National Assembly for Wales

Severn Estuary Tidal Power: Supplemental Information
May 2010

Together with the Severn Estuary Tidal Power research paper, this report provides briefing on the current Severn tidal power situation and includes detailed analysis of the short listed proposals.

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May 2010

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1. Middle barrage (Cardiff – Weston)

1.1. Construction

Construction of caissons[1] and turbines and the employment of general construction labour are the three greatest components that will impact socially and economically on local areas.[2] There is great uncertainty regarding the displacement, or 'leakage' of construction related economic benefits from local to national or even international areas. The sheer number of turbines required in a large (Cardiff – Weston) barrage may result in the turbines being constructed in the region.[3] A smaller barrage for example may see an increased leakage of turbine construction out of the immediate area as technology is sourced from elsewhere. The issue of leakage affects all areas of construction. Turbines have been used as an example as they represent a substantial element of the overall project cost.[4]

1.2. Timeline

The Severn Tidal Power Group (STPG) consider that the Cardiff – Weston barrage could be built in approximately seven years, depending on the number of work yards made available for the construction of caissons, and on the sizes of ship locks[5] required. The ship locks are a key element of a barrage construction and must be completed before the installation of turbine caissons starts to obstruct shipping lanes.[6]

Lord Hunt, Minister of State, Department of Energy and Climate Change gave evidence to the Energy and Climate Change Committee regarding the Severn Tidal Power (STP) schemes timelines: [7]

> If next year it is decided by the Government that we should go forward with one of those schemes, the timescale probably for a smaller scheme might, if it goes well, just allow for one of those schemes to be operational before 2020, though clearly there is an awful lot of work that needs to happen.
>
> On the biggest scheme I would have thought it was very unlikely that it could be up and running by 2020. On the smaller schemes, although challenging, I think it is possible that one of those schemes could be up and running by 2020. Clearly 2020 is an interim target. We are on a journey towards a low-carbon energy structure, so that even if one of these schemes was not able to help us towards the 2020 target, it could help us in the next phase going up to 2050.

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[1] Caissons are watertight chambers used in the construction of foundations in or near a body of water.
[2] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[3] *ibid*
[4] *ibid*
[5] Ship locks are used for raising and lowering ships between bodies of water of differing levels.
[6] Sustainable Development Commission, *Tidal Power in the UK Research Report 3 – Severn barrage proposals*, October 2007 [Accessed on 29 March 2010]
[7] UK Parliament, House of Commons, Energy and Climate Change Committee, Severn Estuary Tidal Power Projects, *HC1011-I*, 14 October 2009 [Accessed on 29 March 2010]

> It is very challenging for 2020. You can construct a timetable, particularly for the smaller schemes, that could show that some of them could be generating electricity by 2020, but clearly I am not quite sure how much optimism bias one needs to put into that in order to get to 2020.

1.3. Projected cost

Given that over £20 billion (bn) of finance would be required for the Cardiff-Weston scheme it is unlikely that the private sector would be able to carry the cost risk of this scheme alone. Taxpayers/consumers would likely bear a large part of the cost burden and risk.[8] The original cost estimate given by the Sustainable Development Commission (SDC) report, *Tidal Power in the UK Research Report 3 – Severn barrage proposals*, prior to the short listing process was £15bn. [9] This has subsequently been amended in the UK Government response to the phase one consultation to a figure of £20.9bn.[10] Further to this costing, Ms Sarah Rhodes, Acting Director for the Office of Renewable Energy Deployment, gave evidence to the Energy and Climate Change Committee and stated:[11]

> The £21 billion itself will change. What is included within that is the capital cost of construction. There is also an element of compensatory habitat cost within that. There is 15 per cent contingency. What we will need to do and what we are doing is to strip out that 15 per cent and put in an optimism bias assessment. We will need to factor in things like Grid costs. We will need to factor in any other environmental costs; for example, if we find that there are changes to flood defences that too would be a cost on the project. So there are a whole series of different calculations that will be made, and we will see where that figure comes out.

1.4. Socio-economic impacts

The main cities along the Severn Estuary are Cardiff, Swansea, Newport, Port Talbot, Bristol, Gloucester, Cheltenham and Weston-Super-Mare. Included within these are major trading ports, industry, mining, commercial fishing, manufacturing, wholesale, retail, hotels, restaurants and real estate. Tourism and recreation are also hugely important in these areas. A STP scheme is likely to have a significant impact on these populations and economies although the magnitude of impacts will vary between proposals.

DTZ were commissioned during the first phase of the feasibility study to undertake an initial regional economic impacts study. The aim of the study was to 'undertake an

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[8] Department of Energy and Climate Change, *Severn Tidal Power Phase One Consultation*, January 2009 [Accessed on 29 March 2010]
[9] Sustainable Development Commission, *Tidal Power in the UK Research Report 3 – Severn barrage proposals*, October 2007 [Accessed on 29 March 2010]
[10] Department of Energy and Climate Change, *Severn Tidal Power Phase One Consultation – Government Response*, July 2009 [Accessed on 29 March 2010]
[11] UK Parliament, House of Commons, Energy and Climate Change Committee, Severn Estuary Tidal Power Projects, *HC1011-I*, 14 October 2009 [Accessed on 29 March 2010]

initial assessment of the potential economic impact of the proposed Severn Tidal Power project on the regional economies of Wales and the South West of England'. [12]

The main conclusions regarding the impact of construction of a large barrage were that 'construction expenditure will support temporary employment in the industry during the development period: the higher the development cost the more employment will be supported'. [13]

The scale of the Cardiff-Weston barrage means it is likely that:[14]

> Substantial leakage will take place. In particular, the Economic Impact Assessment workshop highlighted that a high proportion of materials are likely to be imported given the scale of the materials required.

The STP Strategic Environmental Assessment (SEA) scoping topic paper on society and the economy estimated that the construction of a large barrage would result in approximately 17,600 direct and indirect employment opportunities per annum. This is contrasted with 3,600 opportunities for a small barrage or lagoon option.[15]

1.4.1. Transport and logistics

The DTZ impact assessment focused primarily on the impact of STP proposals upon port usage. Impacts of a Cardiff-Weston barrage '…range from a loss of £1.9 billion Gross Value Added (GVA) (worse case scenario) to a loss of £710 million GVA (best case scenario). At the peak this impact equates to 3,300 jobs (with a range of 2,200 to 4,400) or an annual average ranging from 1,800 jobs (worst case scenario) to 600 jobs (best case scenario)'.[16]

A further impact upon Bristol Port has been noted with regards to the Deep Sea Container Terminal (DSCT) project. It is considered that this project would be less viable with a large barrage option. Bristol Port has stated that investment associated with the DSCT project is likely to be around £500 million.[17] The possible impacts of this were not considered in the DTZ analysis as there is an element of uncertainty regarding the DSCT project irrespective of a STP proposal. The Bristol Port Company's response to the UK Government phase one consultation states: [18]

> In light of this very real threat to future shipping and commercial operations, Bristol Port objects strongly to any seaward barrage options (including tidal reef and fence technologies) being included in any future short list.[…] Bristol Port is located downstream of these barrages where

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[12] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[13] *ibid*
[14] *ibid*
[15] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society and Economy*, December 2008 [Accessed on 29 March 2010]
[16] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society and Economy*, December 2008 [Accessed on 29 March 2010]
[17] Bristol Port Company, *response to UK Government STP Phase one consultation*, April 2009 [Accessed on 29 March 2010]
[18] *ibid*

> the true deepwater channel ends. However, in the same area the channel (with very unstable adjacent sandbanks) narrows to only about 300 metres in width and also shallows rapidly. The Future operation of deep draught vessels depends on the maintenance of this (fragile) navigational *status quo* in the local geomorphology. Accordingly, we view it as being essential that detailed and extensive studies are conducted to establish any likely geomorphological change caused by upstream barrages and consequential effects on navigational channels.

Bristol City Council strongly opposes any STP scheme that would be predicted to undermine the operation of Bristol Port and comment that: [19]

> Given the savings in road haulage emanating from the use of Bristol Port, as opposed to other south and east coast ports (due to its much closer proximity to the urban populations of the Midlands), any scheme that threatened Bristol Port would surely be counterproductive to the country's carbon reduction efforts any way.

Alternative ports in Wales and South West England may not be of a scale large enough to capture the majority of 'lost' port traffic which would then be displaced to competitor sites elsewhere in the UK or overseas.[20]

1.4.2. Tourism

Over £1bn of tourist revenue is made in Somerset, Avon and South East Wales from 7.5 million UK visitors per year.[21] The tourist industry accounts for over half of coastal and marine sector direct jobs in the region of South East Wales, approximately 73,000, equalling £1.6 billion in terms of GVA.[22] The STPG *Energy Paper 57* suggests that tourism for the region may increase by the order of 5 per cent to 20 per cent.[23] One reason for this increase is that the less severe tidal conditions within the Severn Estuary may stimulate greater water-based recreational usage.

The Welsh Government's tourism water sports activities and facility development strategy, *Catching the Wave 2004*, aims to substantially increase revenue generated from the water sports market.[24]

The *Countryside and Rights of Way Act (2000)* includes a commitment for open access or the 'right to roam', for certain uncultivated areas of England and Wales. This measure has the potential to open access to areas which have historically received little tourism or recreation.[25] Further to this, the Welsh Government's strategy to have

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[19] Bristol City Council, *response to UK Government STP Phase one consultation*, April 2009 [Accessed on 29 March 2010]
[20] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[21] Department of Energy & Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, p28, December 2008 [Accessed on 29 March 2010]
[22] Department of Energy & Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society and Economy*, December 2008 [Accessed on 29 March 2010]
[23] The Severn Barrage Project: General Report: Energy Paper 57; HMSO 1989.
[24] Welsh Government, Press Release, *Catching the wave,* 17 September 2004, website [Accessed on 29 March 2010]
[25] *The Countryside and Rights of Way Act 2000*, (chapter 37) [Accessed on 29 March 2010]

an All Wales Coastal Path should be completed by 2012 and this will also extend access to the coast.[26]

A tidal barrage option will also have an effect on the Severn bore phenomenon. It is unclear at this stage whether the occurrence of the bore could be preserved by halting generation from the barrage and allowing water levels to recover to their natural levels at the time of a predicted bore. [27]

The DTZ study also estimated a value range based on the number of visitors to the barrage site itself once construction was complete. Based on a comparison with La Rance (200,000 per annum) and the Thames Barrier (13,000 per annum) visitor numbers, the study concluded that between a £27.4 million (high scenario of 400,000 visitors per annum) and £3.4 million (100,000 per annum) regional impact.[28]

1.5. Fisheries

Taken from the fish STP SEA scoping paper, the comment below describes the current economic situation of the fishing industry within the Severn Estuary.

