Lancaut, Three Cliffs Bay and Oxwich Bay shall be completed by the start of construction.

2.4.27 The rise in mean sea level, of between 0.01 – 0.02m above baseline, predicted by UKCP09 during this period is assumed to have a negligible influence on accessibility to the important geological outcrops.

Baseline During Operation (2020 – 2140), Decommissioning and Longer Term Trends

2.4.28 Increases in MSL predicted by UKCP09 from between 0.02 to 0.26m above baseline will reduce access to the lowermost sections of coastal and foreshore exposures. The importance of such exposures to the different SSSI classifications is not known.

2.4.29 The changes in MSL can be expected to increase the rate of erosion of soft geological or geomorphological features within the tidal range on the coast and in tidal tributaries, as will predicted increases in rainfall intensity.

2.4.30 Erosion rates of important cliff faces are also likely to increase as a result of expected climate changes, however this could be regarded as positive if it improves visibility, particularly of important hard rock exposures.

Soils

Baseline environment (up to 2009)

2.4.31 The variation in soil type within the Study Area is shown on the Soil Map of England and Wales and described in the accompanying handbooks (SSGB, 1983). These show the soils within the low-lying land of the Severn Estuary and Inner Bristol Channel to comprise extensive deposits of the Newchurch and Wallasea Series, with subordinate areas of peat and other hydromorphic soils. These experience a seasonally high water table and can also develop a perched water table at between 20-30cm below ground when compacted (SBDP, 2009a,b).

Baseline during construction (2014 – 2020)

2.4.32 The mean sea level rise predicted by UKCP09 will produce changes in mean sea level of between 0.075– 0.097m over baseline, resulting in marginally increased coastal erosion and salinisation potential. It is assumed that the effects of the national soil strategies for England and Wales will be effective in maintaining the soil resource in the context of these and associated climatic changes. The current baseline will therefore be maintained.

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

2.4.33 Climate changes are anticipated to result in higher mean annual temperatures, wetter winters, drier summers and increased rainfall intensity overall. These changes will put increasing pressure on the soil resource, due to the increased potential for winter flooding and waterlogging. In low-lying areas, erosion, salinisation and reduced carbon content will all act to reduce fertility. Lower water tables and summer river flows, currently estimated by as much as 50-80% by 2050 (EA, 2009a), will result in reduced soil moisture and increased likelihood of reduced quality of peaty soils through aeration and desiccation (Defra, 2009a). Higher mean sea levels, currently estimated to rise from 0.1 to 0.63m above baseline will increase the likelihood of coastal and estuarial erosion, with the associated likelihood of salinisation of adjacent low-lying soils.

Infrastructure

Baseline environment (up to 2009)

2.4.34 The Severn railway tunnel is the largest subterranean feature in the Study Area and is located within bedrock strata. It is over 120 years old and reported to be in a deteriorating condition and very damp, due to the inflows from the Great Spring, alone reported to vary between 104-136 million litres per day (Ml/day) (Daniel, 2000). The provenance of tunnel seepage is complex and not perfectly understood (STP, 2008).

2.4.35 The road crossings were designed to a 120 year life and were constructed in the mid 1960s and 1990s. The first crossing has needed extensive maintenance since opening because of metal fatigue and increased traffic densities.

Baseline during construction (2014 – 2020)

2.4.36 An ambitious programme of house building is planned within current Government plans. It is assumed that this takes place in accordance with current guidance in PPS25 (DCLG, 2006) that advises that new build should not take place within floodplain. For the purposes of this assessment, therefore it has been assumed that the extent of subterranean infrastructure potentially affected by an alternative option will remain approximately as for the existing baseline.

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

2.4.37 The main assumption made through the operational period is that the baseline condition of infrastructure will degrade during this period. Further, whilst major infrastructure, such as bridges, tunnels etc, has a design life of 120 years, all other infrastructure has a typical design life of between 30-50 years. At some stage during operation, infrastructure will require replacement. The possible exception to this is the Second Road Crossing, which will not have reached the end of its design life until into the 22nd Century.

2.5 Key Environmental Issues and Problems

2.5.1 The most important environmental problems associated with this topic are those associated with anticipated climate changes over the operational life of a tidal power project. If the predictions are correct, significant changes will occur that will affect the availability and quality of water resources and the soil resource. Although linked, the comparative effects of predicted sea level rise on the current baseline environment over the same timeframe appear small. Regulatory mechanisms have been initiated by Government to manage these issues as they affect water resources and soils with what are, in effect, 5 year plans and reviews. For the purposes of this assessment it has been assumed these mechanisms will be successful.

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.

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

2.6.3 The values proposed for each receptor group were initially presented and discussed at the first Technical Workshop in June 2009 and, where necessary, revised. The values adopted upon are summarised below in Table 2.1, whilst the rationale behind these is summarised in Appendix A (STP, 2009c).

Table 2.1 Value of Receptors

Receptor Group	Assigned Value
Surface Waters	High
Groundwater	High
Water abstractions for the Public Water Supply	High
All other abstractions	Low
Geological Sites of Special Scientific Interest	High
Other designated sites of geological or geomorphological interest	Low
Soils	High
Infrastructure of national importance	High
Other infrastructure, ie of regional or local importance	Low

2.6.4 Appendix A also summarises the approach to the assignment of Vulnerability for each of these receptor groups. The Vulnerability assigned to these is summarised in Table 2.2.

Table 2.2 Vulnerability of Receptors

Receptor Group	Assigned Vulnerability
Surface Waters	High
Groundwater	High
Water abstractions for the Public Water Supply (PWS)	
Purton – BWW abstraction from Sharpness Canal	High
Other surface abstractions, eg on the Wye and Usk	Moderate
Clevedon PS (BWW) and Great Spring (DC)	Moderate
Other groundwater abstractions, eg WW sources	Low
All other abstractions	Low / High [1]
Geological Sites of Special Scientific Interest	Low / High [2]
Other designated sites of geological or geomorphological interest	Low / High [2]
Soils	High
Infrastructure of national importance	Low / High
Other infrastructure, ie of regional or local importance	Low / High [1]

[1] Dependent on type, use, location and other site-specific factors
[2] Dependent on type of exposure, location and other site-specific factors

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

General Considerations

3.2.2 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.

3.2.3 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.

3.2.4 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 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.

3.2.6 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.

3.2.7 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).

3.2.8 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.

3.2.9 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.

<u>Specific Considerations Relevant to this Topic</u>

3.2.10 Most of the assessment undertaken in this topic has been desk-based and semi-quantitative. It has been informed by the output from the predictive modelling studies undertaken as part of the Hydrodynamics and Gemorphology (H&G), Flood Risk and Land Drainage (FR&LD) and the Marine Water Quality (MWQ) topics (STP, 2010b,c,d), supported by simple scoping calculations, as well as professional experience and judgement. The principal modelling studies used were as follows:

- **H&G**: informed the assessment of water resources (both surface water and groundwater), water supplies, geological and geomorphological sites of nature conservation interest (SNCI);

- **FR&LD**: informed water resources and soils;

- **MWQ**: informed surface and groundwater quality, water supplies.

3.2.11 The water environment can be understood a system of related hydrological processes, where precipitation, surface flows and groundwater movement all interact with each other and the ground. The assessment was based upon a conceptual understanding of these inter-relationships within the Severn estuary and its coastal fringes. This conceptualisation can be considered as the superposition of sequential tiers of information, and may be simplified as follows:

- Synthesis of baseline physical information, such as topography, soils, geology and their variations, discussed in Section 2;
- Superposition of hydrological processes based on an understanding of the hydraulic properties of these materials and their regional constraints or controls (i.e. boundary conditions);
- On to this understanding were overlain the receptors identified in Section 2;
- Over this were placed the scheme alignments to assess for direct loss as a result of construction;
- Following this the results of the various modelling studies were superimposed to assess for different indirect effects, dependent on the type of receptor, and adjusted, as required; and
- Finally, the findings were reviewed and revised, as necessary, and uncertainties documented.

3.2.12 As an example, the results from the H&G modelling studies were reviewed as part of the assessment of effects on geological and geomorphological SSSIs (the effects to RIGS not being determined, as outlined in paragraph 2.1.31). These modelling results included changes to median water levels, peak wave heights, water velocities and sedimentation / erosion potential, etc each of which could affect the value of a designation. In many cases, however, the results could not be applied directly but needed to be considered in the context of other factors, such as, for example, the elevation of a particular outcrop and its material composition, e.g. whether it was hard or soft. This information was not always available (or not always available in a form that was useful) and therefore, whilst every effort was made to remove uncertainty, there remains an element of subjectivity in the assessment.

3.2.13 A potential indirect effect arising from the alternative options is the loss of GCR or SSSI features to meet the demand for aggregate for the construction of the option. The conclusion from the Supply Chain Study (DECC, 2010) indicates that there is sufficient capacity within existing licensed quarries. This assumed, such an effect would be associated with the rate of quarrying/depletion of the resource, but would not necessarily result in the loss of the exposure. It is acknowledged that further study would be needed to select the most appropriate sources of aggregates, both within the UK and potentially within Europe, in terms of transportation requirements, material characteristics and availability of permitted resources.

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.

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 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 landfall 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 an embankment approximately 16km long, proposed to run from landfalls at Brean Down in the north to just east of Hinkley 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 identified during Phase 1 Scoping were as follows:

- Altered freshwater quality;
- Altered freshwater groundwater regimes;
- Altered water quality affecting the Public Water Supply; and
- Changes to geological and geomorphological SSSIs.

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.

Alternative Option B3: Brean Down to Lavernock Point Barrage

3.5.2 The likely effects of this alternative option are summarised in Table 3.1.

Direct Effects

3.5.3 Direct effects will be limited to the potential permanent direct loss of geological outcrop at the southern end of Penarth Coast SSSI. Brean Down SSSI on the English side will not be affected (see Figure 12).

3.5.4 There will be no direct effects associated with the operational or decommissioning phases, all direct effects assumed to have occurred during construction.

Indirect Effects

3.5.5 Indirect effects will occur during the operational and decommissioning phases.

Operational Phase

Surface and Groundwater Resources

3.5.6 Impoundment will raise median sea levels by approximately 2.6m to between 2.8-2.9m AOD at Cardiff, Newport and Avonmouth. This will result in a permanently higher water table within the ground immediately behind the impoundment and higher water levels in surface watercourses and ditch systems. The amount of water table rise and surface water level increase will be greatest near the coast and become progressively less inland. These changes will result in altered hydraulic gradients within the ground, increased baseflows to the local drainage systems and correspondingly reduced groundwater flux to the Severn estuary (including submarine springs emerging from the Carboniferous Limestone). On a regional scale, the changes will be small because of the subtle changes to regional hydraulic gradients and the low permeability of the alluvial soils which border much of the estuary (Lloyd and Wilkinson, 1988). The lateral extent of these effects inland is difficult to predict as they will also be influenced by land drainage but they are likely to be limited to the floodplain landward of the impoundment.

3.5.7 Locally, however, particularly where the ground is more permeable, and adjacent to the coast landward of the impoundment, where changes to the hydraulic gradient will be greater, effects will be more marked. Higher piezometric pressures will be observed in the fluvio-glacial gravel aquifer beneath Cardiff, away from the influence of Cardiff Bay Barrage, and in the dune sand deposits adjacent to the coast In Weston-super-Mare. Rises may also be observed in the pockets of Terrace Deposits that border the estuary upstream of the road crossings, particularly on the Welsh side.

3.5.8 The higher sea level and increased mean salinity within the impoundment will result in increased salinity within porewater adjacent to the coast, particularly where higher permeability deposits are present. In general, however, the extent of saline intrusion will be limited because of the low permeability of the alluvial soils and by land drainage; and because the hydrology of the estuary is dominated by surface flow processes. The higher water table will increase the potential for leaching of contaminants, however the potential for local groundwater and surface water quality to be affected is low because of the general low permeability of the land bordering the coast.

3.5.9 The results from the water quality modelling indicate the following water quality implications on the main tributaries open to the Severn estuary:

- No changes to the natural variation of salinity in the Avon and Parrett and minor changes in the Usk, Wye and Severn. At the highest Spring tides and Q_{90} river flows the saline interface was observed to move seaward by about 2km in the River Usk, 2.6km in the River Severn, and about 0.6km upstream in the River Wye (ABPmer 2010);

- No effect from pathogens from the existing major coastal outfalls; and

- Probably no effect in terms of increased eutrophication potential, although this is complicated by the uncertainties associated with turbidity post construction, which is the main limiting factor on nutrient uptake.

3.5.10 The above effects will occur almost immediately following closure of the barrage and continue over its operational life.

Abstractions

3.5.11 Three PWS will be affected by this alternative option: the Bristol Water abstraction from the Sharpness Canal at Purton, and the Welsh Water groundwater sources at Caldicot, also known as the Great Spring as it takes water intercepted by the Severn Railway Tunnel, and Bristol Water's Clevedon source, which abstracts groundwater from the Carboniferous Limestone.

3.5.12 The Purton offtake will be slightly better protected from the effects of seawater inflow on Spring tides, especially during periods of low river flow in the River Severn. Both the Great Spring and the Clevedon sources will suffer a theoretical decline in yield, due to the marginal decrease in hydraulic gradient and greater potential for saline intrusion due to the higher sea levels and salinity adjacent to the coast. Historically there has been anecdotal evidence for saline influence within the Clevedon source, however consultation with the operators as part of this assessment suggests this is not currently an issue. As a consequence, the effects to PWS sources are judged not to be significant.