> …the rivers entering the Severn Estuary support a diverse range of fisheries, including coarse, migratory salmonids and eel. River angling is a major recreational pastime, and contributes considerably to the regional economy. The Rivers Severn, Usk, Wye and Taff alone represent 8% of the England and Wales salmon rod catch. Sea angling in the Bristol Channel is of recreational importance although there is relatively little commercial fishing activity in the area. […] The fishery is now small and as a result of buyouts, however the remaining fisheries are traditional and often unique and as such are of cultural and heritage importance.[29]

The scoping paper also comments that the impact of any specific STP proposal upon the fisheries is a relative unknown. The DTZ assessment comments that '…the scale of impact is not substantial at a Wales and South West of England level (i.e. will not have a significant impact on the whole economy). The impacts will primarily be contained to rural and coastal areas where angling activity takes place'. [30] The Environment Agency believes that the DTZ assessment did not fully consider the wider impacts upon the Severn Estuary as an important nursery ground.[31]

> The Severn Estuary is important as a nursery area. These stocks support fisheries over a very widespread area. The DTZ study has confined its consideration of impact to the narrow geographic region defined. It is important to recognise that the value of fish and fisheries are not

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[26] Welsh Government, Press Release, *First Minister announces plans for all Wales coastal path*, 9 June 2006 [Accessed on 29 March 2010]
[27] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society and Economy*, p46, December 2008 [Accessed on 29 March 2010]
[28] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p129-130, January 2009 [Accessed on 29 March 2010]
[29] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Migratory & Estuarine Fish*, December 2008 [Accessed on 29 March 2010]
[30] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[31] Environment Agency, *Environment Agency Response* to Department for Energy and Climate Change, SW regional development agency, Welsh Government Consultation, April 2009 [Accessed on 29 March 2010]

only reflected by employment and income in this region. We believe that it would be helpful to pull all the fish and fisheries evaluations together.

In written response to the UK Government's phase one consultation, the Wye and Usk Foundation, the Angling Trust, Wye Salmon Fishery Owners Association and the United Usk Fishermen's Association commented that 'Salmon are currently the most economically important of the Severn Estuary fish and this stems from a recreational rather than commercial value'.[32]

The Bristol Channel is extensively fished both by local and visiting commercial boats from the EU. A number of reviews have documented the commercial fishing interests within the Severn Estuary. Salmon and eels are commercially the two most important species and three nationally important salmon fisheries (Severn, Wye and Usk) are located within the study area of the STP feasibility SEA and represent 8 per cent of the total England and Wales salmon catch.[33]

1.6. Environmental impacts

According to the STP SEA terrestrial and freshwater ecology scoping paper, predicted ecological impacts of the STP proposals would include some or all and would not be limited to the following:[34]

- Permanent and temporary habitat loss
- Habitat fragmentation
- Habitat degradation
- Disruption of Ecological networks
- Species mortality
- Disturbance (direct and indirect including noise and vibration, visual)
- Pollution (air, ground and water)

1.6.1. Terrestrial and freshwater ecology

The Severn Estuary encompasses a wide range of terrestrial and freshwater ecology features and includes sites designated under European legislation. These include a number of Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar sites. In addition to these areas there are also a large number of Sites of Special Scientific Interest (SSSIs) and a small number of National Nature Reserves

[32] *Wye and Usk Foundation, Angling Trust, Wye Salmon Fishery Owners Association, United Usk Fishermen's Association, response to STP phase one consultation*, April 2009 [Accessed on 29 March 2010]
[33] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, December 2008 [Accessed on 29 March 2010]
[34] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Terrestrial and Freshwater Ecology*, December 2008 [Accessed on 29 March 2010]

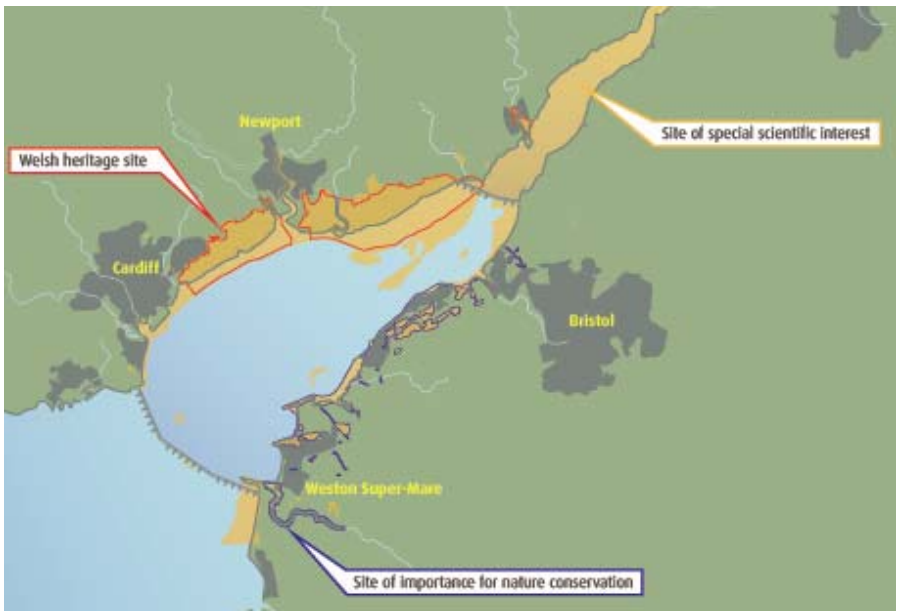
(NNRs). The designated sites are in varying conditions ranging from favourable, mixed condition and unfavourable.[35] Furthermore, within the study area there are known to be Local Nature Reserves (LNRs), locally designated wildlife sites and assemblages of flora and fauna protected under European and UK wildlife legislation, UK Biodiversity Action Plan (BAP) priority species and habitats and Local Biodiversity Action Plan (LBAP) habitats and species.[36]

The large Cardiff-Weston barrage is likely to have far reaching direct and indirect effects on terrestrial and freshwater ecology within the Severn Estuary. Wetland sites and species that rely on areas with specific hydrological regimes are likely to be most affected, however all habitats and species will be affected to some degree.[37] Terrestrial habitat loss is a certainty for all STP options however it is expected that the Cardiff-Weston barrage will result in the greatest loss both as a result of the large construction process and from the reduction of tidal range over the large area.[38]

Figure 1. Showing areas of high value habitats and their international protection[39]

[35] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Terrestrial and Freshwater Ecology*, December 2008 [Accessed on 29 March 2010]
[36] *ibid*
[37] *ibid*
[38] *ibid*
[39] Sustainable Development Commission, *Review of the Severn Barrage Proposals*, July 2007 [Accessed on 29 March 2010]

Figure 2. Showing high value habitats and their local protection designations. [40]



To date no studies have examined in detail terrestrial and freshwater ecology considerations arising from a tidal energy development within the Severn Estuary. The absence of such information presents some limitation when considering the effects of specific tidal power schemes.[41]

Certain fish species located within the Severn Estuary or its tributaries are protected under the *EU Habitats Directive*.[42] These include: Atlantic Salmon, Allis and Twaite Shad, and sea and river Lamprey. There are also socio-economically important species including the Sea Trout and endangered Eel.

The Cardiff-Weston barrage is predicted to have the greatest impact upon freshwater ecology, in comparison to other STP proposals, due to its location impounding the greatest volume of water. The Cardiff-Weston barrage will have a basin area of approximately 480km^2 at mean sea level, compared to the basin area of the Shoots barrage of 90km^2.[43]

1.6.2. Ornithology

The RSPB are opposed to a Cardiff-Weston barrage:[44]

> We are sceptical that the Cardiff-Weston barrage is a viable option. The level of environmental destruction that would result from the Cardiff-Weston proposal, which would be extremely difficult to adequately compensate for, coupled with the huge financial cost means that it is difficult to see how this could be a viable option for harnessing the Severn Estuary's potential for renewable

[40] Sustainable Development Commission, *Review of the Severn Barrage Proposals*, July 2007 [Accessed on 29 March 2010]
[41] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Terrestrial and Freshwater Ecology*, December 2008 [Accessed on 29 March 2010]
[42] *The Conservation (Natural Habitats, &c.) Regulations*, SI 1994/ 2716 [Accessed on 29 March 2010]
[43] Sustainable Development Commission, *Review of the Severn Barrage Proposals*, July 2007 [Accessed on 29 March 2010]

> power. Including the Cardiff-Weston barrage on the short list risks it sucking resources away from investment in technology that could be both sustainable and transferable to other estuaries.

The 2005-06 Wetland Bird Survey concluded that a total of 68,000 over-wintering waterfowl, including five species of international significant and a further ten species of national importance utilise the Severn Estuary.[45] Under the provision of the *EU Birds Directive*, much of the Severn Estuary upstream of the proposed Cardiff-Weston barrage is designated as a Special Protection Area.[46] In addition to this the estuary is designated under the international Ramsar Convention due to its significant numbers of wetland bird species. A proposed build would be required to develop compensatory habitat which RSPB Cymru consider would be a difficult undertaking:[47]

> [...] UK Government would have a legal responsibility to find an alternative, compensatory site for the species and habitats put at risk by the decision to proceed. However, locating alternative habitat equivalent to that which would be lost from the Severn would not be easy, if indeed possible at all. The designated bird species currently feed from 14,000 hectares of inter-tidal mudflats and sandflats – equivalent in area to around 35,000 football pitches! The equivalent new habitat would need to be found within the geographical "flyway" of the displaced bird species, with the additional costs down to be met by the project developers – such costs could easily exceed £1billion. Moreover, the new site would need to be made ready before any work could begin in the Severn itself.

It is an agreed consensus that barrage structures in general reduce tidal range and as a result reduce the area of intertidal habitat. This may in turn reduce the area available to birds for feeding. The Cardiff-Weston barrage is estimated to reduce the area of intertidal habitat within the Severn Estuary by 20,000 hectares. Further impacts of barrage structures on bird life include a reduction in feeding time as intertidal habitats are exposed for shorter lengths of time.[48] Finally there is the possibility that a reduction in the submergence of long established saltmarshes may lead them to becoming fresh water marshes, or even dry out altogether. It has been suggested that this could be mitigated by flood pumping.[49] It has also been suggested that the sediment composition of intertidal habitats may impact on the feeding efficiency of bird species. One the most numerous waterbird species found in the Severn Estuary is the Dunlin. [50] These birds were found to group concentrate their feeding patterns on sediments containing a higher percentage of silt and clay. [51] It is proposed that the Dunlin wintering on the Severn could be maintained in a post barrage landscape if the proportion of silt and clay in the intertidal sediments was increased by 10 per cent.

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[44] Royal Society for the Protection of Birds, *response to Severn Estuary Tidal Power Feasibility Study Phase One Consultation*, April 2009 [Accessed on 29 March 2010]
[45] Royal Society for the Protection of Birds, Press Release, *New Report Reveals the Ups and Downs of Wales' Waterbirds*, 19 February 2010 [Accessed on 29 March 2010]
[46] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, December 2008 [Accessed on 29 March 2010]
[47] Royal Society for the Protection of Birds, *Large-scale Renewable Energy and the Proposal for a Severn Barrage,* November 2008
[48] Clark N.A. (2006) Tidal Barrages and Birds, *Annual Spring Conference of the British-Ornithologists-Union,* University of Leicester.
[49] *ibid*
[50] McCulloch, N & Clark, N.A. (1992) Habitat Utilisation by Dunlin on British Estuaries, *BTO Research Report 86.*
[51] *ibid*

Intertidal habitats would have to be protected from wave erosion for this to be the case.[52]

Overall a reduction in intertidal habitat is likely to result in a reduced abundance of birds wintering within the Severn Estuary as they seek food elsewhere. A study looked at the effect of relocating the Redshank as a result of the formation of the freshwater lake in Cardiff Bay due to the construction of the barrage. Individual Redshanks were observed to have a reduced survival rate for at least three years following relocation brought about by the construction of the Cardiff Bay barrage. [53] The cause of this was not considered to be a result of birds moving to lower quality feeding sites, as the survival rate of birds wintering at the new site in previous years was unchanged. [54]

1.6.3. Bird watching

There are a number of popular bird watching sites including Bridgewater Bay, the Gwent Levels, the Caldicot Levels, Newport Wetland and Slimbridge. The latter attracts approximately 200,000 visitors a year. [55] It is likely that the predicted reduction in waterbird numbers within the Severn Estuary will have a negative impact on the popularity of the location as a bird watching site. To what extent the decrease in visitors will be displaced to other locations would depend on the position and success or failure of any compensatory habitats.

1.6.4. Marine ecology

The unique physical conditions, created by the high tidal range, are the evolutionary driving forces upon the composition, geographical distribution and abundance of flora and fauna within the Severn Estuary. Phytoplankton growth within the estuary is limited by the high turbidity in the water and significant growth occurs only towards the outer Bristol Channel.[56] The impact of a large barrage on the planktonic community is not known although the likely impact is being investigated in the marine SEA. Marine mammals are not common users of the highly turbid waters of the Estuary although seasonal sightings of harbour porpoise are seen to the west of Worms Head. As there are relatively few sightings of marine mammals within the Severn Estuary, it is believed that the potential for collision with barrage turbines would be low. [57] Provisions of the *Conservation Regulations 1994 (as amended)*[58] and Schedule 5 to the *Wildlife and*

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[52] Clark N.A. (2006) Tidal Barrages and Birds, *Annual Spring Conference of the British-Ornithologists-Union,* University of Leicester.
[53] Burton N.H.K, Rehfisch M.M & Clark N.A. (2003) The effect of the Cardiff Bay Barrage no waterbird populations – Final report *BTO research paper 343*
[54] *ibid*
[55] Black & Veatch, Tidal Power in the UK contract 3 – *Review of the Severn Barrage proposals*, Report for the Sustainable Development Commission, July 2007 [Accessed on 26 March 2010]
[56] Joint I.R. (1984) The Microbial Ecology of the Bristol Channel, *Marine Pollution Bulletin* 15, (2), p62-66
[57] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, December 2008 [Accessed on 29 March 2010]
[58] *The Conservation (Natural Habitats, &c.) Regulations 1994*, [Accessed on 29 March 2010]

Countryside Act 1981 (as amended)[59] bestow protection upon a variety of marine species, in particular marine mammals.

The *EC Water Framework Directive* (WFD) *(2000/60/EC)* sets out objectives for the quality of estuarine and marine waters relating to both the chemical and ecological quality of these waters. The impact of a STP development must be considered against the WFD objectives and this is being incorporated within the marine SEA.

The waters of the Severn Estuary are characterised by a high sediment load. A result of this is that these waters are not very productive as light penetration is poor and thus macroalgae are unable to photosynthesise. A large barrage option would reduce the upstream sediment load which may have the impact of increasing algae productivity with positive benefits being accrued up the food chain. Algae populations are also likely to thrive on the barrage structure itself which will provide a surface for attachment. It is likely that these changes would result in an alteration of species assemblage which is part of the character of the Severn Estuary.[60]

1.7. Geomorphology

It is widely recognised that the high-energy environment of the Bristol Channel and Severn Estuary is a dynamic system that responds to the influence of tides and storms, events that can move large quantities of sediments and alter channel morphologies.[61] This hydrodynamic character is partly due to the geographical location and partly due to its funnel shaped form. The majority of estuary-wide surveys on hydrodynamics and geomorphology originate from the period 1979 to 1980 under the guidance of the Severn Barrage Committee.[62]

A large-scale tidal power development within the Severn Estuary has the potential to redefine the pattern of tidal exchange over a wide area. Geomorphology is therefore considered as a fundamental component to other SEAs within phase two of the STP feasibility study. The effects of any short-listed option on present tidal regime may be immediate or manifest over the longer-term as the estuary evolves. The geomorphology STP SEA includes longer-term effects which might occur over the next 100 years including issues such as sea level rise.[63] The largest threat to the Severn Estuary over the next 100 years, with the exception of any major tidal project, is the increase in sea level and possibly Atlantic storm frequency. The combined effect of these issues is the potential for the loss of intertidal features.

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[59] *The Wildlife and Countryside Act 1981* (chapter 69) [Accessed on 29 March 2010]
[60] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, December 2008 [Accessed on 29 March 2010]
[61] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Hydraulics and Geomorphology*, December 2008 [Accessed on 29 March 2010]
[62] *ibid*
[63] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Hydraulics and Geomorphology*, December 2008 [Accessed on 29 March 2010]

The high-energy nature of the Severn Estuary, as a result of the large tidal range and strong tidal currents through the main body of the estuary, currently maintains the deeper channels to a more or less fixed depth. [64] The direction of currents is strongly influenced by the morphology of the seabed with currents aligned through the main channels. A barrage type structure has the potential to markedly alter the present pattern of flows within the estuary by impeding the passage of the tide.[65]

1.8. Flood risk

There is a general consensus that sea levels are rising with a related impact on flood risk for many low lying areas.[66] A 'do nothing' approach in relation to a STP project will take this into account when comparisons of flood risk impacts between STP proposals are made. The flood risk SEA will be heavily influenced by the geomorphology SEA.[67] Large areas of land along the coast of the Severn Estuary and Bristol Channel lie below the level of the highest spring tides and are susceptible to flooding. These areas are protected by tidal defence and land drainage systems. Certain natural features such as saltmarshes and marshland offer flood storage sites to reduce flood risk. About 47,000 residential and commercial properties associated infrastructure and amenity and agricultural land are located in these risk areas.[68] The Department for Environment, Food and Rural Affairs (DEFRA) has overall responsibility for sustainable flood and coastal erosion risk policy in England and the Welsh Government takes a similar role in Wales. Operating authorities such as the Environment Agency deliver the wider policies and have particular powers to manage, maintain and improve many of the flood defences and water level management systems.[69] A small number of defences remain the responsibility of other third parties and landowners.

The Environment Agency is currently undertaking '*The River Severn Strategies'* review to determine the strategic approach to flood risk over the next 100 years in the face of climate change, and in particular, sea level rise.[70] The flood risk effects of tidal power generation options must be considered in this context. The Cardiff-Weston barrage has a potential lifetime of 120 years.[71]

The key changes resulting from the development of the Cardiff-Weston barrage, in relation to flood risk, would include but not be limited to:

- Attenuation of surge tides

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[64] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Hydraulics and Geomorphology*, December 2008 [Accessed on 29 March 2010]
[65] *ibid*
[66] Intergovernmental Panel on Climate Change, Assessment Reports, *IPCC Fourth Assessment Report – Climate Change 2007*, website [Accessed on 29 March 2010]
[67] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Hydraulics and Geomorphology*, December 2008 [Accessed on 29 March 2010]
[68] Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, December 2008 [Accessed on 29 March 2010]
[69] Environment Agency, *What we do*, website [Accessed on 29 March 2010]
[70] Environment Agency, Floods, *The River Severn Strategies*, website [Accessed on 29 March 2010]
[71] Department of Energy and Climate Change, *Analysis of options for tidal power development in the Severn Estuary – Interim Option Analysis Report Vol. 1*, December 2008 [Accessed on 26 March 2010]

- Wave climate
- Reduction of tidal range

Barrage structures such as the proposed Cardiff-Weston barrage may have the potential to limit the transfer of surge tide peaks upstream and thus may have the beneficial effect of reducing surge floods.[72] Downstream effects of a barrage are less clear, although it is considered unlikely that there will be any significant tidal range alteration.[73]

The change in direction from east-west orientation of the Inner Bristol Channel to the north-east orientation of the Severn Estuary means that exposure to Atlantic swells is limited. Wave climate is considered to be largely wind generated. The Cardiff-Weston barrage is considered to have the potential to restrict wave action from the south west approaches, affecting existing defences. High tides will be held for longer and low tides will not be as low.[74] As a result of higher levels of impounded water it has been predicted that there may be the potential for increased erosion at the base of current tidal defences in many locations. Confirmation of this is being investigated in the flood risk STP SEA.[75] A further issue to be investigated is that of waves reflected downstream off the large Cardiff-Weston barrage structure.

Studies have indicated that a Cardiff-Weston barrage would reduce the upstream tidal range of the Severn Estuary by approximately 50 per cent.[76] Absolute levels throughout the tidal cycle for all locations will be determined as part of the flood risk SEA.[77] A reduction in tidal range would be important for any land drainage of other outfalls discharging into the upper estuary with certain sites of discharge becoming exposed to extended periods of 'tide lock'.[78]. Many outfalls currently experience periods of tide lock, but a barrage structure would extend this period as high tides are held for longer time periods.