3.5.13 The effects on other licensed surface and groundwater abstractions will not be significant.

Geological and Gemorphological SSSIs

3.5.14 Access will be reduced upstream of the barrage to the lowermost geological exposures at 10 geological SSSIs (Purton Passage, Lidney Cliff, Otter Hole, Aust Cliff, Rhymney River Section, Portishead Pier to Black Nore, Penarth Coast, Flat Holm, Middle Hope and Brean Down). Access to the Otter Hole cave system will become permanently submerged due to the increase in lowest tide level from approximately -6m AOD to 0m AOD. A large proportion of outcrop on Flat Holm will become submerged. The relict river terraces within the River Wye (Lower Wye) SSSI will not be affected.

3.5.15 Access to coastal exposures will be slightly improved downstream of the barrage, with lower peak (Spring) tide levels of about 0.6m at Sully Island and Bridgwater Bay, gradually reducing to zero at Bridgend on the Welsh coast and Hele on the English coast.

3.5.16 Small increases in the peak tidal range of about 0.05m in Bury Inlet will increase the erosion potential of soft sediments. This is not thought to be significant to the SSSIs present in the Gower but will need to be reappraised should this alternative option proceed beyond SEA stage.

Soils

3.5.17 The increase in water table, combined with the surface drainage effects described in the FR&LD topic paper (STP, 2010b) will result in increased soil wetness over an area of approximately 360km^2. This is likely to lead to immediate degradation of soil quality (by waterlogging) particularly on the Caldicot and Gwent Levels (~90km^2) and parts of the northern Somerset Levels (~200km^2). In the longer term, however, increased soil wetness could be advantageous in reducing the impacts of climate change (paragraph 2.4.33).

Infrastructure

3.5.18 Leakage will increase into the Severn Railway Tunnel and National Grid cable tunnel. Effects to the Severn road crossings will not be significant.

3.5.19 Increased soil wetness due to a regionally higher water table and higher confining pressures in the fluvio-gravel aquifer beneath Cardiff (away from the effects of CBB) have the potential to impact subterranean infrastructure of local importance. The extent of the infrastructure potentially at risk is unknown but properties in parts of coastal Weston-super-Mare will be affected, whilst those in some low-lying parts of southern Cardiff, Newport and Caldicot, on the Welsh side, and Avonmouth, Portishead and Clevedon on the English side, could be affected.

Decommissioning Phase

3.5.20 Decommissioning will result in a reduction in the median sea level that occurred within the lagoon during the operational phase, however the existing baseline conditions will not be achieved due to the anticipated sea level rise of 0.63m. As a consequence, decommissioning will reduce the magnitude of the indirect effects identified above but will not remove them entirely.

Far-field Effects

3.5.21 Possible far-field effects have been identified with this alternative option, with potential increases in peak tidal levels over much of the W Wales coastline, up to a maximum of 0.2 to 0.25m in the north of Cardigan Bay and the Lleyn peninsula, with increases of less than 0.1m predicted on the north coast of Devon and Cornwall. In terms of this topic, this has possible implications for low lying soft coastal geological or geomorphological features in this area.

Cumulative Effects

3.5.22 Projects identified for implementation during the construction and operational phases, particularly those involving use of large amounts of concrete, such as the construction / decommissioning of power stations at Oldbury and Hinkley, will increase the demand on local water resources. This could result in new sources being developed, however, for the purposes of this assessment it is assumed that demand will be regulated through the EA's framework, which incorporates licensing through RBMPs.

Consequential Development Effects

3.5.23 Development of energy intensive industry adjacent to a tidal power scheme would have the potential to affect the geological and soil resource, particularly if it were placed in a coastal location.

3.5.24 No other consequential development effects relevant to this topic are envisaged.

Summary of Likely Significant Effects on the Environment

3.5.25 The likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases are:

- Loss of soil resource, due to increased soil wetness over an approximate area of up to 360 km^2;
- Loss of access to 10 sites designated for important geological features, including direct loss of the southernmost portion of Penarth Coast SSSI, loss of safe access to the Otter Hole cave system, and loss to access at 8 others; and
- Loss of local infrastructure through the effects of groundwater flooding, particularly in parts of Weston-super-Mare, although other low-lying urban areas could also be affected (see paragraph 3.5.18).

Assumptions, Limitations and Uncertainties

3.5.26 The assessment of effects for this alternative option relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP, 2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):

- The value of the lowermost geological exposures at the geological SSSIs that may be covered by the increased sea levels;
- The importance of the extent of subterranean infrastructure in the areas identified potentially at risk; and
- The land quality where the soil resource will be depleted, which does not affect the assessment of effects but has implications for economic analysis.

Table 3.1 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)
Surface Water value (H); vulnerability (H) (i) – flows										
Surface watercourses in designated floodplain upstream of impoundment	*Increased baseflow contribution to surface watercourses & ditches as a result of permanently raised groundwater levels*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*VL*	*Regional – Severn Estuary upstream of impoundment but probably limited laterally to 200 year floodplain*	*Negative (to land drainage) but could be positive in terms of water quality*	*Spatial extent of effect inland*	*N*
Severn Estuary	*Reduction in flows of freshwater springs emanating at or below MSL (mainly sourced from Carboniferous Limestone)*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Changes to operating gradients – small*	*N*
Surface Water value (H); vulnerability (H) (ii) water quality										
Surface watercourses in designated floodplain upstream of impoundment	*Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations*	*Indirect*	*Medium (only 1no. site in floodplain*	*Operation – M*	*Reversible Permanent*	*L*	*Regional – Severn Estuary upstream of impoundment*	*Negative*	*Number and severity of contaminated sites not on public registers*	*N*
River Severn	*Change in water quality as a result of movement of saline interface*	*Direct*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*N*
Cardiff Bay (River Taff and Ely River)	*Deterioration of water quality within Cardiff Bay as a result of saline intrusion caused by impoundment raising median water levels to 2.6mAOD*	*Indirect*	*VL (median water levels in Cardiff Bay 4.5m AOD)*	*Operation – L*	*Reversible Permanent*	*VL*	*Local*	*Negative*	*Degree of hydraulic linkage between gravel aquifer and Cardiff Bay and operating conditions of Cardiff Bay*	*N*
River Usk	*Change in water quality as a result of movement of saline interface (up to ~ 2km downstream)*	*Indirect*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*N*
River Wye	*Change in water quality as a result of movement of saline interface up to ~0.6km upstream*	*Indirect*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*As for WQ modelling*	*N*
Sharpness Canal	*Reduced potential of salinity effects at low river flow*	*Indirect*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*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)
Groundwater value (H); vulnerability (H)										
Fluvio-glacial gravel aquifer in / adjacent to Cardiff	*Increased piezometric pressure as a result of increased hydrostatic loading from impoundment*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*L*	*District*	*Positive*	*Extent of confined aquifer and effect*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High – away from influence of Cardiff Bay*	*Operation – L*	*Reversible Permanent*	*L*	*District*	*Negative*	*Extent of influence of Cardiff Bay*	*N?*
Dune sand deposits, particularly in / adjacent to Weston Super Mare	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*High – adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L - adjacent to coast*	*District – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by drainage and sewer systems*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L*	*District – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*N*
Estuarine alluvium upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*High – adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L - adjacent to coast*	*Regional – Severn estuary – probably limited to within floodplain*	*Positive (in terms of water resources)*	*As above*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L*	*Regional – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*As above*	*N*
River terrace deposits upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*L - immediately adjacent to coast*	*Local – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of outcrops in relation to changes in median water elevation*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*L*	*Local – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of outcrops in relation to changes in median water elevation*	*N*
Severn Estuary	*Reduction in groundwater flux into as a result of increased MSL*	*Indirect*	*H*	*Operation - L*	*Reversible Permanent*	*L -*	*Regional*	*Negative*	*Changes to operating gradients – small*	*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)
Water abstractions for Public Water Supply value (H)										
Purton offtake from Sharpness Canal vulnerability (H)	*Reduced potential for saline influence at low river flows in Severn*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL*	*Local*	*Positive*	*Gain ultimately removed by sea level rise*	*N*
Caldicot source (Great Spring) vulnerability (M)	*Reduced groundwater flows. Reduced quality as a result of increased potential for saline influence in tunnel drainage*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*VL*	*Local*	*Negative*	*Hydraulic mechanism for course and changes to driving head*	*N*
Clevedon PS Vulnerability (M)	*Reduction in groundwater quality as a result of saline intrusion caused by high median water levels in Severn estuary*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Depends on hydraulic linkage between source and sea and operating rules*	*N*
Other Licensed Abstractions value (L)										
Groundwater abstractions adjacent to coastal fringe vulnerability (H-L)	*Changes to water quality (as a result of increased saline intrusion) and/or quantity (as a result of altered hydraulic gradients)*	*Indirect*	*Low / Medium*	*Operation - L*	*Reversible Permanent*	*VL, L*	*Local*	*Water quality – Negative* *Yield – Positive / Negative*	*Moderate – because of no. of variables involved*	*N*
Geological and Geomorphological SSSIs value (H), vulnerability (H)										
Tidal River Severn (Purton Passage, Lydney Cliff, Aust Cliff, River Wye at Lancaut (Lower Wye), Otter Hole)	*Increase in low minimum low water form -5m AOD to -1 mAOD will prevent safe access to and egress from Otter Hole cave system*	*Indirect (secondary)*	*High*	*Operation – L*	*Reversible Permanent*	*H*	*Local*	*Negative*	*High level of certainty regarding increase in water levels and elevations of cave sump.*	*Y*
	Increase in low minimum low water form -5m AOD to -1 mAOD will prevent access to lower exposures at Purton Passage, Aust Cliff. River Wye (Lower Wye)unaffected	*Indirect (secondary)*	*High*	*Operation – L*	*Reversible Permanent*	*Unknown*	*Local*	*Negative*	*High level of certainty regarding increase in water levels; uncertainty over quality of geological exposure becoming inaccessible*	*Unknown* *River Wye - N*
Inner Severn (Aust Cliff)	*Reduced accessibility to lowest exposures caused by*	*Indirect (secondary)*	*High*	*Operation - L*	*Reversible Permanent*	*Unknown*	*Local*	*Negative*	*High level of certainty*	*Unknown – possibly 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)
	increase in median sea level from 0.26m AOD to 2.90m AOD. Lowest elevation reduced from c. -6m AOD to c.-1m AOD.								*regarding increase in water levels; uncertainty over quality of geological exposure becoming inaccessible*	
Mid Severn (Avon Gorge, Portishead Pier to Black Nore)	*Reduced accessibility to exposures on Portishead coast caused by increase in median sea level from 0.26m AOD to 2.90m AOD. Lowest elevation reduced from c. -6m AOD to c.-1m AOD. Avon Gorge outcrop unaffected*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*H*	*Local*	*Negative*	*Uncertainty over magnitude of effect on Aust Cliff*	*Y*
Outer Severn (Welsh) Penarth Coast, Flat Holm, Rhymney River Section	*Reduced accessibility caused by increase in median sea level from 0.2m AOD to 2.83m AOD. Lowest elevation reduced from approx. -5 to -6m AOD to between -1 to -2m AOD*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*H – Flat Holm* *M – Rhymney River Section* *M – Penarth Coast*	*Local*	*Negative*	*As above*	*Y – Flat Holm;* *Possibly N - Rhymney River Section*
	Southern portion of Penarth Coast SSSI covered by construction	*Direct –covered by construction*	*High*	*Construction - L Decommissioning – L*	*Irreversible Permanent*	*H*	*Local*	*Negative*	*High level of certainty*	*Y*
Outer Severn (English) – Brean Down, Middle Hope	*Reduced accessibility caused by increase in median sea level from 0.2m AOD to 2.83m AOD. Lowest elevation reduced from approx. -5 to -6m AOD to between -1 to -2m AOD*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*Unknown – possibly L*	*Local*	*Negative*	*Uncertainty over quality of geological exposure becoming inaccessible*	*Unknown*
Bristol Channel (Welsh) – Sully Island to Swansea Bay	*Greater accessibility (and marginally less erosion) caused by reduction in peak Spring water level of 0.6m at Sully Island to ~0.1m at Pant-y-Slade*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As above*	*N*
	Reduced erosion caused by lower peak tidal range and lower peak water velocities	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As above*	*N*
Bristol Channel (Welsh) Swansea Bay to Carmarthen Bay	*Potential increase in erosion potential of low lying soft sediments caused by predicted increase in peak Spring tide water level of 0.05-0.1m.in Bury Inlet and in western Carmarthen Bay.*	*Indirect – Far Field*	*Unknown?*	*Operation – L*	*Reversible Permanent*		*Local*	*Positive / Negative*	*Uncertainty over whether increase in peak tide level may be positive or negative*	*Unknown*