Overall, the reduction in peak tide levels as a result of the Cardiff-Weston barrage is likely to reduce pressure on flood defences, particularly during storms. Depending on the location within the estuary, there is the potential for either a reduction (sheltering effects) or increase (greater average water depth) in wave energy. Finally as a result of increased occurrences of tidal lock, some sites may see an increase in flood risk due to a restriction on fluvial discharge.[79]

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[72] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, December 2008 [Accessed on 29 March 2010]
[73] *ibid*
[74] *ibid*
[75] *ibid*
[76] *ibid*
[77] *ibid*
[78] Tide lock is a term used to describe the restricting effect of high tide levels on free discharge from outfalls or natural river channels.
[79] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, December 2008 [Accessed on 29 March 2010]

1.9. Historic environment

The historic environment of the Severn Estuary is extremely significant in the UK and consists of both natural and built components.[80] The potential of the Severn Estuary is not limited to the number of nationally designated sites, but also includes many non-designated sites and finds, and has a high potential for the discovery of new finds. There are a considerable number of investigations on-going in the Severn Estuary which have included discoveries in intertidal areas of exceptionally well preserved historic evidence. The Severn Estuary is the focus of an academic journal, *Archaeology in the Severn Estuary*, published by the Severn Estuary Levels Research Committee.[81] This journal has been producing detailed accounts of fieldwork over the last 18 years. Historic environment is considered an irreplaceable, non-renewable resource and therefore alterations to it, and to its environment, must be carefully considered. Large areas of the Severn Estuary have not yet received systematic study, and research has focused on certain time periods to the neglect of others.[82] There is no regional framework within which to examine the importance of individual sites and finds.

The Somerset Levels and Moors have been proposed as a potential World Heritage Site (WHS). On the Welsh side of the Severn Estuary, the Gwent Levels are included on the non-statutory Register of Landscapes of Historic Interest and the designation extends into the intertidal area.

The potentially significant issues regarding the effects of developments include direct, indirect and secondary effects:

Direct effects include:

- Direct damage to structures, features, deposits and artefacts
- Disturbance of relationships between these and their wider surroundings

Indirect effects include:

- Changes to hydrodynamics, coastline, tidal movement, sedimentation, erosion, water level and water quality

Secondary effects:

- Access to roads and anchorages for construction vessels.

The STP SEA scoping paper on historic environment considered a large barrage proposal situated approximately at the point of the Cardiff-Weston barrage scheme. A

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[80] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]
[81] Department of Energy and Climate Change, Severn Estuary Levels Research Committee website, *Archaeology in the Severn Estuary*, December 2008 [Accessed on 29 March 2010]
[82] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]

hypothetical study area around this site was developed.[83] Contained within this site were 129 sites of archaeological evidence, 5 excavated shipwrecks or obstructions, and 53 recorded ship losses. This gives an indication as to the extent to which the historic environment of the Severn Estuary has yet to be unearthed.[84]

1.10. Navigation

As previously mentioned, the Severn Estuary is the location of a number of commercial ports including significant facilities at Bristol, Cardiff, Newport and Sharpness/Gloucester. The largest port, the Port of Bristol comprises both Avonmouth and Royal Portbury docks. The Royal Portbury dock was constructed in the 1970s and contains seven berths which can accept ships with a draught of 14.5 metres. Associated British Ports owns and operates both Cardiff and Newport ports. The Port of Cardiff can accept vessels of up to 10.3m draught and 35,000 deadweight tonnage (dwt). The Port of Newport can handle vessels up to 10.5m draught and 40,000dwt.

Sharpness Dock provides access to Gloucester via a canal and is under the jurisdiction of British Waterways as statutory harbour authority. There are heritage harbour facilities located at Lydney and Gloucester. Sharpness Dock can accept vessels of up to 6.5m draught and 10,000dwt.

In total the Bristol and South Wales ports and the services they provide handle around 3 per cent of the UK trade and are an important part of the local and regional economy, generating over 15,000 jobs collectively. The proximity of the Severn Estuary Ports to the main centres of demand reduces subsequent road and rail transport by comparison with other ports where transit times by road or rail may be longer and thus more expensive.

The Severn Estuary is also used by smaller non-commercial vessels for recreational use. The large tidal differences and significant current provide a challenging environment for smaller vessels. However, the Royal Yachting Association (RYA) formally carry out many water activities within the Severn Estuary including dinghy sailing, keep boat racing/cruising and motor boating. The RYA has 30 training centres or affiliated boating clubs within the SEA study area.[85]

The Cardiff-Weston barrage is likely to reduce spring tide levels which will decrease the access window that vessels with large draughts will have to access the ports and parts of the upper estuary.

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[83] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]
[84] *ibid*
[85] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, December 2008 [Accessed on 29 March 2010]

The Cardiff-Weston barrage is also likely to increase low water levels for both spring and neap tides which will increase the access windows that vessels with smaller draughts will have to access some ports. Certain marine structures will be permanently immersed as a result of increased low water. A Cardiff-Weston barrage is also likely to reduce upstream estuary salinity. Ships sit lower in fresh water than sea water due to a reduction in density; therefore, a reduction in salinity will increase the draft requirements for vessels.

The longer periods of high water, although lower than current peak natural tides, have the potential to provide greater flexibility for vessels entering and leaving dock facilities as the access window is lengthened.

An overall reduction in tidal energy, as expected by the construction of the Cardiff-Weston barrage, is likely to increase the dredging requirement, particularly for navigation channels. Silt suspension will be reduced with decreasing tidal energy up stream of a Cardiff-Weston barrage leading to movement of siltation to other areas of the estuary.

1.11. Marine aggregates

The prominent and characteristic sandbank features of the Severn Estuary are also an important source of sand. This is extracted under licence from The Crown Estate and used to supply approximately 80-90 per cent of the demand from the construction industry in South Wales. Marine extraction in England and Wales reached a peak of 28 million tonnes in 1989 but has fallen steadily since. In 2006 1.57 million tonnes were extracted from the Bristol Channel. Two thirds of the sand harvested from the Bristol Channel is landed at Cardiff, Newport and Avonmouth ports.[86] The Crown Estate estimates that by 2015 800,000 tonnes or less will come from Welsh waters in the Severn Estuary and Inner Bristol Channel. It is estimated that around 1,700 jobs are linked directly or indirectly to aggregate dredging in South Wales. The Welsh Government's *Interim Marine Aggregates Dredging Policy* sets out an integrated strategy for the supply of fine aggregates to South Wales, stating that 'aggregates dredging will progressively, over the next ten years, become focused in areas offshore and to the west of the Bristol Channel'.[87]

1.12. Marine waste disposal

The disposal of most types of industrial waste and sewage sludge at sea is now prohibited by the Oslo Convention and Paris Commission and has been discontinued in

[86] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, December 2008 [Accessed on 29 March 2010]
[87] Welsh Government, *Interim Marine Aggregates Dredging Policy South Wales*, November 2004 [Accessed on 29 March 2010]

UK waters since 1998.[88] However, treated sewage and industrial discharge from point sources still occurs in the Severn Estuary. The largest source is a facility located at Avonmouth which discharges approximately 160,000m^3 of treated sewage per day. [89] It is expected that a requirement for waste disposal within the Severn Estuary will continue although industrial discharge may decline as commercial operators locate overseas.[90]

[88] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, December 2008 [Accessed on 29 March 2010]
[89] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, December 2008 [Accessed on 29 March 2010]
[90] *ibid*

2. Small barrages (Shoots barrage and Beachley barrage)

2.1. Construction

The Shoots barrage would be located just south of the Severn road crossings and is estimated to have the potential to generate 2.7TWh/y which is the equivalent to 1 per cent of the UK electricity demand. [91] The STPG estimate that construction would take 5 years until first power and a further year before the barrage is fully online.[92] It is estimated to cost £2.9–£3.5bn and provides the cheapest unit cost of energy of all the short listed schemes. The Shoots barrage is the largest barrage that could be taken forward with limited Government involvement in risk and cost.

The Beachley barrage would be located north of the Severn road crossings and is estimated to have the potential to generate 1.7TWh/y. [93] It is the smallest STP proposal on the short list in terms of capital costs and electricity generation. The Beachley barrage is estimated to cost between £2.1–£2.5bn with a construction time of 4 years until first power and a further year before the barrage is fully operational.[94]

Construction for both the smaller barrages would be completed in the same method as the Cardiff-Weston barrage with purpose built caissons floated into position. This method avoids the expensive and hugely environmentally damaging method of cofferdam construction[95] and the complete closure of the estuary during the project build.

2.2. Socio-economic impacts

The DTZ commissioned study during the first phase of the feasibility study considered the regional impacts of the Shoots and Beachley Barrage schemes together, assuming that impacts would be broadly similar. [96] The study reported that due to the smaller number of turbines and caissons required for the Shoots and Beachley options, compared to the Cardiff-Weston scheme, it is unlikely that this represents a large enough demand to encourage a regional manufacturer to enter this market.[97] As such there is likely to be substantial displacement or 'leakage' to further areas in the UK or Europe. In contrast, the smaller workforce requirements could enable a higher

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[91] Black & Veatch, Tidal Power in the UK contract 3 – *Review of the Severn Barrage proposals*, Report for the Sustainable Development Commission, July 2007 [Accessed on 26 March 2010]
[92] *ibid*
[93] Department of Energy and Climate Change, *Severn Tidal Power Phase one consultation*, January 2009 [Accessed on 10 March 2010]
[94] *ibid*
[95] A cofferdam is an enclosure within a water environment constructed to create a dry work environment. Unlike a caisson a cofferdam is usually land connected.
[96] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[97] *ibid*

proportion of labour to be sourced locally from within Wales and the South West. [98] The DTZ study concluded that a small barrage would create, according to a central scenario, 700 annual jobs over the five year construction period. [99]

2.2.1. Transport and logistics

The DTZ regional impact assessment focused mainly on the impact of STP proposals on port usage and specifically upon the impacts of the Cardiff-Weston barrage. The Shoots and Beachley schemes have a much reduced impact on port usage, compared to the Cardiff-Weston proposal, due to their position upstream of the main Severn ports of Cardiff, Bristol and Newport. Shipping for these ports would not need to pass through barrage locks and would be relatively unaffected by the presence of either the Shoots or the Beachley barrages.

The Highways Agency was commissioned as part of the STP feasibility study to investigate whether there should be an inclusion in any of the barrage proposals for a highway infrastructure.[100] The conclusions drawn were that 'a Shoots barrage highway connection would not provide levels of access that do not already exist. The construction of a highway link over the Shoots barrage would not be an economic alternative to continuing to maintain the M48 Severn Bridge to the end of its design life'.[101]

In a similar study, Network Rail (NR) was asked by the Department for Transport (DfT) to undertake a study to look at the potential for including rail infrastructure in a Severn barrage. The report considered the consequences of a Shoots barrage rail link as a replacement or as an addition to the current Severn Tunnel: [102]

> …an opportunity to replace an existing major piece of infrastructure (the Severn Tunnel) due to its close proximity. With fairly substantial infrastructure changes at either end of the barrage, existing south Wales – England links could be maintained with the added bonus of capacity and journey time improvements. […] Construction of a barrage at this location would provide an opportunity to double the capacity across the River Severn at this point as the Severn Tunnel would be retained. Existing south Wales – England links would be maintained with the added bonus of capacity and journey time improvements.

However, in conclusion Network Rail was of the opinion that: [103]

> The existing tunnel is relatively young by NR tunnels asset population and is classified to be in good/fair condition in relation to other operational tunnels on the network, costs a fraction of the road crossings to maintain (based on Highways Agency cost) and provides sufficient capacity to meet current and foreseeable demand. There are relatively low cost options to increase capacity if

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[98] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[99] *ibid*
[100] Highways Agency, *Severn Barrage Highway Infrastructure Feasibility Study*, August 2008 [Accessed on 29 March 2010]
[101] *ibid*
[102] Network Rail, *Severn Barrage Railway Infrastructure Feasibility Study*, August 2008 [Accessed on 29 March 2010]
[103] *ibid*

required, and it may be possible to reduce pumping costs and make other improvements to the tunnel if a business case can be made.

2.2.2. Tourism

The DTZ study found that a small barrage, such as the Shoots or Beachley proposals, would likely have a negative effect on local tourism due to increased traffic congestion during the construction period. [104] After the build period the report considered it highly likely that the barrage itself would be a significant draw for tourists. This conclusion was, in part, based on the tourism figures for similar structures such as La Rance barrage (200,000 visitors per annum) and the Thames Barrier (13,000 per annum).[105] The DTZ report placed a value range on this tourism attraction, depending on visitor numbers, at between £2.5 million (low visitor scenario of 37,500 per annum) and £19.9 million (high visitor scenario 300,000 per annum).[106] Visitor numbers for a small barrage were assumed to be 75 per cent of those for the Cardiff-Weston proposal due to the weaker visual appeal.[107]

A tidal barrage option will also have an effect on the Severn bore phenomenon. It is unclear at this stage whether the occurrence of the bore could be preserved by halting generation from the barrage and allowing water levels to recover to their natural levels at the time of a predicted bore.[108]

2.3. Fisheries

The smaller barrages of the Shoots and Beachley proposals are likely to have a significantly reduced impact on commercial and recreational fishing within the Severn Estuary compared to the Cardiff-Weston barrage. [109] The smaller barrages encompass fewer rivers within the Severn Estuary. The Beachley scheme, unlike the Shoots proposal, is located upstream of the River Wye confluence and the negative impact on fisheries is therefore likely to be further reduced.

With regards to the impacts of a barrage structure, the total construction time is an important factor as impacts during construction, especially on fisheries, are likely to be minimal in comparison to impacts of a fully operation barrage. Thus a smaller barrage, although affecting a smaller area, will be completed in a shorter period, and as such

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[104] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[105] *ibid*
[106] *ibid*
[107] *ibid*
[108] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society & Economy*, p46, December 2008 [Accessed on 29 March 2010]
[109] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]

impacting to its fullest extent sooner. This is also the case for the Beachley scheme which has an estimated build time one year shorter than the Shoots proposal. [110]

2.4. Environmental impact

According to the STP SEA terrestrial and freshwater ecology scoping paper, predicted ecological impacts of an STP proposal would include some or all, but would not be limited to the following:[111]

- Permanent and temporary habitat loss
- Habitat fragmentation
- Habitat degradation
- Disruption of ecological networks
- Species mortality
- Disturbance (direct and indirect including noise and vibration and visual).
- Pollution (air, ground and water).

2.4.1. Terrestrial and freshwater ecology

In terms of impact on terrestrial ecology, a small barrage is likely to include:[112]

- A significant terrestrial land take area which is likely to be subject to temporary and permanent habitat loss and numerous ecological effects associated with construction activities including, but not limited to, disturbance, pollution and species mortality.
- Given the reduction in scale compared to a large barrage, the indirect effects to terrestrial ecology features could be reduced.
- Sites such as wetland sites and the species that rely on areas which have specific hydrological regimes are likely to be most affected. However it is likely that all sites, habitats and species, including all tiers of species hierarchy, irrespective of their association with water will be affected to a degree.[113]

2.4.2. Ornithology

The STP scoping paper on ornithology laid out the terms of references for the phase 2 SEA on bird life within the Severn Estuary. Due to existing reliable data on their abundance in or around the Severn Estuary from such sources as the Wetland Bird

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[110] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[111] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Terrestrial and Freshwater Ecology*, December 2008 [Accessed on 29 March 2010]
[112] *ibid*
[113] *ibid*

Survey (WeBS) Core Count Scheme[114] 27 waterbird species were designated as indicators. [115]

In relation to different STP schemes the ornithology scoping paper considers that: [116]

> In most cases, these changes are broadly generic to the barrage and lagoon options being considered. However, the magnitude of the changes associated with each option will vary depending on their scale and the option's location relative to the distribution of key species. Most of the changes will primarily affect estuarine wintering waterbirds, although predominantly freshwater species and other groups such as gulls that are also included as interest features of designated sites may additionally be affected by some of the issues identified.

The Shoots and Beachley barrage schemes have a much reduced impact on waterbirds or seabirds, compared to the Cardiff-Weston scheme, when considering the magnitude of the loss of intertidal habitat. The construction phase of the development however, is likely to cause a similar level of disruption for all three schemes.[117] The main impact during the construction phase will be the loss of habitat as a result of site disturbance, an impact that was observed during the construction of the amenity barrage at Cardiff Bay in South Wales.[118] Displaced birds show a reduced survival rate due to an incapability of learning how to survive in a new environment and are thus at a competitive disadvantage and/or subdominant to the resident birds.[119]

The extent of intertidal habitat loss, as a result of barrage closure and the associated alteration to the tidal range, will vary considerably between STP proposals. The Shoots and Beachley schemes would respectively result in 5,000 hectares (ha) and 3,500ha of intertidal habitat loss. Although this is vastly smaller than the 20,000ha loss predicted by the Cardiff-Weston proposal they are still significant losses in their own right.[120] Further effects of altered geomorphology upstream of the estuary is likely to induce changes in saltmarsh, freshwater wetland and mudflat composition and abundance with further direct and indirect effects on the overall estuary waterbird assemblage.[121]

2.4.3. Marine ecology

The main impacts of the Cardiff-Weston barrage on the marine ecology of the Severn Estuary are shared with the Shoots and Beachley proposals. However due to the

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[114] Wetland Bird Survey Core Count Scheme, *SPA site access data*, website [Accessed on 29 March 2010]
[115] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, December 2008 [Accessed on 29 March 2010]
[116] *ibid*
[117] *ibid*
[118] Burton N.H.K, Rehfisch M.M & Clark N.A. (2002) Impacts of disturbance from construction work on the densities and feeding behaviour of waterbirds using the intertidal mudflats of Cardiff Bay, UK. *Environmental Management* 30 p865-871
[119] Burton N.H.K, Rehfisch M.M, Clark N.A & Dodd S.G. (2006) Impacts of sudden winter habitat loss on the body condition and survival of redshank *Tringa tetanus*. *Journal of Applied Ecology*. 43 p464-473
[120] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, December 2008 [Accessed on 29 March 2010]
[121] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, December 2008 [Accessed on 29 March 2010]

reduction in impounded water volume the magnitude of these effects is predicted to be reduced.[122]

A reduction in turbidity and the resulting associated increase in light penetration of the water column, as a direct result of a barrage construction, have been predicted to promote or allow the increased growth of phytoplankton and macroalgae.[123] However the smaller area of impounded water inherent with the location of the Shoots and Beachley barrage means that a high enough turbidity to restrict an increase in phytoplankton and macroalgae growth is predicted.[124]

The known *Zostera* (eelgrass) beds in the Severn Estuary are located downstream of the Shoots and Beachley schemes. *Zostera* beds are a notable community of the Severn Estuary and are an important food source for overwintering birds. However, they are present at only one known site within the estuary and as such their contribution is limited.[125] *Zostera* are known to be extremely sensitive to human-induced changes in the coastal environment, particularly in relation to sedimentation and turbidity.[126] Both of these are likely to be altered as a result of an upstream construction of a barrage. The full extent of downstream impacts of barrage construction are not fully understood although research undertaken by the Severn Tidal Power Group revealed that a reduced tidal range (high water slightly lower and low water higher by up to 1m) is likely over a seaward distance of up to 20km.[127]

2.5. Geomorphology

The impacts of a barrage construction, large or small, on the geomorphology of the Severn Estuary are likely to have knock-on effects for most, if not all of the STP SEAs.[128]

Similar to the Cardiff-Weston barrage, a reduction in tidal range and increased mean water depths upstream of the Shoots or Beachley barrage will lead to a general reduction in peak currents in this area of the estuary.[129] The position of the sluices and turbines will influence local currents which are likely to increase during barrage operation. An alteration in tidal currents is likely to drive the evolution of the underlying geomorphology within the Severn Estuary, thereby modifying the flow regime and consequently the existing deepwater channels.[130]

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[122] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, December 2008 [Accessed on 29 March 2010]
[123] *ibid*
[124] *ibid*
[125] *ibid*
[126] Holt T.J, Hartnoll R.G & Hawkins S.J (1997) Sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, *Zostera* beds and *Sabellaria spinulosa* reefs. *English Nature Research Report* No. 234
[127] Severn Tidal Power Group (1986) *Tidal Power from the Severn, Engineering and economic studies – The Cardiff Weston Scheme and English Stones scheme*. The Severn Tidal Power Group.
[128] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Hydraulics and Geomorphology*, December 2008 [Accessed on 29 March 2010]
[129] *ibid*
[130] *ibid*

An important issue with both the Shoots and Beachley proposals is the potential build up of sediment upstream of the barrage and this is being investigated in more detail during phase 2 of the feasibility study.