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)
	*May affect saltmarsh geomorphology in Bury Inlet and but may also be slightly beneficial. Considered in *** topic paper. Remainder of Gower unaffected.*									
Bristol Channel (Welsh) West of Carmarthen Bay to Lleyn Peninsula	*Potential increase in erosion potential of low-lying soft sediments caused by increase in predicted peak Spring tide water levels of between 0.05m at Carmarthen Bay increasing to between 0.3-0.4m at Lleyn peninsula*	*Indirect – Far Field*	*Unknown?*	*Operation – L*	*Reversible Permanent*		*Local*	*Negative*	*Receptors not identified outside study area. High level of uncertainty associated with predicted 'far field' effects*	*Unknown*
Bristol Channel (N Somerset & Devon coast to Barnstaple)	*Greater accessibility (and marginally less erosion) caused by reduction in peak water level of 0.6m at Bridgwater Bay to ~0.1m at Hele.*	*Indirect – Far Field*	*Unknown?*	*Operation – L*	*Reversible Permanent*		*Local*	*Positive*		*Unknown*
Bristol Channel (S of Barnstaple	*Potential increase in erosion potential of low lying soft sediments caused by increase in predicted peak water level on Spring tides of 0.05-0.1m.*	*Indirect – Far Field*	*Unknown*	*Operation – L*	*Reversible Permanent*		*Local*	*Negative*	*Receptors not identified outside study area. High level of uncertainty associated with predicted 'far field' effects*	*Unknown*
Soils value (H), vulnerability (H)										
Tidal River Severn upstream of original road crossing (both sides)	*Degradation of soil quality as a result of waterlogging*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Increased soil wetness over ~ 73km^2, most on English side where floodplain wider*	*District – likely to be limited to floodplain*	*Negative*	*Area over which soil degradation likely – more complex than assessing inundation as v. sensitive to variation in topography and drainage*	*Unknown*
Welsh Side downstream of original road crossing	*As above*	*Indirect - result of raised water table*	*High over large proportion of Gwent Levels*	*Operation – L*	*Reversible Permanent*	*Increased soil wetness over ~ 90km^2,*	*Regional – likely to be limited to floodplain*	*Negative*	*As above*	*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)
English Side downstream of original road crossing	*As above*	*Indirect - result of raised water table*	*Unknown – could be High*	*Operation – L*	*Reversible Permanent*	*Increased soil wetness over ~ 200km², *	*Regional – likely to be limited to floodplain*	*Negative*	*As above*	*Probably Y*
Infrastructure of national importance value (H)										
Severn Railway Tunnel vulnerability (H)	*Increased rate of deterioration caused by increase in flow into the tunnel due to increase in mean tidal level of about 2.1m*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*Unknown but likely to be Low because tunnel already in deteriorating condition*	*Local*	*Negative*	*Magnitude of increased inflow due to uncertainty in current flow mechanisms*	*N*
Severn Road bridges Vulnerability (L)	*Increased stability due to reduction in peak bed shear stress*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*Low*	*Local*	*Positive*	*As for H&G modelling*	*N*
National Grid Cable Tunnel	*Increased rate of deterioration caused by increase in flow into the tunnel due to increase in mean tidal level of about 2.1m*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*Unknown but likely to be Low*	*Local*	*Negative*	*Magnitude of current seepage*	*N*
Other infrastructure Value (L)										
Tidal River Severn and Inner Severn (Welsh)	*Increased dampness in basements and flows in sewers in low lying areas (? Parts of Caldicot)*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – possibly VL because of narrow width of floodplain and geology (Terrace Deposits)*	*Local / District – likely to be limited to floodplain*	*Negative*	*Number and locations of receptors at potential risk; ground conditions; 'headspace' in and effectiveness of existing drains*	*Unknown*
Tidal River Severn and Inner Severn (English)	*Increased dampness in basements and flows in sewers in low – lying areas*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – but may be > VL because of greater width of floodplain and ground conditions (alluvium), although little urbanisation*	*As above*	*Negative*	*As above*	*Unknown – potentially Y*
Mid Severn (Welsh)	*Increased dampness in basements and flows in sewers in low – lying southern parts of Newport as a result of raised water table*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – but may be > L because of local drainage conditions*	*As above*	*Negative*	*As above*	*Unknown – potentially Y*
Mid Severn (English)	*Increased dampness in basements and flows in sewers in low – lying parts of Portishead and Avonmouth*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – but likely to be > VL because of local drainage*	*As above*	*Negative*	*As above*	*Unknown – potentially 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)
						conditions				
Outer Severn (Welsh)	*Increased dampness in basements and flows in sewers in parts of Cardiff*	*Indirect – cumulative - result of higher piezometric pressures in parts of gravel aquifer in addition to that cased by CBB*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown (potentially VL if existing infrastructure effective in draining substrata)*	*As above but may extend outside floodplain*	*Negative*	*As above*	*Unknown*
Outer Severn (English)	*Increased dampness in basements and flows in sewers in low – lying parts of Weston- Super-Mare and Clevedon*	*Indirect - result of raised water table*	*Medium – some basements known to suffer during existing Spring tides*	*Operation – L*	*Reversible Permanent*	*Unknown – but likely to be > M because of known geology and effects at current Spring tides at W-S-M*	*Regional – likely to be limited to existing floodplain*	*Negative*	*As above*	*Y*

Alternative Option B4: Shoots Barrage

3.5.27 The likely effects of this alternative option are summarised in Table 3.2.

Direct Effects

3.5.28 There will be no direct effects associated with the construction, operation or decommissioning phases.

Indirect Effects

3.5.29 Indirect effects will occur during the operational and decommissioning phases.

Operational Phase

Surface and Groundwater Resources

3.5.30 Impoundment will raise median sea levels by approximately 2.5m to 3.6m AOD at Sharpness. This will result in a permanently higher water table within the ground immediately behind the impoundment and higher water levels in surface watercourses and ditch systems. The amount of water table rise and surface water level increase will be greatest near the coast and become progressively less inland. These changes will result in altered hydraulic gradients within the ground, increased baseflows to the local drainage system and reduced groundwater flux to the Severn estuary. Such changes will be small because of the low general permeability of the alluvial soils, particularly on the southern side (Lloyd and Wilkinson, 1988). The lateral extent of these effects inland is difficult to predict as they will also be influenced by land drainage but they are likely to be limited to the floodplain landward of the impoundment.

3.5.31 The higher sea level and increased mean salinity within the impoundment will result in increased salinity within porewater adjacent to the coast, particularly where higher permeability River Terrace deposits are present. In general, however, the extent of saline intrusion will be limited because of the low permeability of the alluvial soils and by land drainage; the hydrology being dominated by surface flow processes. The higher water table will increase the potential for leaching of contaminants, however the potential for local groundwater and surface water quality to be affected is very low because of the 'greenfield' nature of the land inland of the impoundment.

3.5.32 The results from the water quality modelling indicate the following water quality implications on the main tributaries open to the Severn estuary:

- No changes to the natural variation of salinity in the Usk, Avon and Parrett and minor changes in the Wye and Severn. At the highest Spring tides and Q_{90} river flows the saline interface was observed to move seaward by about 1km in the River Severn and about 1km upstream in the River Wye (ABPmer 2010);

- No effect from pathogens from the existing major coastal outfalls; and

3.5.33 Probably no effect in terms of increased eutrophication potential, although this is complicated by the uncertainties associated with turbidity post construction, which is the main limiting factor on nutrient uptake.

3.5.34 The above effects will occur almost immediately following closure of the lagoon and continue over the operational life.

Abstractions

3.5.35 Two PWS will be affected by this alternative option: the Bristol Water abstraction from the Sharpness Canal at Purton, and the Welsh Water groundwater sources at Caldicot, also known as the Great Spring.

3.5.36 The Purton offtake will be slightly better protected from the effects seawater inflow on Spring tides, especially during periods of low river flow in the River Severn, whilst the Great Spring sources will suffer a theoretical decline in yield, due to the marginal decrease in hydraulic gradient.

3.5.37 The effects on other licensed surface and groundwater abstractions will not be significant.

Geological and Gemorphological SNCIs

3.5.38 Access may be reduced to the lowermost geological exposures at Purton Passage, Lidney Cliff, Otter Hole and Aust Cliff SSSIs. Access to the Otter Hole cave system would become permanently submerged due to the increase in lowest tide level from about -6m AOD to 0m AOD. The relict river terraces within the River Wye at Lancaut GCR site (within the Lower Wye SSSI) will not be affected.

Soils

3.5.39 The increase in water table, combined with the surface drainage effects described in the FR&LD topic paper (STP, 2010b) will result in increased soil wetness over an area of approximately $90km^2$, greatest on the eastern side. This would cause degradation of soil quality.

Infrastructure

3.5.40 Leakage will increase into the Severn Railway Tunnel and National Grid cable tunnel. Effects to the Severn road crossings will not be significant.

3.5.41 Increased soil wetness due to a regionally higher water table has the potential to impact subterranean infrastructure of local importance. The extent of the infrastructure potentially at risk is unknown but is likely to be limited because of the absence of urban development in the floodplain upstream of the impoundment, with the exception of the lower-lying parts of Caldicot.

Decommissioning Phase

3.5.42 Decommissioning will result in a reduction in the median sea level that occurred within the lagoon during the operational phase, however the existing baseline conditions will not be achieved due to the anticipated sea level rise of 0.63m. As a consequence, decommissioning will reduce the magnitude of the indirect effects identified above but will not remove them entirely.

Far-field Effects

3.5.43 These effects are not considered significant at this stage, because they are localised and less than +/- 0.1m, however this may need to be confirmed by further modelling at project stage if this option were to be pursued.

Cumulative Effects

3.5.44 Projects identified for implementation during the construction and operational phases, particularly those involving use of large amounts of concrete, such as the construction / decommissioning of power stations at Oldbury and Hinkley, will increase the demand on local water resources. This could result in new sources being developed, however, for the purposes of this assessment it is assumed that demand will be regulated through the EA's framework, which incorporates licensing through RBMPs.

Consequential Development Effects

3.5.45 Development of energy intensive industry adjacent to a tidal power scheme would have the potential to impact the geological resource, particularly if it were placed in a coastal location.

Summary of Likely Significant Effects on the Environment

3.5.46 The likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases are:

- Loss of soil resource, due to increased soil wetness over an area of approximately 90 km^2 as a result of flooding; and
- Loss of access to one geological SSSI (Otter Hole) and partial access to four others.

Assumptions, Limitations and Uncertainties

3.5.47 The assessment of effects for this alternative option relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):

- The value of the lowermost geological exposures at the geological SSSIs that may be covered by the increased sea levels;
- The importance of the extent of subterranean infrastructure in the areas identified potentially at risk; and
- The land quality where the soil resource will be depleted, which does not affect the assessment of effects but has implications for economic analysis.

Table 3.2 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)
Surface Water value (H); vulnerability (H) (i) - flows										
Surface watercourses in designated floodplain upstream of impoundment	*Increased baseflow contribution to surface watercourses & ditches as a result of permanently raised groundwater levels*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL*	*Regional – Severn estuary*	*Negative (to land drainage) but could be positive in terms of water quality*	*Spatial extent of effect inland*	*N*
Severn Estuary	*Reduction in flows of freshwater springs emanating at or below MSL (mainly sourced from Carboniferous Limestone)*	*Indirect*	*H*	*Operation - L*	*Reversible Permanent*	*VL*	*Local*	*Negative*	*Changes to operating gradients – small*	*N*
Surface Water value (H); vulnerability (H) (ii) water quality										
Surface watercourses in designated floodplain upstream of impoundment	*Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations*	*Indirect*	*VL (no Special Sites in floodplain) and low industrial activity*	*Operation – L*	*Reversible Permanent*	*L*	*Regional – Severn estuary*	*Negative*	*Number and severity of contaminated sites not on public registers*	*N*
River Severn	*Change in water quality as a result of movement of saline interface up to ~1km downstream*	*Direct*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*N*
River Wye	*Change in water quality as a result of movement of saline interface up to ~1km upstream*	*Direct*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*As for WQ modelling*	*N*
Sharpness Canal	*Reduced potential of salinity effects at low river flow*	*Indirect*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*N*
Groundwater value (H); vulnerability (H)										
Estuarine alluvium upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~*	*Indirect*	*High – adjacent to coast*	*Operation - L*	*Reversible Permanent*	*L - adjacent to coast*	*Regional – Severn estuary but probably limited to within*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by surface water*	*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)
	2.6m AOD)						*floodplain*		*drainage and sewer systems*	
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation - L*	*Reversible Permanent*	*L*	*Regional – Severn estuary – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*N*
River terrace deposits upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*L - adjacent to coast*	*Local – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of outcrops in relation to changes in median water elevation*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*L*	*Local – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of outcrops in relation to changes in median water elevation*	*N*
Severn Estuary	*Reduction in groundwater flux into as a result of increased MSL*	*Indirect*	*H*	*Operation - L*	*Reversible Permanent*	*VL -*	*Regional*	*Negative*	*Changes to operating gradients – small*	*N*
Water abstractions for Public Water Supply value (H)										
Purton offtake from Sharpness Canal vulnerability (H)	*Reduced potential for saline influence at low river flows in Severn*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*VL*	*Local*	*Positive*	*Gain ultimately removed by sea level rise*	*N*
Caldicot source (Great Spring) vulnerability (M)	*Reduced groundwater flows and quality from saline infuence*	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*VL*	*Local*	*Negative*	*Hydraulic mechanism for course and changes to driving head*	*N*
Other Licensed Abstractions value (L)										
Groundwater abstractions adjacent to coastal fringe vulnerability (H-L)	*Changes to water quality (as a result of increased saline intrusion) and/or quantity (as a result of altered hydraulic gradients)*	*Indirect*	*Low / Medium*	*Operation - L*	*Reversible Permanent*	*VL, L*	*Local*	*Water quality – Negative* *Yield – Positive / Negative*	*Moderate because of number of variables involved.*	*N*
Geological and Geomorphological SSSIs value (H), vulnerability (H)										
Tidal River Severn (Purton Passage,	*Reduced accessibility to*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*H*	*Local*	*Negative*	*High level of certainty*	*Y – Otter Hole* *N – River Wye at*

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)
Lydney Cliff, Aust Cliff, River Wye at Lancaut (Lower Wye), Otter Hole)	*lowermost exposures caused by increase in lowest sea level from -5 to -6m AOD to ~-1m AOD. Submergence of access to Otter Hole.*								*regarding increase in water levels; uncertainty over quality of geological exposure becoming inaccessible*	*Lancaut (Lower Wye)*
Inner Severn (Aust Cliff)	*Reduced accessibility – as above*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*Unkown*	*Local*	*Negative*	*As above*	*Unknown*
Soils value (H), vulnerability (H)										
Tidal River Severn and Inner Severn upstream of original road crossing (both sides)	*Degradation of soil quality as a result of flooding and waterlogging*	*Indirect - result of raised water table*	*Unknown*	*Operation - L*	*Reversible Permanent*	*Increased soil wetness over ~ 73km^2, most on English side where floodplain wider*	*District – likely to be limited to floodplain*	*Negative*	*Area over which soil degradation likely – more complex than assessing inundation as v. sensitive to variation in topography and drainage*	*Likely Y*
Infrastructure of national importance value (H)										
Severn Railway Tunnel vulnerability (H)	*Increased rate of deterioration caused by increase in flow into the tunnel due to increase in mean tidal level of about 2.1m*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*Unknown but likely to be Low because tunnel already in deteriorating condition*	*Local*	*Negative*	*Magnitude of increased inflow due to uncertainty in current flow mechanisms*	*N*
Severn Road bridges Vulnerability (L)	*Increased stability due to reduction in peak bed shear stress*	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*Low*	*Local*	*Positive*	*As for H&G modelling*	*N*
National Grid cable tunnel (H)	*Increased flow into the tunnel due to increase in mean tidal level of about 2.1m*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*Unknown but likely to be Low*	*Local*	*Negative*	*Magnitude of increased inflow*	*N*
Other infrastructure Value (L)										
Tidal River Severn and Inner Severn (Welsh)	*Increased dampness in basements and*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – possibly VL because of*	*Local – likely to be limited to floodplain*	*Negative*	*Number and locations of receptors at*	*Unknown*

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)
	flows in sewers in low lying areas (? parts of Caldicot)					*narrow width of floodplain and geology (Terrace Deposits)*			*potential risk; ground conditions; 'headspace' in and effectiveness of existing drains*	
Tidal River Severn and Inner Severn (English)	*Increased dampness in basements and flows in sewers in low – lying areas*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – but may be > VL because of greater width of floodplain and ground conditions (alluvium), although little urbanisation*	*As above*	*Negative*	*As above*	*Unknown – probably N*

Alternative Option B5: Beachley Barrage

3.5.48 The likely effects of this alternative option are summarised in Table 3.3.

Direct Effects

3.5.49 Direct effects will be limited to the potential permanent direct loss of geological outcrop on the lowermost exposures at Aust Cliff geological SSSI, should the barrage construction or its access roads impinge on its footprint (see Figure 13).

3.5.50 There will be no direct effects associated with the operational or decommissioning phases, all direct effects assumed to have occurred during construction.

Indirect Effects

3.5.51 Indirect effects will occur during the operational and decommissioning phases.

Operational Phase

Surface and Groundwater Resources

3.5.52 Impoundment will raise median sea levels by approximately 2.25m to 3.15m AOD at Sharpness. This will result in a permanently higher water table within the ground immediately behind the impoundment and higher water levels in surface watercourses and ditch systems. The amount of water table rise and surface water level increase will be greatest near the coast and become progressively less inland. These changes will result in altered hydraulic gradients within the ground, increased baseflows to the local drainage system and reduced groundwater flux to the Severn estuary. Such changes will be small because of the low general permeability of the alluvial soils, particularly on the southern side (Lloyd and Wilkinson, 1988). The lateral extent of these effects inland is difficult to predict as they will also be influenced by land drainage but they are likely to be limited to the floodplain landward of the impoundment.

3.5.53 The higher sea level and increased mean salinity within the impoundment will result in increased salinity within porewater adjacent to the coast, particularly where higher permeability River Terrace deposits are present. In general, however, the extent of saline intrusion will be limited because of the low permeability of the alluvial soils and by land drainage; the hydrology being dominated by surface flow processes. The higher water table will increase the potential for leaching of contaminants, however the potential for local groundwater and surface water quality to be affected is very low because of the 'greenfield' nature of the land inland of the impoundment.

3.5.54 The results from the water quality modelling indicate the following water quality implications on the main tributaries open to the Severn estuary:

- No changes to the natural variation of salinity in the main sub-tributaries, however at the highest Spring tides and Q_{90} river flows the saline interface within the River Severn was observed to move seaward by about 3.2km (ABPmer 2010);
- No effect from pathogens from the existing major coastal outfalls; and

3.5.55 Probably no effect in terms of increased eutrophication potential, although this is complicated by the uncertainties associated with turbidity post construction, which is the main limiting factor on nutrient uptake.

3.5.56 The above effects will occur almost immediately following closure of the lagoon and continue over the operational life.

Abstractions

3.5.57 The only PWS affected by this alternative option is the Bristol Water abstraction from the Sharpness Canal at Purton, which will be slightly better protected from the effects seawater inflow on Spring tides, especially during periods of low river flow (in the River Severn).

3.5.58 The effects on other licensed surface and groundwater abstractions will not be significant.

Geological and Gemorphological SSSIs

3.5.59 Access may be reduced to the lowermost geological exposures at Purton Passage, Lidney Cliff and Aust Cliff SSSIs.

Soils

3.5.60 The increase in water table, combined with the surface drainage effects described in the FR&LD topic paper (STP 2010b) will result in increased soil wetness and degradation of soil quality over an area of approximately 73km^2, greatest on the eastern side.

Infrastructure

3.5.61 These effects also have the potential to impact subterranean infrastructure of local importance. The extent of the infrastructure potentially at risk is unknown but is likely to be limited because of the absence of urban development in the floodplain upstream of the impoundment.

Decommissioning Phase

3.5.62 Decommissioning will result in a reduction in the median sea level that occurred within the lagoon during the operational phase, however the existing baseline conditions will not be achieved due to the anticipated sea level rise of 0.63m. As a consequence, decommissioning will reduce the magnitude of the indirect effects identified above but will not remove them entirely.

Far-field Effects

3.5.63 Far-field effects are not considered significant at this stage as they appear to be much less than +/- 0.1m, however this may need to be confirmed by further modelling at project stage if this option were to be pursued.

Cumulative Effects

3.5.64 Projects identified for implementation during the construction and operational phases, particularly those involving use of large amounts of concrete, such as the construction

/ decommissioning of power stations at Oldbury and Hinkley, will increase the demand on local water resources. This could result in new sources being developed, however, for the purposes of this assessment it is assumed that demand will be regulated through the EA's framework, which incorporates licensing through RBMPs.

Consequential Development Effects

3.5.65 Development of energy intensive industry adjacent to a tidal power scheme would have the potential to impact the geological resource, particularly if it were placed in a coastal location.

Summary of Likely Significant Effects on the Environment

3.5.66 The likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases are:

- The potential for direct loss of part of Aust Cliff SSSI and reduced access at two others (Purton Passage and Lidney Cliff); and
- Loss of soil resource, over an area of approximately $73km^2$.

Assumptions, Limitations and Uncertainties

3.5.67 The assessment of effects for this alternative option relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP 2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):

- The extent of subterranean infrastructure in the areas identified potentially at risk;
- The value of the lowermost geological exposures at the geological SSSIs that may be covered by the increased sea levels;
- The land quality where the soil resource will be depleted, which does not affect the assessment of effects but has implications for economic analysis.

Table 3.3 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)
Surface Water value (H); vulnerability (H) (i) - flows										
Surface watercourses in designated floodplain upstream of impoundment	*Increased baseflow contribution to surface watercourses & ditches as a result of permanently raised groundwater levels*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL*	*Regional – Severn estuary*	*Negative (to land drainage) but could be positive in terms of water quality*	*Spatial extent of effect inand*	*N*
Severn Estuary	*Reduction in groundwater flux as a result of increased MSL*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Changes to operating gradients – small*	*N*
Surface Water value (H); vulnerability (H) (ii) water quality										
Surface watercourses in designated floodplain upstream of impoundment	*Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations*	*Indirect*	*L*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Number and severity of contaminated sites not on public registers*	*N*
River Severn	*Change in water quality as a result of movement of saline interface up to ~3.2km downstream*	*Direct*	*High*	*Operation –L*	*Reversible Permanent*	*L*	*Local*	*Positive*	*As for WQ modelling*	*N*
Sharpness Canal	*Reduced potential of salinity effects at low river flow*	*Indirect*	*High*	*Operation –L*	*Reversible Permanent*	*VL*	*Local*	*Positive*	*As for WQ modelling*	*N*
Groundwater value (H); vulnerability (H)										
Estuarine alluvium upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*High – adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L - adjacent to coast*	*Local – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation - L*	*Reversible Permanent*	*L*	*Local – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*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)
	Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations	*Indirect*	*L*	*Operation – L*	*Reversible Permanent*	*L or VL (mainly greenfield)*	*Local*	*Negative*	*As above plus no. and severity of contaminated sites not on public registers*	*N*
River terrace deposits upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*High adjacent to coast*	*Local – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of outcrops in relation to changes in median water elevation*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*L*	*Local – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*As above*	*N*
	Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations	*Indirect*	*L*	*Operation – L*	*Reversible Permanent*	*L or VL (mainly greenfield)*	*Local*	*Negative*	*As above plus no. and severity of contaminated sites not on public registers*	*N*
Severn Estuary	*Reduction in groundwater flux into as a result of increased MSL*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*L -*	*Regional*	*Negative*	*Changes to operating gradients – small*	*N*
Water abstractions for Public Water Supply value (H)										
Purton offtake from Sharpness Canal vulnerability (H)	*Reduced potential for saline influence at low river flows in Severn*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL*	*Local*	*Positive*	*Gain ultimately removed by sea level rise*	*N*
Other Licensed Abstractions value (L)										
Groundwater abstractions adjacent to coastal fringe vulnerability (H-L)	*Changes to water quality (as a result of increased saline intrusion) and/or quantity (as a result of altered hydraulic gradients)*	*Indirect*	*Low / Medium*	*Operation - L*	*Reversible Permanent*	*VL, L*	*Local*	*Water quality – Negative* *Yield – Positive / Negative*	*Moderate because of number of variables involved.*	*N*
Geological and Geomorphological SSSIs value (H), vulnerability (H)										
Tidal River Severn (Purton Passage, Lydney Cliff, Aust Cliff)	*Increase in lowest water level from ~-6m AOD to -1m AOD will reduce accessibility to lower*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*Unknown*	*Local*	*Negative*	*High level of certainty regarding increase in water levels;*	*Unknown*

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)
	exposures.								*uncertainty over quality of geological exposure becoming inaccessible*	
	Direct loss of part of Aust Cliff as a result of construction	*Direct*	*High*	*Construction*	*Reversible Permanent*	*H*	*Local*	*Negative*	*Value of exposure in vicinity of construction access*	*Possibly Y*
Soils value (H), vulnerability (H)										
Tidal River Severn upstream of original road crossing (both sides)	*Degradation of soil quality as a result of waterlogging*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Increased soil wetness over ~ 73km^2, most on English side where floodplain wider*	*Local – likely to be limited to floodplain*	*Negative*	*Area over which soil degradation likely – more complex than assessing inundation as v. sensitive to variation in topography and drainage*	*Y*
Other infrastructure Value (L)										
Tidal River Severn (Welsh)	*Increased dampness in basements and flows in sewers in low lying areas)*	*Indirect - result of raised water table*	*Un known*	*Operation – L*	*Reversible Permanent*	*Unknown – possibly VL because of narrow width of floodplain and geology (Terrace Deposits)*	*Local – likely to be limited to floodplain*	*Negative*	*Number and locations of receptors at potential risk; ground conditions; 'headspace' in and effectiveness of existing drains*	*N*
Tidal River Severn (English)	*Increased dampness in basements and flows in sewers in low – lying areas*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – probably VL because of little urbanisation*	*As above*	*Negative*	*As above*	*Unknown – Probably N*

Alternative Option L2: Welsh Grounds Lagoon

3.5.68 The likely effects of this alternative option are summarised in Table 3.4.

Direct Effects

3.5.69 There will be no direct effects associated with the construction, operation or decommissioning phases, all direct effects assumed to have occurred during construction.

Indirect Effects

3.5.70 Indirect effects will occur during the operational and decommissioning phases.

Operational Phase

Surface and Groundwater Resources

3.5.71 Impoundment will raise median sea levels to approximately 3.3m AOD within the lagoon. This will result in a permanently higher water table within the alluvial soils immediately behind the impoundment, higher water levels in surface watercourses and ditch systems. The amount of water table rise and surface water level increase will be greatest near the coast and become progressively less inland. These changes will result in altered hydraulic gradients within the alluvium, increased baseflows to the reen system and reduced groundwater flux to the Severn estuary. Such changes will be very small because of the low permeability of the alluvium (Lloyd and Wilkinson, 1988). The lateral extent of these effects inland is difficult to predict as they will also be influenced by land drainage but they are likely to be limited to the floodplain landward of the impoundment.

3.5.72 The higher sea level and increased mean salinity within the impoundment will result in increased salinity within porewater adjacent to the coast, however the extent of saline intrusion will be limited because of the low permeability of the soils and by land drainage; the hydrology being dominated by surface flow processes. The higher water table will increase the potential for leaching of contaminants, however the potential for local groundwater and surface water quality to be affected is very low because of the 'greenfield' nature of the land inland of the impoundment.

3.5.73 The results from the water quality modelling indicate the following water quality implications on the main tributaries open to the Severn estuary:

- No changes to the natural variation of salinity in the Avon and Parrett and minor changes in the Usk, Wye and Severn. At the highest Spring tides and Q_{90} river flows the saline interface was observed to move seaward by just over 3km in the River Usk, slightly over 1km in the River Wye and 4.5km in the River Severn (ABPmer 2010);

- No effect from pathogens from the existing major coastal outfalls; and

3.5.74 Probably no effect in terms of increased eutrophication potential, although this is complicated by the uncertainties associated with turbidity post construction, which is the main limiting factor on nutrient uptake.