2.6. Flood risk

The main discussions concerning flood risk and the STP proposals centres around the two issues of protection against storm surge and the increased risk as a result of reduced land drainage area.[131]

The location of the Shoots and Beachley barrages further upstream from the Cardiff-Weston barrage means that a significantly reduced area will be protected from storm surge events and wave overtopping. The effect of wave reflection from the seaward face of a barrage on downstream flood risk is not fully understood and is being investigated as part of the flood risk SEA.[132]

The reduction in land drainage area upstream of a barrage structure is brought about by a reduction in tidal range. Certain sites for drainage or outfalls have the potential to be exposed to extended periods of tide lock.[133] This would impact upon the efficiency and maintenance of these sites where the window of access is reduced. As for the protection against storm surges, the location of the Shoots and Beachley proposals mean that a reduced number of outfall sites would be affected by a reduced tidal range.[134]

Integral to the workings of a tidal power barrage is the impounding of high tide upstream of a barrage structure to create the larger gradient required for energy generation. The maintenance of high water levels has the potential to cause extensive erosion along land drainage sites and other flood defences. Again the reduced area upstream of the Shoots and Beachley proposals means that any potential negative impacts of erosion will be significantly less than for the Cardiff-Weston proposal.[135]

2.7. Historic environment

The environment of the Severn Estuary contains many historic features which are extremely significant to the UK.[136] The effect of a small barrage on the historic environment of the Severn Estuary would likely be more localised than with the larger

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[131] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, December 2008 [Accessed on 29 March 2010]
[132] *ibid*
[133] *ibid*
[134] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, December 2008 [Accessed on 29 March 2010]
[135] *ibid*
[136] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]

Cardiff-Weston barrage, however the effects would still be significant and should be examined in more detail as part of the historic environment STP SEA. [137]

The STP SEA scoping paper on historic environment considered a small barrage proposal situated approximately at the point of the Shoots scheme. A hypothetical study area around this site was developed. Contained within this site were 18 sites of archaeological evidence and 8 recorded ship losses.[138] Significantly, one of the sites is a scheduled ancient monument and as such is protected by the *Ancient Monuments and Archaeological Areas Act (1979).*[139]

It is to be noted that the effects of a barrage structure are likely to be felt outside of the hypothetical study area but the magnitude of these effects on the historic environment of the Severn Estuary is, at present, not fully understood.[140]

2.8. Navigation

The Severn Estuary is used extensively for commercial shipping and to a lesser extent, recreational boating. There are a number of significant port facilities including Bristol, Cardiff, Newport and Gloucester. All of the major ports carefully plan ship movements according to available draughts as a direct consequence of the extremely large tidal range and predicted high waters. Any impacts on the navigation of the main shipping channels as a result of a barrage structure will have a direct influence on the draught requirements of vessels navigating the estuary.[141]

The four main issues arising with regards to navigation are: water levels, water density, geomorphology and sedimentation.[142]

The water levels within the Severn Estuary are likely to be reduced by up to 1 metre on high water spring tides.[143] This change in tidal regime could have implications for large vessels which are reliant upon spring tides to navigate the Severn Estuary. The Shoots and Beachley barrages are located upstream of the main ports of Bristol, Cardiff and Newport and are thus predicted to have a lesser impact upon the navigation requirements of these ports. Gloucester is situated upstream of the Shoots and Beachley locations and will be affected. The likely impact will be as a result of an

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[137] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]
[138] *ibid*
[139] *Ancient Monuments and Archaeological Areas Act 1979*, (chapter 46)
[140] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, p105, December 2008 [Accessed on 29 March 2010]
[141] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p2-3, December 2008 [Accessed on 29 March 2010]
[142] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p30-40, December 2008 [Accessed on 29 March 2010]
[143] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p2-3, December 2008 [Accessed on 29 March 2010]

increased low tide which will permanently submerge certain marine structures in the port, precluding maintenance, which at present is carried out during low water.[144]

The Severn Estuary is defined by the area of water which is brackish, neither saltwater nor freshwater but a mixture of the two. The effect of this mixing is that the water density is in between that of fresh or salt water and thus the buoyancy of vessels is altered accordingly. Vessels sit deeper in freshwater than brackish or saltwater. The impact of a small barrage on the water density is predicted to be small, due to the proximity of the fresh water influence.[145]

Although situated upstream of the port of Bristol, the Shoots and Beachley barrage proposals have the potential to alter local downstream geomorphology, specifically in the area known as King Road.[146] The STP SEA of geomorphology and navigation will investigate this potential impact further.

The waters of the Severn Estuary are characterised as containing a high and mixed sediment load. The effect of a barrage upon this would be reducing the tidal energy and consequently a reduction in sediment load within the water column. Smaller barrages are more at risk from sedimentation than larger basins and, in that context, dredging requirements upstream of a barrage may be affected. As part of the STP SEA on geomorphology both the Shoots and Beachley barrage impacts on sediment regimes are being investigated in further detail.[147]

2.9. Other sea uses

The impacts of a small barrage, such as the Shoots or Beachley barrage proposals, are likely to be similar to those of the Cardiff-Weston scheme but at a significantly reduced magnitude.[148] The main considerations under the STP SEA other sea uses scoping paper include: marine aggregates, marine waste disposal, commercial fishing and boating.

Marine aggregates are predominantly harvested from within the Bristol Channel, downstream of the Shoots and Beachley locations. Furthermore, the majority of aggregates harvested within the Severn Estuary and Bristol Channel are offloaded at Cardiff, Newport or Bristol ports.

Recreational boating is not carried out within the Severn Estuary to a great extent, mainly due to the challenging nature of the tidal regime. A barrage structure would

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[144] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p30-31, December 2008 [Accessed on 29 March 2010]
[145] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p32-33, December 2008 [Accessed on 29 March 2010]
[146] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p33, December 2008 [Accessed on 29 March 2010]
[147] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology*, December 2008 [Accessed on 29 March 2010]

stabilise the upstream tidal characteristics of the estuary and it may be the case that boating activities in the area increase.[149] The magnitude of this increase would be dependent on the location and area of impounded water. The latter is likely to mean that the Shoots and Beachley schemes offer a smaller opportunity to boating in comparison to the Cardiff-Weston scheme.[150]

[148] *ibid*
[149] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, December 2008 [Accessed on 29 March 2010]
[150] *ibid*

3. Tidal lagoons (Fleming and Bridgewater Bay lagoons)

Tidal lagoons and tidal barrages are similar in that they both comprise a solid structure that is used to impound water. The difference between the two is that a lagoon structure does not span the entire width of a channel and instead impounds a smaller area. Tidal lagoons can be either completely offshore or semi-circular, with each end connected to the same shoreline. The two tidal lagoon options that have been short listed for the STP project are both land-connected lagoons as the cost of energy for offshore lagoons was considered too high. [151]

A significant difference between the potential for tidal lagoons and tidal barrages is that the presence of a barrage is likely to preclude any further barrage construction within the same estuary as the tidal range upstream of a barrage is significantly reduced. Tidal lagoons are a relatively new technology and no significant projects have been completed, although a proposal has been put forward by Tidal Electric for a 60MW offshore lagoon project in Swansea Bay.

3.1. Construction

The Fleming lagoon, also known as the Welsh Grounds lagoon, would be situated on the Welsh shore of the Severn Estuary between Newport and the Severn road crossings. The proposal is a land-connected lagoon with the potential to generate 2.3 TWh/year, or 0.65 per cent of UK electricity generation. Construction costs are estimated at between £4.1–£4.9bn.[152]

The Bridgewater Bay lagoon would be situated on the English shore of the Severn Estuary between Hinkley Point and Weston Super Mare. The proposal is a land-connected lagoon with the potential to generate 2.6 TWh/year, or 0.7 per cent of the UK electricity generation.[153] Construction costs are estimated at between £3.4–£4.1bn

3.2. Socio-economic impacts

The DTZ commissioned study on the regional economic impacts of a Severn tidal power proposal focused specifically on the Fleming lagoon proposal rather than the Bridgewater Bay scheme. [154] The lagoons are similar in size and generating potential and thus many similarities exist with regards to their generic regional impacts.[155] The study concluded that, similar to the smaller barrage proposals, the local capacity of

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[151] Black & Veatch, Tidal Power in the UK contract 3 – *Review of the Severn Barrage proposals*, Report for the Sustainable Development Commission, July 2007 [Accessed on 26 March 2010]
[152] *ibid*
[153] *ibid*
[154] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[155] *ibid*

caisson construction yards would need to be investigated before any assessment of regional supply could be made. If the local capacity is insufficient then it is likely that a proportion of the caissons may be constructed in the region alongside substantial leakage to other areas in the UK. [156] Similarly with turbine construction it is predicted that because of the lower numbers of turbines required, compared to the Cardiff-Weston scheme, this would prohibit the emergence of a regional manufacturer specifically for this contract. As a result there is likely to be substantial leakage of turbine construction to other areas of the UK or Europe. [157] This does depend on the potential for the region to develop a specialism within the market and thus in future to supply national and international tidal power projects. The STP SEA scoping paper for society and the economy predicted a land-connected lagoon option would create approximately 3,600 direct employment opportunities during the course of construction.[158]

3.2.1. Transport and logistics

The DTZ study concluded that the Fleming lagoon proposal would likely have a much reduced impact upon port usage in comparison to the Cardiff-Weston scheme and a similar impact as the small barrage schemes. [159] Both of the lagoon options are located so as to avoid presenting a physical barrier to shipping for any of the major ports within the Severn Estuary. This difference was not considered in the DTZ study which concluded that, in relation to port usage: [160]

> …both the small barrage and lagoon option impacts range from a loss of £220 million GVA (worst case scenario) to no net loss (best case scenario). At the peak this impact equates to 550 jobs or an annual average ranging from 190 jobs (worst case scenario) to no net job losses (best case scenario)

3.2.2. Tourism

The DTZ study anticipated that lagoons would not have any substantial impact on the future levels of marine recreational activity within the Severn Estuary. Water turbidity and water quality, which are at present within the Severn Estuary the prohibitive factors on recreational marine activity, are not likely to be affected to the same extent as in the barrage scenarios. [161] The study also makes reference to the possibility of increased