3.5.75 The above effects will occur almost immediately following closure of the lagoon and continue over the operational life.

Abstractions

3.5.76 No PWS sources or other licensed sources will be affected.

Geological and Gemorphological SNCIs

3.5.77 The modelling studies identified increased erosion potential on the English coast opposite to this alternative option (STP 2010b,c), which might affect Aust Cliff SSSI and Portishead Pier to Black Nore SSSI.

Soils

3.5.78 The increase in water table, combined with the surface drainage effects described in the FR&LD topic (STP 2010b) will result in increased soil wetness and degradation of soil quality from waterlogging over an area of approximately $47km^2$.

Infrastructure

3.5.79 These effects also have the potential to impact subterranean infrastructure of local importance, most notably in the low-lying areas of Caldicot and Llanwern and, to a lesser degree, in the southern parts of Newport, on the eastern side of the River Usk. The extent of infrastructure potentially at risk in these areas is unknown.

Decommissioning Phase

3.5.80 Decommissioning will result in a reduction in the median sea level that occurred within the lagoon during the operational phase, however the existing baseline conditions will not be achieved due to the anticipated sea level rise of 0.63m. As a consequence, decommissioning will reduce the magnitude of the indirect effects identified above but will not remove them entirely.

Far-field Effects

3.5.81 These effects are not considered significant at this stage, because they are localised and much less than +/- 0.1m, however this may need to be confirmed by further modelling at project stage if this option were to be pursued.

Cumulative Effects

3.5.82 Projects identified for implementation during the construction and operational phases, particularly those involving use of large amounts of concrete, such as the construction / decommissioning of power stations at Oldbury and Hinkley, will increase the demand on local water resources. This could result in new sources being developed, however, for the purposes of this assessment it is assumed that demand will be regulated through the EA's framework, which incorporates licensing through RBMPs.

Consequential Development Effects

3.5.83 Development of energy intensive industry adjacent to a tidal power scheme would have the potential to impact the geological resource, particularly if it were placed in a coastal location.

Summary of Likely Significant Effects on the Environment

3.5.84 The likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases are:

- Loss of soil resource, due to waterlogging over an area of approximately 47km^2; and
- Potential impacts to subterranean infrastructure in Llanwern, eastern Caldicot and southern Newport, on the eastern side of the River Usk.

Assumptions, Limitations and Uncertainties

3.5.85 The assessment of effects for this alternative option relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP 2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):

- The extent of subterranean infrastructure in the areas identified potentially at risk;
- The land quality where the soil resource will be depleted – whilst this does not affect the assessment of effects, it has implications for economic analysis; and
- The degree of increased erosion on the English coast and the magnitude of effect on Aust Cliff SSSI and the Portishead Coast SSSI.

Table 3.4 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)
Surface Water value (H); vulnerability (H)										
Surface watercourses in designated floodplain upstream of impoundment	*Increased baseflow contribution to surface watercourses & ditches as a result of permanently raised groundwater levels*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL*	*Regional*	*Negative (to land drainage) but could be positive in terms of water quality*	*Spatial extent of effect inland*	*N*
	Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations	*Indirect*	*VL (greenfield)*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Only sites registered as 'Contaminated Land' reviewed*	*N*
Groundwater value (H); vulnerability (H)										
Estuarine alluvium upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels (to ~ 3.3m AOD)*	*Indirect*	*High – adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L - adjacent to coast*	*District – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage*	*N*
	Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations	*Indirect*	*VL (greenfield)*	*Operation – L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*Only sites registered as 'Contaminated Land' reviewed*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L*	*Unitary Authority – probably limited to immediate coastal fringe along impounded length of coast*	*Negative (in terms of water resources)*	*As above*	*N*
Severn Estuary	*Reduction in groundwater flux into as a result of increased MSL*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*VL -*	*As above*	*Negative*	*Changes to operating gradients – small*	*N*
Geological SSSIs value (H) vulnerability (H)										
Mid Severn (English) (Aust Cliff, Portishead Pier to Black Nore)	*Increased erosion at Aust Cliff and Portishead coast*	*Indirect*	*Medium*	*Operation – L*	*Reversible Permanent*	*Unknown*	*Unitary Authority*	*Negative*	*Magnitude and scale of erosion*	*Unknown – Probably 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)
	Reduced accessibility to 2 coastal exposures outside SSSI designation caused by increase in median water level to 3.3m AOD and in lowest tides from -6m to -1m AOD.	*Indirect*	*M*	*Operation – L*	*Reversible Permanent*	*Unknown*	*Local*	*Negative*	*Extent and value of geological exposure that may be covered*	*N*
Soils value (H), vulnerability (H)										
Mid Severn (Welsh Side)	*Degradation through waterlogging*	*Indirect - result of raised water table*	*High over large proportion of Gwent Levels*	*Operation – L*	*Reversible Permanent*	*Increased soil wetness over ~ 47km^2*	*Regional – likely to be limited to floodplain*	*Negative*	*As for FR&LD assessment; Land quality*	*Y*
Local infrastructure value (L) vulnerability (H)										
Mid Severn (Welsh) Llanwern, low-lying parts of Caldicot and S. Newport, east of R. Usk	*Increased dampness in basements and flows in sewers*	*Indirect - result of raised water table*	*Unknown*	*Operation – L*	*Reversible Permanent*	*Unknown – but may be > VL because of local drainage conditions*	*As above*	*Negative*	*As above*	*Possibly Y*

Alternative Option L3d: Bridgwater Bay Lagoon

3.5.86 The likely effects of this alternative option are summarised in Table 3.5.

Direct Effects

3.5.87 There will be no direct effects associated with the construction, operational or decommissioning phases associated with this alternative option.

Indirect Effects

3.5.88 Indirect effects will occur during the operational and decommissioning phases.

Operational Phase

Surface and Groundwater Resources

3.5.89 Impoundment and ebb / flood operation will raise median sea levels by approximately 0.4m (at Burnham). This will result in a permanently slightly higher water table within the soils immediately behind the impoundment, which comprise estuarine alluvium, localised beach dune deposits and Made Ground in urban areas, as well as slightly higher water levels in surface watercourses and ditch systems. The amount of water table rise and surface water level increase will be greatest near to the coast and become progressively less inland. These changes will result in altered hydraulic gradients within the ground, increased baseflows to the rhyne system and reduced groundwater flux to the Severn estuary. Such changes will be very small because of the low permeability of the alluvium (Lloyd and Wilkinson, 1988) and the small increase in median sea level. The lateral extent of these effects inland is difficult to predict as they will also be influenced by the land drainage system but they are likely to be limited to the floodplain landward of the impoundment.

3.5.90 The higher sea level and increased mean salinity within the impoundment will result in higher salinity within porewater adjacent to the coast, which will extend inland. The extent of saline intrusion will be greater within the dune sand deposits than within the estuarine alluvium because of the difference in permeability of these materials, however in both cases it will be controlled by land drainage effects. The higher water table will increase the potential for leaching of contaminants, however the potential for local groundwater and surface water quality to be affected is very low because of the very small rise in water table that occur inland of the impoundment.

3.5.91 The results from the water quality modelling indicate the following water quality implications on the main tributaries open to the Severn estuary:

- No changes to the natural variation of salinity in the influent River Severn and its major sub-tributaries, with the exception of the River Parrett, where the saline interface was estimated to move landward by about 2.5km when the highest Spring tides coincided with Q_{90} river flows (ABPmer 2010);
- No effect from pathogens from the existing major coastal outfalls; and

3.5.92 Probably no effect in terms of increased eutrophication potential, although this is complicated by the uncertainties associated with turbidity post construction, which is the main limiting factor on nutrient uptake.

3.5.93 The above effects will occur almost immediately following closure of the lagoon and continue over the operational life.

3.5.94 No PWS sources or other licensed sources are likely to be affected.

Geological and Gemorphological SNCIs

3.5.95 The modelling studies identified a reduced Spring tidal range on both sides of the Severn estuary of between 0.1- 0.3m downstream of the barrage as far west as a line between Bridgend and Hele, and of about 0.4m inland as far as Gloucester (STP 2010c?). This will result in slightly greater accessibility and slightly lower erosion potential to coastal sites of geological and geomorphological interest, although the Welsh coast either side of Penarth will experience marginally increased peak wave heights due to wave reflection, which may offset any gains in reduced erosion.

Soils

3.5.96 The increase in water table, combined with the surface drainage effects described in the FR&LD topic (STP 2010b) will result in increased soil wetness and degradation of soil quality over an area of approximately 200km^2.

Infrastructure

3.5.97 These effects also have the potential to impact subterranean infrastructure of local importance, most notably in the low-lying areas of Bridgwater. Whilst the extent and condition of such infrastructure is unknown, the effects are unlikely to be significant because of the small increase in median sea level that will occur.

Decommissioning Phase

3.5.98 Decommissioning will result in a reduction in the median sea level that occurred within the lagoon during the operational phase, however the existing baseline conditions will not be achieved due to the anticipated sea level rise of 0.63m. As a consequence, decommissioning will reduce the magnitude of the indirect effects identified above but will not remove them entirely.

Far-field Effects

3.5.99 These effects are not considered significant at this stage, because they are localised and approximately +/- 0.1m, however this may need to be confirmed by further modelling at project stage if this option were to be pursued.

Cumulative Effects

3.5.100 Projects identified for implementation during the construction and operational phases, particularly those involving use of large amounts of concrete, such as the construction / decommissioning of power stations at Oldbury and Hinkley, will increase the demand on local water resources. This could result in new sources being developed, however, for the purposes of this assessment it is assumed that demand will be regulated through the EA's framework, which incorporates licensing through RBMPs.

Consequential Development Effects

3.5.101 Development of energy intensive industry adjacent to a tidal power scheme would have the potential to impact the geological resource, particularly if it were placed in a coastal location.

Summary of Likely Significant Effects on the Environment

3.5.102 The likely significant effects (direct, indirect, far-field, cumulative and consequential development effects) of the alternative option on the receptors during construction, operation and decommissioning phases are:

- Loss of soil resource over an area of approximately 200 km^2; and
- Potential impacts to subterranean infrastructure, most likely in southern parts of Bridgwater.

Assumptions, Limitations and Uncertainties

3.5.103 The assessment of effects for this alternative option relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP 2010b,c,d). In addition, the following limitations and uncertainties should be noted (in order of importance):

- The extent of subterranean infrastructure in the areas identified potentially at risk; and
- The land quality where the soil resource will be depleted, which does not affect the assessment of effects but has implications for economic analysis.

Table 3.5 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)
Surface Water value (H); vulnerability (H)										
Surface watercourses in designated floodplain upstream of impoundment	*Increased baseflow contribution to surface watercourses & ditches as a result of permanently raised groundwater levels*	*Indirect*	*High*	*Operation – L*	*Reversible Permanent*	*VL – median sea level increase of 0.4m*	*Regional*	*Negative (to land drainage)*	*Spatial extent of effect inland*	*N*
	Increased leaching of contaminants in unsaturated zone as a result of raised groundwater elevations	*Indirect*	*Low – increases in groundwater elevation not great <0.4m*	*Operation – L*	*Reversible Permanent*	*VL – as above*	*Local*	*Negative*	*Number and severity of contaminated sites not on public registers*	*N*
River Parrett	*Change in water quality as a result of movement of saline interface up to ~2.5km inland at low flow*	*Direct*	*Medium*	*Operation –L*	*Reversible Permanent*	*VL*	*Local*	*Positive*	*As for WQ modelling*	*N*
Groundwater value (H); vulnerability (H)										
Estuarine alluvium upstream of impoundment	*Increase in phreatic surface as a result of increased median sea levels by ~ 0.4m*	*Indirect*	*High – adjacent to coast*	*Operation – L*	*Reversible Permanent*	*VL - adjacent to coast*	*Local – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation – L*	*Reversible Permanent*	*L*	*Local – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*As above*	*N*
	Increased leaching of contaminants in unsaturated zone as a result of raised water table	*Indirect*	*Low – increases in groundwater elevation not great <0.4m*	*Operation – L*	*Reversible Permanent*	*VL –median sea level increase of 0.4m*	*Local*	*Negative*	*Number and severity of contaminated sites not on public registers*	*N*
Coastal dune sand deposits, south of Brean Down	*Increase in phreatic surface as a result of increased median sea levels (to ~ 2.6m AOD)*	*Indirect*	*High – adjacent to coast*	*Operation - L*	*Reversible Permanent*	*L - adjacent to coast*	*District – probably limited to within floodplain*	*Positive (in terms of water resources)*	*Extent of effect, level of influence by drainage and sewer systems*	*N*
	Movement of saline interface inland as a result of impoundment	*Indirect*	*High - adjacent to coast*	*Operation - L*	*Reversible Permanent*	*L*	*District – probably limited to immediate coastal fringe*	*Negative (in terms of water resources)*	*Extent of effect, level of influence by surface water drainage and sewer systems*	*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)
Severn Estuary	*Reduction in groundwater flux into as a result of increased MSL*	*Indirect*	*H*	*Operation – L*	*Reversible Permanent*	*VL – as above*	*Local*	*Negative*	*Changes to operating gradients – small*	*N*
Geological and Geomorphological SSSIs value (H), vulnerability (H)										
Tidal River Severn, Inner, Mid and Outer Severn (both sides) Otter Hole, Wye River Section, Ryhmney River Section, Aust Cliff, Purton Passage, Portishead Coast, Penarth Coast, Middle Hope, Brean Down	*Lower erosion potential and greater accessibility due to reduced tidal range of up to 0.4m*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*VL – benefit will largely disappear at end of operational phase due to predicted sea level rise*	*Local*	*Positive*	*Magnitude of erosion of important outcrops – likely to be low*	*N*
Outer Severn (Welsh side) Penarth Coast	*Greater erosion potential caused by increased 1 year wave height of between 0.05-0.35m*	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*As above*	*N*
Bristol Channel (Welsh) – Sully Island to Swansea Bay	*Greater accessibility (and marginally less erosion) caused by reduction in peak tidal range of 0.4m at Sully Island to Barry Island*	*Indirect*	*High*	*Operation - L*	*Reversible Permanent*	*VL - benefit will largely disappear at end of operational phase due to predicted sea level rise*	*Local*	*Positive*	*Benefit of marginally greater exposure – assumed VL*	*N*
	Greater erosion potential caused by increased 1 year wave height of between 0.05-0.35m	*Indirect*	*Medium*	*Operation - L*	*Reversible Permanent*	*L*	*Local*	*Negative*	*As above*	*N*
Bristol Channel (N Somerset & Devon coast to Barnstaple)	*Greater accessibility (and marginally less erosion) to Blue Anchor to Lilstock Coast caused by reduction in peak water levels of ~ 0.4m at Bridgwater Bay to 0.1m at Hele*	*Indirect*	*High*	*Operation - L*	*Irreversible*	*VL - benefit will largely disappear at end of operational phase due to predicted sea level rise*	*Local*	*Positive*	*As above*	*N*
Soils value (H), vulnerability (H)										
English Side downstream of original road crossing	*As above*	*Indirect - result of raised water table*	*Unknown – could be High*	*Operation - L*	*Reversible Permanent*	*H - Increased soil wetness over ~ 200km^2,*	*Regional – likely to be limited to floodplain*	*Negative*	*As for FR&LD assessment; extent of reduced soil fertility*	*Probably Y*
Locally important infrastructure value (L); vulnerability – assumed (H)										

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)
Outer Severn (English)	*Increased dampness in basements and flows in sewers in low – lying parts of Bridgwater as a result of flooding*	*Indirect - result of raised water table*	*L – due to small increase in median water level of 0.4m and ebb/flood operation*	*Operation - L*	*Reversible Permanent*	*Unknown – but likely to L or VL*	*Local / Unitary Authority – likely to be limited to floodplain*	*Negative*	*Vulnerability of infrastructure and extent of effect*	*Unknown – but likely to be N*

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 will 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.

Measures to Prevent or Reduce Effects

3.6.3 The measures identified to prevent or reduce likely significant adverse environmental effects within this topic are described below.

Geological and Geomorphological SSSIs

3.6.4 During optimisation the land fall on the English side of B3: Brean Down to Lavernock Point Barrage, and of L3d: Bridgwater Bay Lagoon were located to the south of Brean Down to avoid direct loss to this SSSI.

3.6.5 Direct loss of the southern part of Penarth coast SSSI will occur at the landfall for B3: Brean Down to Lavernock Point Barrage on the Welsh side, however. Direct loss may also occur to the Aust Cliff SSSI with the land fall of B5: Beachley Barrage on the English side. This direct and potential direct loss could be mitigated by slight adjustments to the alignments of these alternative options. The inevitable consequences of realignment would need to be taken into account, such as the proximity to local population receptors.

3.6.6 Most of the indirect effects to SSSIs, however, are due to submergence and loss of access to important geological outcrop as a result of submergence. To reduce the effect of the loss of safe access to the Otter Hole cave system caused by B3 Brean Down to Lavernock Point Barrage and B4: Shoots Barrage, provision of alternative access could be considered. In all other cases, however, the indirect effects cannot be prevented or reduced. Theoretical engineering measures can be considered for maintaining access to some locations (such as provision of local cofferdams) but these would be neither practical nor safe.

Soils

3.6.7 No measures were taken during optimisation to mitigate for effects to the soil resource.

3.6.8 The soil resource is likely to be affected significantly by all of the alternative options because of the effects arising from impeded land drainage, which is likely to increase soil wetness over large areas and, in the worst case, waterlogging for extended periods in some areas. This would ultimately affect the quality and diversity of the soil resource but could be prevented by provision of increased drainage (i.e. pumping from existing watercourses).

3.6.9 The drainage measures recommended by the FR&LD topic paper to prevent increased flooding risk to properties would reduce the effects to the soil resource but not prevent them entirely, as these are weighted towards urbanised areas. Extra provision above what is proposed by FR&LD would therefore be required and could be incorporated into similar requirements to reduce and / or prevent significant effects to water-dependent sites of nature conservation importance (STP 2010e). Climate change effects are likely to mean that the amount of 'additional' drainage provision required to remove the significant effects to soils would be likely to reduce through the operational phase, particularly in summer periods.

Infrastructure

3.6.10 No measures were taken during optimisation to prevent or minimise effects to subterranean infrastructure.

3.6.11 The likely significant effects to infrastructure result from raised water tables beneath buildings and urban areas and the increased dampness that could result in below ground structures, such as basements, and loss of capacity in sewers and other services. This could be reduced and, in many cases prevented, by provision of increased drainage in urban areas.

3.6.12 The drainage measures recommended by the FR&LD topic paper to prevent increased flooding risk to properties would reduce the effects to infrastructure (and might remove them entirely) in some areas. However, these would not prevent significant effects to infrastructure entirely, particularly where this is present in high permeability soils near the coastal fringe. Extra provision above what is proposed by FR&LD would therefore be required. The disruption associated with implementation of this could be large because of the constraints of working within urban areas.

3.6.13 Unlike the situation with soils, discussed above, the additional pumping required in low-lying land near the coastal fringe would be likely to be necessary throughout the operational phase of an alternative option, particularly where there is good hydraulic connection with the impounded waters, e.g. through dune sands. In such cases, the amount of intercepted water could be large and therefore costly to maintain. Where the permeability of the ground is lower, e.g. in more clay-rich soils, the volume of water requiring pumping and its associated operational cost would be correspondingly smaller, however, the capital cost of installing effective drainage schemes could be higher in relative terms. It is possible that in some situations, however, the local ground conditions could be such that increased moisture within basements could not be prevented.

Measures Needed to Offset Effects

3.6.14 The identification of offsetting measures is a requirement of the SEA Directive. For the purposes of this SEA, these are measures to as fully as possible offset any significant adverse environmental effects. Such measures 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).

3.6.15 The need for offsetting measures will be identified within this topic. However, it will not be possible to describe full details of offsetting measures, such as geographic locations, at this strategic level. Therefore, generic suggestions will be made. Compensation measures are even more indefinite in scope, being dependent on preceding tests within the Habitats Directive. Thus it will only be possible to describe the need for such measures under the Habitats Directive, rather than scope them in any detail. A separate Compensation Workstream has been tasked by DECC to consider compensation requirements as part of the Feasibility Study.

Geological and Geomorphological SSSIs

3.6.16 Some form of off-setting will be required for the loss of access to SSSI outcrops caused by submergence, especially that caused by alternative option B3: Brean Down to Lavernock Point Barrage.

3.6.17 The Geological Conservation Review (GCR) includes over 3000 sites that encompass the best examples of the range of geological and geomorphological features in Britain. The information obtained by the GCR forms the basis for SSSI designation. In some cases, it may be that a GCR site is one of several similar examples of that particular geology. In such cases there is a possibility that the geological information lost to research by submergence of SSSI outcrop (caused by the chosen STP scheme) could be offset by designation of a similar outcrop elsewhere, possibly somewhere else in the country. In this instance, providing that designation could be secured, and that there was access for observation and study, very little additional offsetting requirements would be necessary. Conversely, it is also possible that the particular geological and geomorphological features are unique to a particular GCR outcrop, such as the dinosaur footprints at Bendrick Rock[1]. In such a situation, no offsetting would be possible.

3.6.18 The feasibility of offsetting discrete geological outcrops that may be affected by the alternative options is outside the scope of this strategic study because of the level of detail required, however, it would need to be considered at a later planning stage.

Soils

3.6.19 No offsetting measures have been considered for the soil resource as the likely significant effects can be mitigated by improved drainage.

Infrastructure

3.6.20 It is possible that some form of measures could be required to off-set significant impacts to subterranean infrastructure, such as provision of replacement services. This may not be realistic for all receptors, however, such as in the case of private basements, where increased dampness as a result of impoundment cannot be prevented. It is not known to what extent this may be an issue.

Assumptions, Limitations and Uncertainty

3.6.21 In identifying measures to prevent, reduce and as fully as possible offset any likely significant adverse effects on the environment and making suggestions, there are some limitations, and assumptions have been made. Furthermore, particularly because the suggestions made are high level, uncertainty is inherently associated with the assessment of the effects of the measures. These issues are discussed for this topic below.

[1] It should be noted that Bendrick Rock SSSI is not currently anticipated to be at risk of adverse effect as a result of the alternative options.

Geological and Geomorphological SSSIs

3.6.22 The following have been assumed:

- In alternative option B3: Brean Down to Lavernock Point Barrage, prevention of the loss of the southern part of Penarth Coast SSSI occurs by adjustment of the alignment to the west of the scheme described herein and that the consequences of realignment are acceptable.
- In alternative options B3: Brean Down to Lavernock Point Barrage and B4: Shoots Barrage, alternative access to Otter Hole is technically feasible and can be undertaken without damage to the cave system. There is a high level of uncertainty regarding the feasibility of this.
- In alternative options B3: Brean Down to Lavernock Point Barrage, B4: Shoots Barrage and B5: Beachley Barrage, that the other geological outcrops that will be submerged are important and will need to be offset. There is a moderate level of certainty regarding this.
- There is a low level of certainty regarding the feasibility of offsetting the outcrop with alternative GCR sites.

3.6.23 The provision of improved access to alternative sites could result in significant effects (e.g. to landscape etc).

Soils

3.6.24 The main assumption made regarding soils is that the important resources occur mainly within rural areas, that the provision of improved drainage can be undertaken relatively easily and will result in no significant effects. There is a moderate level of certainty regarding this.

Infrastructure

3.6.25 The main assumption made regarding infrastructure is that the important features that would be affected occur mainly within urban areas. It has been assumed that the effects of raised water tables on underground infrastructure could be offset by provision of improved drainage (including capacity). The provision of this could be problematic because of the constraints in such areas. Implementation could result in a large amount of local disruption and could be therefore result in significant effects. There is a moderate level of certainty regarding this.

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 will 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 will 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 4.1summarises the SEA Objectives assessment which is described in further detail below in relation to the scope of this topic paper. Where particular Objectives also relate to other topics, this is highlighted.

SEA Objective FE.1: To avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality

Surface Water

4.3.2 The findings of the surface water modelling undertaken suggest this Objective will be largely achieved for all options. (STP 2010d)

4.3.3 For most of the alternative options there is either no predicted change in the location of the saline limit (+/- 0.5km) in most of the main tributaries or a slight seaward migration, which is greatest in the influent River Severn. The exceptions are predicted slight landward migrations of 0.6km and 1.0km within the River Wye for alternative options B3 and B4 respectively, and of 2.5km in the River Parrett for alternative option L3d when high Spring tides coincide with low river flows (ABPmer 2010).

4.3.4 No changes in the concentrations of pathogens, dissolved oxygen or nutrients, or changes in pH are predicted within the main tributaries. Regarding the potential for eutrophication, the limiting control on the growth of phytoplankton is turbidity. This will not reduce within the tributaries and hence there is no increase in the potential for eutrophication within non-tidal waters (ABPmer 2010).

Groundwater

4.3.5 Objective FE.1 is met for Options B4: Shoots Barrage, B5: Beachley Barrage and L2: Welsh Grounds Lagoon, principally because the geology is such that saline intrusion will be limited in extent. This is because of a combination of either low permeability or fracture flow hydraulics, with small changes to regional hydraulic gradients.

4.3.6 The Objective is not met for B3: Brean Down to Lavernock Point Barrage and L3d: Bridgwater Bay Lagoon, however, because of the presence of higher permeability deposits that occur near the coast for these alternative options. These are likely to result in increased saline intrusion in parts of the fluvio-glacial aquifer in the vicinity of Cardiff and in the beach sand deposits in the vicinity of Weston-super-Mare and Brean. Even though saline intrusion is not permitted within the current regulatory regime (see Section 5.2), it is assumed that measures would not be implemented to offset this, as saline intrusion already occurs in these locations to some extent.

Coastal Waters

4.3.7 Compliance with this Objective is considered within the Marine Water Quality Topic Paper (STP 2010d).

SEA Objective FE.2: To avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users

Humans

4.3.8 The findings of the surface water modelling undertaken for pathogens indicate that Objective FE.2 will be achieved (and possibly improved) for all options (STP 2010d).

Flora & Fauna

4.3.9 The findings of the FR&LD topic and the salinity modelling undertaken within the MWQ topic, indicate that this Objective will be achieved for all options (STP 2010b,d).

Recreation & Other Users

4.3.10 The findings of the surface water modelling undertaken for pathogens and eutrophication suggest this Objective will be achieved for all options, notwithstanding the uncertainties associated with the latter (STP 2010d).