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[156] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[157] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p61-62, January 2009 [Accessed on 29 March 2010]
[158] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Society & Economy*, p38, December 2008 [Accessed on 29 March 2010]
[159] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, January 2009 [Accessed on 29 March 2010]
[160] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p88, January 2009 [Accessed on 29 March 2010]
[161] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p127-128, January 2009 [Accessed on 29 March 2010]

marine activity within the lagoon enclosure, taking advantage of reduced water turbidity; however the practicalities of this require further investigation. [162]

The DTZ study estimated the economic benefits of visitors to the site of the project itself as a value range of between £0.4m (10,000 visitors per annum) and £3.2m (80,000 visitors per annum) based on comparisons with visitor numbers at La Rance (200,000 per annum) and the Thames Barrier (13,000 per annum). [163] Visitor number projections for a lagoon option used the Fleming lagoon proposal. There was no consideration of potential differences with the Bridgewater Bay location.[164] Visitor numbers to a lagoon option were considered to be 20 per cent of the Cardiff-Weston scheme due to the less visually striking nature of the project.[165]

3.3. Fisheries

The DTZ study highlighted significant uncertainty concerning the impact of a tidal lagoon project upon recreational and commercial fishing within the Severn Estuary: [166]

> The impact of lagoons on migratory cues is dependent on their precise location and which rivers are encompassed. In addition, the impact on fish passages, water quality, temperature etc are less clear. However, given the potential scale of lagoons and the potential for multiple lagoon developments, for the purpose of this assessment, the development of lagoons are assumed to have the same negative impact on recreational freshwater migratory angling in the river Severn, Usk and Wye as the barrage options. Whilst there is uncertainty here, the potential for increased fish mortality from turbine passage remains a significant risk, and therefore this assumption is considered appropriate.

3.4. Environmental impact

There is no precedent for the environmental impacts of a tidal lagoon as they are a relatively new technology and as yet, none have been constructed. A tidal lagoon scheme is the preferred approach of Friends of the Earth Cymru: [167]

> On the basis of this preliminary analysis and comparison, tidal lagoons could provide a major source of safe, clean, regionally generated renewable electricity. Lagoons also appear to offer numerous significant economic and environmental advantages over a Severn Barrage.
>
> …for these reasons, Friends of the Earth Cymru recommends that an environmentally benign tidal lagoon demonstration scheme is given strong support at the very least, and built as soon as possible, be it Swansea Bay or another location.[168]

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[162] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p127-128, January 2009 [Accessed on 29 March 2010]
[163] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p129-130, January 2009 [Accessed on 29 March 2010]
[164] *ibid*
[165] *ibid*
[166] Welsh Government, Research, Severn Tidal Power, *Assessment of the Regional Economic Impacts of Tidal Power Generation in the Severn Estuary – Final Report*, p94-95, January 2009 [Accessed on 29 March 2010]
[167] Friends of the Earth Cymru, *Briefing – A Severn barrage of tidal lagoons?* A comparison, January 2004 [Accessed 18 March 2010]
[168] Friends of the Earth Cymru, *The Severn Barrage*, September 2007 [Accessed on 18 March 2010]

3.4.1. Terrestrial and freshwater ecology

The environmental impacts of tidal lagoons upon terrestrial and freshwater ecology are not fully understood.[169] It is likely that terrestrial habitats are temporarily or permanently lost as a result of construction activity such as the establishment of a dry dock area.[170]

Intertidal habitat loss is predicted to occur within the lagoon enclosures and as such the area of habitat loss is significantly less than the Cardiff-Weston scheme but on a similar scale to the Shoots and Beachley barrage proposals. [171]

Table 1: Comparison of impounded areas for each of the short listed STP proposals[172]

Tidal Power Option	Impounded Area
	Km^2
Cardiff - Weston Barrage	480
Shoots Barrage	85
Beachley Barrage	57
Fleming Lagoon	72
Bridgewater Bay	91

3.4.2. Ornithology

The environmental impact of the Fleming and Bridgewater Bay tidal lagoon options is predicted to be of a similar scale to the Shoots and Beachley barrage options. Construction phase effects are likely to be similar with disturbance related habitat loss and consequent waterbird displacement.[173]

The STP SEA scoping paper on ornithology predicts that the loss of intertidal habitat likely to occur as a result of a land-connected tidal lagoon construction would be a potentially damaging impact on the overall waterbird assemblage of the Severn Estuary.[174] The predicted habitat loss for the Fleming and Bridgewater Bay lagoons is 6,500 hectares and 5,500 hectares respectively, compared to the 5,000 hectares lost from the Shoots barrage scheme and the 20,000 hectares loss from the Cardiff-Weston scheme.

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[169] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: Terrestrial Ecology, December 2008 [Accessed on 25 January 2010]
[170] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: Terrestrial Ecology, p38-39, December 2008 [Accessed on 25 January 2010]
[171] Department of Energy and Climate Change, *Phase one consultation, Government response*, p61-62, July 2009 [Accessed on 26 March 2010]
[172] Department of Energy and Climate Change, *Analysis of options for tidal power development in the Severn Estuary - Interim Options Analysis Report Volume 1*, p38, December 2008 [Accessed on 29 March 2010]
[173] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, p65-66, December 2008 [Accessed on 29 March 2010]
[174] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Ornithology*, p74, December 2008 [Accessed on 29 March 2010]

3.4.3. Marine ecology

The main impacts upon marine ecology are similar to those for the large and small barrage proposals for the areas of impounded water within the lagoon options.[175]

Within the lagoon enclosure there is likely to be a reduction in water turbidity and an associated increase in macroalgae and phytoplankton productivity as a consequence of increased light penetration within the water column. It is not known if these effects will be seen outside of the lagoon enclosure, although it is predicted that the presence of a lagoon scheme will reduce the tidal range of the estuary. [176] The magnitude of this change is not fully understood and will be investigated further in phase 2 of the feasibility study.[177]

Changes to the estuary saltmarshes, and subtidal sandbanks brought about by a tidal lagoon scheme will be driven by changes in the hydrodynamic and sedimentary regime.[178] The magnitude of these changes would require detailed modelling to be fully understood.[179]

3.5. Geomorphology

The main areas of interest with regards to geomorphology include water levels, tidal currents, wave action and sediment regime.

The full impacts of tidal lagoon schemes on water levels in the Severn Estuary require further evaluation in phase 2 of the feasibility study. The impacts of a tidal lagoon scheme are expected to be less than for the barrage schemes; however there are no models for predicting the effects of a lagoon structure on water levels outside of the lagoon enclosure. It is possible that a lagoon structure may affect the range, height and propagation of the tide over a significant distance upstream of the enclosure.[180]

With regards to tidal currents, a tidal lagoon scheme is predicted to alter local tidal flow as a result of the structure itself and the sluice and turbine operation. It is likely that any alterations in tidal flow over intertidal areas will lead to changes in erosion patterns and supply and deposition of sediment.[181]

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[175] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, December 2008 [Accessed on 29 March 2010]
[176] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, p50 – 60, December 2008 [Accessed on 29 March 2010]
[177] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, p51-52, December 2008 [Accessed on 29 March 2010]
[178] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, p52-54, December 2008 [Accessed on 29 March 2010]
[179] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Marine Ecology*, p52-54, December 2008 [Accessed on 29 March 2010]
[180] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology & Hydrodynamics*, p51-52, December 2008 [Accessed on 29 March 2010]
[181] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology & Hydrodynamics*, p53, December 2008 [Accessed on 29 March 2010]

It is likely that a tidal lagoon structure will have an affect on wave action by altering wind-wave conditions under certain wind directions depending upon the location of the lagoon structure itself. Extreme waves will be reduced as a result of a reduction in fetch length, which is the area from which a wave is generated by the wind.[182] Within the main body of the enclosure the fetch length will also be reduced, however this may be counteracted by the increased average water depth.[183]

It is predicted that land-connected lagoons such as the Bridgewater Bay lagoon or the Fleming lagoon, will become sediment sinks which will require management if the tidal status of the enclosure is to be maintained.[184] Further investigation of the sedimentation of tidal lagoons, alongside the smaller barrages is being carried out as part of phase 2 of the feasibility study.

3.6. Flood risk

Land-connected tidal lagoons are predicted to have similar impacts on their enclosed shoreline with respect to flood risk, as the barrage options are expected to have on the upstream shorelines. That is, a protection against storm surge flooding, potential erosion of present natural and man made flood defences, and tide lock of present areas of land drainage.[185] Overall the potential flood risk impacts of land-connected tidal lagoons are not considered to be significant, apart from, potentially, the impounded shoreline.[186]

3.7. Historic environment

The Severn Estuary contains many historic features which are extremely significant to the UK.[187] As for the large and small barrage proposals, the STP SEA scoping paper on historic environment designated a hypothetical area around the proposed location for the Fleming lagoon. There was no consideration of the Bridgewater Bay proposal.

The scoping paper predicted that the impact of a tidal lagoon at the Fleming proposal location would impact on a local scale rather than an estuary-wide scale. However, due to the lagoon location in shallow water areas the predicted impact on any intertidal or submerged receptors would be enormous.[188] Within the hypothetical area of the Fleming proposal there are 49 Welsh and English National Maritime Recorded (NMR)

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[182] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology & Hydrodynamics*, p54-55, December 2008 [Accessed on 29 March 2010]
[183] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology & Hydrodynamics*, p55, December 2008 [Accessed on 29 March 2010]
[184] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Geomorphology & Hydrodynamics*, p56-57, December 2008 [Accessed on 29 March 2010]
[185] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Flood Risk*, p31-42, December 2008 [Accessed on 29 March 2010]
[186] *ibid*
[187] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, December 2008 [Accessed on 29 March 2010]
[188] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, p48-49, December 2008 [Accessed on 29 March 2010]

list sites, including 6 scheduled ancient monuments, 2 Listed Grade I buildings, and 6 Listed Grade II buildings, as well as 36 recorded losses. The lagoon would be located on six distinct historic landscape areas of the Gwent Levels between the River Usk and Sudbrook. [189] Within this area there are a number of excavated shipwrecks, including Magor Pill 1, Magor Pill II, and Collister Pill suggesting the possibility of additional discoveries.[190] Coastal erosion within the study area as a result of a tidal lagoon construction could have the benefit of exposing more of the intertidal historic environment, allowing investigation, however the evidence could also be destroyed.[191]

3.8. Navigation

The Severn Estuary is used extensively for commercial shipping which must carefully plan their voyages according to available draughts as a consequence of the extremely large tidal range. Any impacts on the commercial shipping lanes as a result of a STP construction are likely to have an indirect economic impact.[192]

The Fleming and Bridgewater Bay tidal lagoon proposals are not predicted to impede navigation of the Severn Estuary to any significant extent, although the full geomorphological changes that will evolve as a result of a land-connected lagoon structure require further investigation.[193] Further evaluation on the impacts of land-connected lagoons on water levels is required in phase 2 of the feasibility study whilst the impact upon water density is expected to be minimal as the majority of water within the lagoons will be discharged on each tide.[194]

It is predicted that land-connected lagoons will act as sediment traps and consideration of how sediment materials are to be removed and returned to the estuary will be required.[195]

3.9. Other sea uses

The main sea uses apart from commercial shipping include: marine aggregates, marine waste disposal, boating and commercial fishing.