SEA Objective FE.3: To avoid adverse effects on water abstractions (whether surface water of groundwater), particularly those utilised for the PWS

PWS Sources

4.3.11 This objective is largely met for all alternative options, however, there are subtle differences between the three barrage alternatives, principally because of size, extent of effect and because there is little that can be implemented to offset for potential effects (other than exploiting alternative water supply sources, probably remote from the region). Option B3: Brean Down to Lavernock Point Barrage increases the potential for saline intrusion at Clevedon Pumping Station, which will increase through the operational phase because of reducing groundwater resources as a result of climate change effects. The likelihood of this source experiencing increased salinity is, however, uncertain as little is known about the source mechanisms. Both B3: Brean Down to Lavernock Point Barrage and B4: Shoots Barrage increase the theoretical potential for increased salinity and the Great Spring, however the likelihood of this occurring is negligible because of what is known about this source. All barrage options, reduce the potential for saline influence at the Purton offtake on the Sharpness Canal, although the benefits reduce with time. The three barrage alternatives have therefore been graded accordingly.

Other Licensed Abstractions

4.3.12 This objective is met for all alternative options.

SEA Objective FE.4: To avoid adverse effects to the water regime of designated water-dependent sites of nature conservation interest.

4.3.13 This objective should be largely met for all alternative Options. This is because all result in generally higher water tables and soil moisture, which can be managed by increased drainage capacity, and because the water quality modelling undertaken indicate little change outside the existing natural variation (STP 2010d). Over the full life of an Option the increased soil moisture could be viewed as beneficial in the context of climate change effects, which can be expected to result in reduced soil moisture and increasing stress on water-dependent sites of nature conservation interest. This is considered within the Terrestrial & Freshwater Ecology Topic Paper (STP 2010e).

SEA Objective FE.5: To avoid adverse effects to buildings and infrastructure.

Infrastructure of national importance

4.3.14 Objective FE.5 is met for all alternative options.

Infrastructure of local importance

4.3.15 This Objective is met for all alternative options with the exception of B3: Brean Down to Lavernock Point Barrage. In the case of B4: Shoots Barrage, B5: Beachley Barrrage and L2: Welsh Grounds Lagoon, this is because it is assumed that improved drainage can be relatively easily implemented to remove the effects to the relatively small number of buildings and urban areas that may be affected. In the case of alternative option L3d: Bridgwater Bay Lagoon, the potential effects cover a much larger urban area than for B5: Beachley Barrage or L2: Welsh Grounds Lagoon, however the scale of water table rise is an order of magnitude lower, because of the ebb and flood operation of the lagoon. It is also assumed that the water table effects can be removed by increased drainage.

4.3.16 There is also uncertainty regarding compliance of this Objective with alternative option B3: Brean Down to Lavernock Point Barrage, particularly with respect to underground infrastructure in Cardiff and Weston-super-Mare, as well as at Avonmouth, noted above. In Cardiff this is associated with the extent over which potential increases in piezometric pressure may occur within the confined fluvio-glacial gravel aquifer away from the influence of Cardiff Bay Barrage (CBB) and, to what extent the infrastructure provided during construction of the CBB might be able to cope with any additional effects. In Weston-super-Mare, however, the uncertainties are much greater because of the existing problems at high Spring tides in some locations. In addition and in contract with southern Cardiff, Weston-super-Mare has not had the benefit of additional, recently installed pumping capacity to mitigate the effects of increased water tables. Given these uncertainties, it is judged that alternative option B3: Brean Down to Lavernock Point Barrage does not meet this Objective.

<u>SEA Objective FE.6: To avoid adverse effects to the soil resource</u>

4.3.17 All of the alternative options result in generally higher water tables and soil moisture, which can be managed by increased drainage capacity, this objective should be largely met for all alternative options. Over the full life of an alternative option this could be viewed as beneficial in the context of climate change effects, which can be expected to result in reduced soil moisture and increasing stress on the soil resource. The principle difference between the alternative options is of scale.

<u>SEA Objective FE.7: To avoid adverse effects to agricultural land currently in use</u>

4.3.18 In principle, however, as the alternative options result in generally higher water tables and soil moisture, which can be managed by increased drainage capacity, this objective should be largely met for all alternative options. Over the full life of an alternative option increased soil moisture could be beneficial in reducing the anticipated effects of climate change, which is expected to result in increased stress on agricultural land. The principle difference between the alternative options is of scale. This is considered in further detail within the Communities Topic Paper with the Society & Economy theme (STP 2010a).

<u>SEA Objective FE.8: To avoid adverse effects on geological and geomorphological sites of international and national importance.</u>

4.3.19 This objective is not met for the any of the barrage options, and will result in loss of access to the lowermost sections of the following important geological sites:

- B3 - nine SSSIs, excluding the loss of safe access to the Otter Hole cave system and the direct loss to Penarth Coast SSSI, which it has been assumed can be offset;

- B4 – four sites, excluding the loss of safe access to the Otter Hole cave system, which it is assumed can be offset; and

- B5 – two sites, excluding effects to Aust Cliff, which it is assumed can be offset.

4.3.20 There remains uncertainty regarding to what extent loss of important geological outcrop will occur and to what extent offsetting measure can be implemented and these differences between the alternative options have been graded accordingly.

4.3.21 Objective FE.8 is met for alternative lagoon options L2: Welsh Grounds Lagoon and L3d: Bridgwater Bay Lagoon.

SEA Objective FE.9: To conserve and enhance designated geological and geomorphological site features.

4.3.22 Similarly, this Objective is met for the two alternative lagoon options but is not met for the alternative barrage schemes, which do not conserve or enhance the designated geological outcrop. Option B3: Brean Down to Lavernock Point is judged to be less compliant because of the number of sites affected and the potential for far field effects, as yet poorly understood.

Assumptions, Limitations and Uncertainty

4.3.23 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.

4.3.24 The assessment of objective compliance relies on the output from the hydraulics and geomorphology, marine water quality and flood risk and land drainage topics and the assumptions, limitations and uncertainties described there also apply (STP 2010b,c,d). Notwithstanding the uncertainties associated with climate change effects, which are assumed to be similar for all alternative options throughout the operational life, the following generalisations are made:

- Most certainty associated with the alternative lagoon options, with least certainty associated with the alternative barrage options. This is due to the smaller length of coastline affected and, in the case of L3d: Bridgwater Bay Lagoon, to ebb and flood operation.

- More certainty associated with smaller alternative barrage options than with the larger alternative lagoon options.

4.3.25 In general, therefore, there is most uncertainty of compliance associated with the largest alternative option, B3: Brean Down to Lavernock Point Barrage, which affects the greatest length of coastline, the greatest number of tributaries and has most chance of causing ‘far-field’ effects.

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**
FE.1. To avoid adverse effects on water quality (whether surface water, groundwater or coastal waters) in relation to water quality standards.	Surface Waters	0 No change predicted in key parameters. Predicted landward movement of saline interface in R Wye of up to 0.6km at low river flow	0 No change predicted in key parameters. Predicted landward movement of saline interface in R Wye of up to 1km at low river flow	0 No change predicted in key parameters. Either no change or slight seaward movement of saline interface	0 No change predicted in key parameters. Either no change or slight seaward movement of saline interface	? No change predicted in key parameters. Predicted landward movement of saline interface in R Parrett of up to 2.5km at low river flow
	Groundwater	- Increased saline intrusion in parts of the fluvio-glacial aquifer in the vicinity of Cardiff and in the beach sand deposits in the vicinity of Weston-super-Mare	0	0	0	- Possible increased saline intrusion in higher permeability deposits in the vicinity of Bridgwater Bay
			Saline intrusion limited by geology			
	Coastal Waters	Considered in Marine Water Quality Topic Paper (STP 2010d)				
FE.2 To avoid adverse effects on water quality which would affect human health, flora and fauna, recreation and other users.	Humans	?	0	0	0	0
		Modelling undertaken for pathogens indicates that water quality will be maintained (and possibly improved).				
	Flora & Fauna	0	0	0	0	0
		The findings of the FR&LD and MWQ topics, indicate that this Objective will be achieved.				
	Recreation & other users	0	0	0	0	0
		The surface water modelling undertaken for pathogens and assessment of eutrophication (nutrients and suspended sediments) suggest this Objective will be achieved				
FE.3 To avoid adverse effects on water abstractions (whether surface water of groundwater), particularly those utilised for the PWS	PWS sources	? Slight increase in potential for saline intrusion at Clevedon Pumping Station. Theoretical increase in potential for increase in salinity of inflow to the Severn railway tunnel harnessed for the PWS - likely to be negligible because of what is known about this source Reduction in potential for saline influence at the Purton off-take on the Sharpness Canal, although the benefits reduce with time.	0 Theoretical increase in potential for increase in salinity of inflow to the Severn railway tunnel harnessed for the PWS - likely to be negligible because of what is known about this source Reduction in potential for saline influence at the Purton off-take on the Sharpness Canal, although the benefits reduce with time.	+ Reduction in potential for saline influence at the Purton off-take on the Sharpness Canal, although the benefits reduce with time.	0	0

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**
	Licensed abstractions for other uses	0	0	0	0	0
		Generally slightly greater security against saline intrusion on surface water system; slightly less security for groundwater adjacent to coast	Generally slightly greater security against saline intrusion on surface water system; slightly less security for groundwater adjacent to coast	Generally slightly greater security against saline intrusion on surface water system; slightly less security for groundwater adjacent to coast	Generally slightly greater security against saline intrusion on surface water system; few groundwater abstractions adjacent to impoundment	Negligible changes to surface or groundwater regimes but increased saline intrusion on R Parrett at high Spring tides & low river flows
FE.4 To avoid adverse effects to the water regime of designated water-dependent sites of nature conservation interest.	Designated sites of nature conservation importance	0	0	0	0	0
		All options result in generally higher water tables and soil moisture, which can be managed by increased drainage capacity (pumping); Water quality modelling undertaken indicate little change outside the existing natural variation.				
FE.5 To avoid adverse effects to buildings and infrastructure.	Infrastructure of national importance	0	0	0	0	0
	Other infrastructure (local importance)	--	0	0	0	0
		Uncertainty particularly with respect to underground infrastructure in Cardiff and Weston-super-Mare, as well as at Avonmouth. In Cardiff this is associated with the extent over which potential increases in piezometric pressure may occur within the confined fluvio-glacial gravel aquifer away from the influence of Cardiff Bay Barrage (CBB) and, to what extent the infrastructure provided during construction of the CBB might be able to cope with any additional effects. In Weston-super-Mare, uncertainties are much greater because of the existing problems at high Spring tides in some locations.	Assumed that improved drainage can be relatively easily implemented to remove the effects to the relatively small number of buildings and urban areas that may be affected.			The potential effects cover a much larger urban area than for B5: Beachley Barrage or L2: Welsh Grounds Lagoon, however the scale of water table rise is an order of magnitude lower, because of the ebb and flood operation of the lagoon. Also assumed that the water table effects can be removed by increased drainage.
FE.6 To avoid adverse effects to the soil resource	Soil resource	0	0	0	0	0
		Higher water tables and soil moisture, which can be managed by increased drainage capacity.				
FE.7 To avoid adverse effects to agricultural land currently in use.	Agricultural land	0	0	0	0	0
		Higher water tables and soil moisture, which can be managed by increased drainage capacity.				
FE.8 To avoid adverse effects on geological and geomorphological sites of international and national importance.	Geological and geomorphological SSSIs	-- Loss of access to 9 sites	- Loss of access to 4 sites	- Possible loss of access to 2 sites	0	0
FE.9 To conserve and enhance designated geological and geomorphological site features.	Geological and geomorphological SSSIs	-- Loss of access to 9 sites	- Loss of access to 4 sites	- Possible loss of access to 2 sites	0	0

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 will 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 will 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 There are three main areas where there are potential issues relevant to this topic:

- Pollution of 'controlled waters,' particularly in relation to saline intrusion of the groundwater resource;
- Conservation and enhancement of geological and / or geomorphological SSSIs; and
- Increased risk of flooding caused by raised groundwater levels.

Pollution of 'Controlled Waters' and 'Aquifers'

5.2.3 Under the WRA it is an offence to "cause or knowingly permit" pollution of controlled waters. "Pollution of controlled waters" is also used in the EPA regarding the definition and designation of contaminated land.

5.2.4 Each of the alternative options would retain an increased level of seawater adjacent to the coast, which would cause intrusion of saline water into 'freshwater' strata. The amount of intrusion that takes place would be a function of the increase in height of the impounded waters, which is least for L3d and greatest for L2, and of the permeability of the deposits adjacent to the impoundments. As explained in Section 2, however, the majority of the deposits are of low permeability (see paragraph 2.1.12), nevertheless, each of the alternative options would contravene a strict interpretation of the current statute, as provided in the WRA.

5.2.5 Implementation of the WFD will be achieved, partly through activation of existing legislation and partly through new statute, however the legislation associated with controlled waters within the WRA will not be revised. Within the WFD, pollution is defined as the "direct or indirect introduction of substances as a result of human activity." Under this definition, the increase in saline intrusion that would occur naturally as a result of increased sea levels due to climate change would not constitute pollution. Increased saline intrusion that occurred as a result of human activity would, however. This suggests that each of the alternative options would contravene a strict interpretation of the WFD because of the human activity involved in construction, even though the amount of such intrusion and the risk it presented would appear to be small.

Geological and / or Geomorphological SSSIs

5.2.6 Under CRoW, relevant authorities have a responsibility to "take reasonable steps to further the conservation and enhancement of…geological or physiographical features by reason of which the site is a SSSI." Each of the alternative barrage options fail this requirement, to a greater or lesser degree.

Flooding Caused by Raised Groundwater Levels

5.2.7 Under the WRA the EA has permissive powers for the management of flood risk arising from designated main rivers and the sea. It is responsible for ensuring that new development does not increase the risk of flooding to life and property and as such, normally takes a precautionary approach until a development is shown not to increase flooding risk. Since the publication of PPS25 this has increasingly included consideration of the risk of flooding from groundwater to which specific reference is made (DCLG, 2006). No such reference is made in the Welsh guidance in TAN15 (paragraph 2.3.9). Although there is no organisation with a statutory obligation for responding to groundwater flooding (EA, 2008), it is likely that any development that was likely to cause increased groundwater flooding of property in either Wales or England would receive strong objection from the EA until that risk had been removed.

Alternative Option B3: Brean Down to Lavernock Point Barrage

5.2.8 The main areas where this alternative option does not comply with existing legislation are:

- Pollution of controlled waters along the impounded coastal fringe under WRA;
- Conservation and enhancement of geological and geomorphological SSSIs under CRoW; and
- Groundwater flooding of property, which appears likely in parts of Weston-super-Mare.

Alternative Option B4: Shoots Barrage

5.2.9 The main areas where this alternative option does not comply with existing legislation are:

- Pollution of controlled waters along the impounded coastal fringe under WRA; and
- Conservation and enhancement of geological and geomorphological SSSIs under CRoW.

Alternative Option B5: Beachley Barrage

5.2.10 The main areas where this alternative option does not comply with existing legislation are:

- Pollution of controlled waters along the impounded coastal fringe under WRA; and

- Conservation and enhancement of geological and geomorphological SSSIs under CRoW.

Alternative Option L2: Welsh Grounds Lagoon

5.2.11 The main area where this alternative option does not comply with existing legislation is:

- Pollution of controlled waters along the impounded coastal fringe under WRA.

Alternative Option L3d: Bridgwater Bay Lagoon

5.2.12 The main area where this alternative option does not comply with existing legislation is:

- Pollution of controlled waters along the impounded coastal fringe under WRA.

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 Significant effects have been identified in relation to geological / geomorphological SSSIs, soils and subterranean assets and a provisional framework for monitoring these receptors is presented in Table 5.1. For an alternative option (or options) to be effective, however, this would need to be based on a greater degree of baseline information than is currently available. Where this is obtained, monitoring requirements would be limited to confirmation of the actual sea level rise at those locations where changes were predicted. The data collection is described briefly below.

Geological / Geomorphological SSSIs

5.3.4 The SSSI citations rarely provide sufficiently detailed information for the significance to be assessed objectively within a ‘desk-based’ review. Where specific information has been provided in this report, such as in the case of the entrance to the Otter Hole cave system, this has been obtained from first-hand knowledge of the respective CCW officers, however obtaining this level of detail has rarely been possible. Should one of the alternative options considered within this report pursued beyond SEA stage, the following detailed baseline information should be obtained for the geological / geomorphological SSSIs downstream of the tidal limit at Gloucester seaward as far as Bude on the English side and round the Welsh coast as far as the northern extremity of Cardigan Bay:

- The type of exposure (eg whether wave-cut platform or cliff sections);
- The nature of the important outcrop in terms of its resistance to erosion (eg whether hard rock or soft sediment);
- The importance of the inter-tidal exposures in relation to the rest of the designation, particularly inland of the line of B3;
- The elevations of the important outcrops within the designations.

5.3.5 It should be noted that information may need to be gathered beyond this area, should any subsequent update of the H&G modelling indicate far-field effects beyond the Cardigan Bay area.

5.3.6 This information would allow the preliminary assessment presented herein to be revised on a more objective and consistent basis. Some may be available within the GCR. When available, 'monitoring' would be limited to confirmation of the actual change in water level and the extent of exposures that were lost by submergence.

Subterranean Assets

5.3.7 Monitoring of the water table elevation and its natural variation is required in order to assess the effect of an alternative option on subterranean assets, however before such information can be used effectively the following information will be required:

- Details of the assets that might be affected, such as type, condition, elevation (including invert elevations); and
- The type of ground within which they sit, including its physical, hydraulic and chemical characteristics and the vertical and lateral extent and variations of this material, including Made Ground, and its hydraulic connection to the surface water system.

5.3.8 A significant amount of relevant information is available in records of ground investigations adjacent to the estuary and in the 'grey' literature.

Soils

5.3.9 Similarly, management of soils which could be both adversely and positively affected an alternative option by increased soil wetness could benefit from better information regarding the local water table elevation and its variation. Before such information could be used effectively, however, a soil condition survey would need to be undertaken over the area potentially affected.

5.3.10 A summary of the monitoring likely to be required is presented in Table 5.1.

Table 5.1 Monitoring of Significant Environmental Effects

Significant Effect	Relevant Receptor	Description of Monitoring
Loss of access to geological / geomorphological SSSIs by submergence Possible 'far-field' effects	Geological / geomorphological SSSIs	Confirmation of rise in mean low water level and extent of exposures lost should an alternative option be implemented.
Loss of functionality and degradation of subterranean assets such as basements and services	Basements of buildings; Other subterranean assets, such as services	Water table elevation and its variation in vicinity of buildings and services deemed potentially 'at risk'.
Loss of soil resource due to increased soil wetness / waterlogging	Soils	Water table elevation and its variation in soils deemed potentially 'at risk' and the relationship with surface water elevations and flows in adjacent watercourses. This could be undertaken in parallel with suggestions for Flood Risk & Land Drainage and Terrestrial and Freshwater Ecology (2010e).

5.4 Areas for Further Research

5.4.1 An increased level of understanding in the flowing areas would be advantageous in reducing the levels of uncertainty associated with this assessment:

Geological / Geomorphological SSSIs

- Further baseline detail on geological/geomorphological SSSI designations, as outlined in paragraph 5.3.4;
- The feasibility and associated cost of providing an alternative access into Otter Hole;
- The feasibility of off-setting significant effects to SSSIs, through other GCR sites.

Subterranean Assets

- Further baseline information regarding subterranean assets, within low-lying land near the coastal fringe, as outlined in paragraph 5.3.7. This is particularly important in the vicinity of Weston-super-Mare, as well as other urban centres near the coast. In low-lying Cardiff, much of this information should already be available from the Cardiff Bay scheme.
- A high-level review should be made of the post-closure closure monitoring information available from the Cardiff Bay scheme to identify actual versus predicted effects from the impoundment on subterranean infrastructure .

- Further information on the Quaternary and recent deposits adjacent to the Severn estuary, in which infrastructure sits, including its physical and hydraulic characteristics and ground elevations.

- The distribution and nature of Made Ground deposits should be reviewed, as well as its potential influence on groundwater quality within the coastal margin.

Soils

- Further baseline information on the distribution of the different soil types, their current condition and quality, and vulnerability to changes in soil moisture, as outlined in paragraph 5.3.9.

SECTION 6

GLOSSARY

6 GLOSSARY

Term	Definition
Abstraction	Removal of water from either surface water or groundwater resources for a particular use. See also licensed abstraction.
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.
Aquifer	A water-bearing rock or unit of strata that contains and is able to transmit sufficient water to be able to maintain water supplies
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.
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	he 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	he generator is mounted in a bulb on the main turbine axis upstream of the runner blades for one way generation. Bulb turbines can be used for one or two way generation depending on the type (see above).
Caissons	Prefabricated concrete units used to construct parts of a barrage, lagoon or other offshore structures. Caissons can be used to house turbines, sluices or to construct navigation locks, or they may just be plain units used for impoundment construction.
Coastal Squeeze	Process whereby the coastal margin is squeezed between a fixed landward boundary and the rising sea level.
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage. Only used in relation to the Habitats Directive (see offsetting, below).
Consequential development	It is conceivable that a major tidal power scheme will facilitate or attract other developments, which may themselves pose significant environmental effects. These developments are described as 'consequential developments'.
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

Term	Definition
	the plan have a combined effect.
Direct effects	The original effect as a result of an option (see indirect effects)
Drift Geology	Material of Quaternary age or younger, typically unconsolidated, the result of recent earth processes. Often referred to as superficial geology.
Ebb	When the sea or tide ebbs, it moves away from the coast and falls to a lower level.
Ebb mode	One way generation on ebb tides only i.e. during the period between high tide and the next low tide in which the sea is receding.
Ebb and flood mode	Two way generation during the ebb and flood tides
Effect	Used to describe changes to the environment as a result of an option (see also direct effects, indirect effects, far-field effects and cumulative effects)
Eutrophication	An increase in chemical nutrients (compounds containing nitrogen or phosphorus). This in turn can lead to 'eutrophication effects' – an increase in an ecosystem's primary productivity (excessive plant growth and decay), and further effects including lack of oxygen and severe reductions in water quality, fish, and other animal populations.
Far-field effects	Effects that are felt outside the Severn Estuary study area.
Flood	The inward flow of the tide - This is the opposite of ebb. This refers to a mode of operation for a STP alternative option.
Future baseline	Baseline during construction (2014-2020) and operation (2020-2140), decommissioning and longer term trends.
Geomorphology	The study of the changing form of the estuarine environment and its components in relation to physical forcing.
Groundwater	Water present within the ground, regardless of geological strata.
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.
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	If the timescale for a receptor's return to baseline condition is greater than 50 years then it will 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.
Licensed abstraction	An abstraction licensed under the Water Resources Act 1991 or preceding legislation.

Term	Definition
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.
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 will last at least for 50 years.
Phase 1	The initial stage of the STP Feasibility Study - i.e. the Decision Making Assessment Framework (to develop a short-list of options) and SEA Scoping.
Phase 2	The second stage of the STP Feasibility Study - i.e. short-listed options appraisal and main assessment stage of the SEA.
Positive effects	Changes which are favourable for a receptor. Can sometimes be referred to as 'beneficial'.
Pumping	Operating turbines in reverse to pump water from lower to higher levels. Pumping can be used during one way generation to raise impounded water levels so that more energy can be generated when the ebb tide is receding.
RAMSAR site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Reversible	If the timescale for a receptor's return to baseline condition is less than 50 years then it will be considered reversible.
Scoping	The process of deciding the scope and level of detail of an SEA, including the environmental effects and alternatives which need to be considered, the assessment methods to be used, and the structure and contents of the Environmental Report.
SEA objective	A statement of what is intended, specifying the desired direction of change in trends.
Seabed	The areas permanently covered by the sea, i.e. below Lowest Astronomical Tide. Sometimes referred to as sub-tidal.

Term	Definition
Severn Estuary	This is the physical extent of the Estuary and does not reflect the Study Area (see below) or nature conservation designations. Downstream limit - headlands at Lavernock Point on the Welsh coast and Brean Down on the English coast passing through the small island features of Flat Holm and Steep Holm. Upstream limit – Haw Bridge, upstream of Gloucester on the River Severn (based on 1 in 100 year flood risk area and also used by Shoreline Management Plan (SMP) (Gifford, 1998) and Coastal Habitat Management Plan (CHaMP) (ABPmer 2006)). N.B. The tidal limit, which for the Severn is at Maisemore (West Parting) and Llanthony (East Parting) weirs, near Gloucester.
Severn Tidal Power Study Area	The general study area used for the project broadly extends downstream on the Estuary as far as Worm's Head to Morte Point. It includes the landward fringe and tributaries such as the River Wye and the River Usk. Study areas for individual topics for Phase 2 may extend beyond this area and these are defined separately according to topic.
Short-listed options	Options screened from long-listed options, to be taken forward for analysis in the SEA following the public consultation conducted in 2009.
Significant environmental effects	Effects on the environment which are significant in the context of a plan or programme. Criteria for assessing significance are set out in Annex II of the SEA Directive (2001/42/EC).
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Sluice caissons	Prefabricated concrete structures placed into the water to house a sluice.
Solid Geology	Material underlying deposits of Quaternary age, typically consolidated. Often referred to as bedrock geology.
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.
Surface Water	Water present at the ground surface or, in the case of flooding, above the ground.
Synergistic effects	Effects which interact to produce a total effect greater than the sum of the individual effects, so that the nature of the final impact is different to the nature of the individual effects. Included within cumulative effects (see above).
Temporary effects	An effects which only lasts part of the project lifetime, e.g. is confined to the construction period.
The Shoots	The downstream boundary extends from Undy along the Welsh coast to Severn Beach along the English coast, just to the south of the M4 motorway crossing. The upstream limit extends just to the north of the M46 motorway crossing,

Term	Definition
	between Beachley on the Welsh coast and Aust on the English coast.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary
Transboundary Effects	An environmental effect upon another EU Member State.
Turbine caissons	Prefabricated concrete structures placed into the water to house turbines.
TWh/year	A unit used to describe how much energy generated, sold, consumed, etc. A terawatt-hour refers to generating or using power at a capacity of 1 terawatt (1012 watts) for one hour. A terawatt-hour per year means the equivalent amount of power sometime within the period of a year.
Two way generation	The operating mode whereby power is generated on both phases of the tidal cycle (ebb and flood)
Upper Severn Estuary	Upstream from the M46 motorway crossing, between Beachley on the Welsh coast and Aust on the English coast, to the tidal limit along the River Severn at Maisemere, Gloucestershire.
Variant	A modified version of the original shortlisted scheme.

SECTION 7

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7 REFERENCES

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FIGURES

APPENDICES

APPENDIX A

PAPER ON RECEPTOR VALUE, VULNERABILITY AND IMPACT MAGNITUDE (PB/BV, SEPTEMBER 2009)

APPENDIX B

DETAILS OF DESIGNATED CONTAMINATED LAND WITHIN STUDY AREA

APPENDIX C

DETAILS OF LICENSED SURFACE WATER ABSTRACTIONS WITHIN STUDY AREA

APPENDIX D

DETAILS OF LICENSED GROUNDWATER ABSTRACTIONS WITHIN STUDY AREA

APPENDIX E

DETAILS OF GEOLOGICAL AND GEOMORPHOLOGICAL SSSIS WITHIN STUDY AREA