Marine aggregate harvesting within the Severn Estuary and Bristol Channel would only be impacted by a land-connected lagoon if the site of harvest was enclosed. Access

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[189] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Historic Environment*, p48-49, December 2008 [Accessed on 29 March 2010]
[190] *ibid*
[191] *ibid*
[192] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, December 2008 [Accessed on 29 March 2010]
[193] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*,p30, December 2008 [Accessed on 29 March 2010]
[194] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p30-39, December 2008 [Accessed on 29 March 2010]
[195] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Navigation*, p33, December 2008 [Accessed on 29 March 2010]

would either be restricted or impractical.[196] Similarly, waste disposal is only likely to be effected for outfalls located within the enclosure, although the full extent of geomorphological impact outside of a lagoon structure is not fully understood.[197]

It has been suggested that tidal lagoons have less of a detrimental impact on migratory fish populations than barrage options.[198] However, fish may still be influenced by the currents associated with turbines, as well as becoming trapped within the lagoon enclosure. The precise risks of a land-connected lagoon structure on commercial fishing remain uncertain.[199]

Recreational boating is not hugely popular within the Severn Estuary as a result of challenging tidal conditions. There is the possibility for recreational boating within a land-connected lagoon enclosure; however this will need to be investigated further.[200]

[196] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, p50-51, December 2008 [Accessed on 29 March 2010]
[197] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, p52, December 2008 [Accessed on 29 March 2010]
[198] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, p53, December 2008 [Accessed on 29 March 2010]
[199] *ibid*
[200] Department of Energy and Climate Change, Severn Tidal Power – Scoping Topic Paper: *Other Sea Uses*, p54, December 2008 [Accessed on 29 March 2010]

4. Comparison with La Rance and Eastern Schelde

4.1. La Rance

The La Rance barrage, situated in the Rance Estuary near St Malo in Brittany, was formally opened on 26 November 1966 and is the only large scale commercial tidal power barrage in the world. The barrage is situated close to the estuary entrance where the equinoctial spring tidal range was formerly 13.5 metres.[201] The Rance Estuary is a ria-type estuary, defined by a steep-sided, funnel shaped river valley branching infrequently and deepening seaward. The barrage has an installed capacity of 240 Megawatts (MW) which supplies the equivalent electricity needs of 100,000 homes.[202]

At the time of construction, species, rather than habitats and ecosystems, were the main aim of biological studies and as such there is no baseline for comparison of pre and post barrage habitat change.[203] The construction method favoured at that time involved blocking the entire estuary with two cofferdam walls, pumping the water out and building the structure as if it was on dry land. The result of this was that during the construction period of five years the estuary became a non-tidal more or less stagnant lake. [204] Today's construction methods, perfected by the offshore oil and gas industry, favour the 'in the wet' build, where a series of prefabricated concrete caissons would be floated and towed into position. Permeability across the estuary would be maintained until the later stages of construction.

The closure of the Rance Estuary during construction resulted in mass mortality of most marine species and the loss of fauna from the former intertidal zone as species failed to adapt to the sudden extreme conditions. [205] Salinity within the estuary reduced progressively becoming completely freshwater in the up-basin reaches. The ecological niche, created by the loss of marine species, was filled by highly tolerant species such as *Nereis diversicolors* (ragworm), *Mytilus edulis* (mussel) and *Promatoschistus* sp. (goby). [206] Following the reopening of the estuary upon completion of the barrage marine waters were once more able to enter the Rance. The new hydrodynamic regime led to an increase in the mean water level by 2.5m and reduced tidal range by 40 per cent, compared to estuary pre-closure measurements. [207] Some believe that the main consequence of the Rance barrage has been an increase in the biodiversity of the estuary.[208] A more benign tidal current regime and the resulting increased sediment

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[201] Kirby R & Retiere C, (2009) Comparing environmental effects of Rance and Severn barrages, *Maritime Engineering 162 p11-26*
[202] *ibid*
[203] *ibid*
[204] *ibid*
[205] *ibid*
[206] *ibid*
[207] *ibid*
[208] *ibid*

stability are given as reasons for this increased carrying capacity. Conversely, others argue that:[209]

> … the use of La Rance as the model for predicting effects on the Severn Estuary is unhelpful. Better correlation is likely to occur in relation to the Eastern Schelde, the morphology of which is closer to that of the Severn. Until now, the arguments have largely centred upon biological responses to immediate physical changes, but our analysis suggests that much more emphasis needs to be placed upon the likely geomorphological evolution if a barrage was to be constructed. "Expert geomorphological analysis" has raised a number of important issues that dispel many of the positive arguments that proponents portray.[…]

It is believed that a Cardiff-Weston option, or any barrage option, would result in significant ecological consequences to the Severn Estuary which would not be compensated for by increases in biodiversity as predicted by some.[210]

> Loss of existing biological interest can be expected to be wide-spread, and there are no grounds for placing faith in the argument that reduced turbidity will benefit wildlife in the long-term. This change will affect all of the existing wildlife interest, and involves the loss of a highly dynamic and unusual system. Whilst proponents of the barrage may argue that this is a wildlife benefit they fail to recognise the importance of range and variation, effectively arguing that conservation objectives should favour a shift towards homogeneity. The impacts will undoubtedly lead to greater homogeneity but this does not constitute a sound argument in favour of a barrage.

4.2. Eastern Schelde

Constructed between 1983 and 1987, the Oosterschelde barrage in The Netherlands aimed to reduce the impacts of storm surges and does not incorporate a tidal power feature. It has been suggested however, that there are similarities between the geomorphological implications of the Oosterschelde barrage and the proposed Cardiff-Weston barrage.[211] Construction of the Oosterschelde barrage was accompanied by detailed pre and post project monitoring which provides a baseline comparison with the STP barrage proposals.

Since the completion of the Oosterschelde barrage there has been a 12 per cent reduction in tidal range, and tidal current velocities have declined by up to 40 per cent in the western and central parts of the Oosterschelde and by as much as 80-100 per cent near to the closure dams. A result of this reduction in tidal energy is that sediment exported from the basin towards the tidal delta has ceased. It is estimated that to establish a new dynamic equilibrium between hydraulic conditions and

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[209] Pethick J.S, Morris R.K.A & Evans D.H, (2009) Nature conservation implications of a Severn tidal barrage – A preliminary assessment of geomorphological change *Journal for Nature Conservation 17 p183-198*
[210] *ibid*
[211] Louters T, Van den Berg J.H & Mulder J.P.M (1999) Geomorphological changes in the Oosterschelde tidal system during and after the implementation of the delta project *Journal of Coastal Research 14(3) p1134-1151* [Accessed on 29 March 2010]

geomorphology will require an import into the basin of 400-600million m^3 of sediment.[212]

An increase in wind-driven waves has been shown to result in a process called 'winnowing', where existing sediments are eroded and reduces the fine fraction of sediments within mudflats. The result of this is that the intertidal habitat becomes sandier and the carrying capacity of these areas is reduced. This has shown to have adverse impacts on the Dunlin, a numerically important species in the Severn Estuary, as they favour highly silt and clay containing surface sediments of intertidal areas.[213]

The RSPB has highlighted the findings of an official Dutch report that detailed the flood risk impacts resulting from the construction of the storm surge barrier across the Eastern Schelde Estuary.[214] The key findings in the Dutch report found that:[215]

- Increased erosion has led to the loss of mudflats along the estuary, leading to higher waves and water levels.
- By 2050, the tidal flats of the Oosterschelde will have more than halved, falling from 11,000ha in 1986 to about 5,000ha in 2045 and 1,500ha by the end of the century.
- Salt marshes will disappear from all but the most sheltered locations by 2050.
- Less intertidal habitat will mean less shellfish and fewer birds. Oystercatcher numbers will decrease by 80 per cent by 2045 and other species will also be severely affected.

Dr Sean Christian, RSPB Cymru's Head of Conservation stated that 'this report makes grim reading. It is the closest we can get to proof that a barrage across the Severn will devastate the estuary'.[216]

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[212] Louters T, Van den Berg J.H & Mulder J.P.M (1999) Geomorphological changes in the Oosterschelde tidal system during and after the implementation of the delta project *Journal of Coastal Research 14(3) p1134-1151* [Accessed on 29 March 2010]
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Annex

A. Glossary of terms

Energy terms

Watt	A measure of instantaneous power or capacity
Kilowatt (kW)	1,000 Watts
Megawatt (MW)	1,000 kW
Gigawatt (GW)	1,000 MW or 1 billion Watts
Terawatt (TW)	1,000 GW
Watt hour (Wh)	One Watt expended for one hour. Watts are normally used to refer to the nominal capacity of an installation whereas Wh, and multiples thereof, are used to refer to actual energy generation over a given time period of an installation or group of installations.

B. Abbreviations

BAP	Biodiversity Action Plan.
BERR	Business, Enterprise and Regulatory Reform (now DECC).
BWEA	British Wind Energy Association.
CCC	Climate Change Committee.
CCW	Countryside Council for Wales.
DECC	Department of Energy and Climate Change.
DEFRA	Department for Environment, Food and Rural Affairs.
DSCT	Deep Sea Container Terminal.
DTI	Department for Trade and Industry.
DTZ	Real estate advisor
DWT	Deadweight tonnage
EA	Environment Agency.
EIA	Environmental Impact Assessment.
GHG	Greenhouse Gas.
GVA	Gross Value Added (measurement of contribution to the economy of each individual producer, industry or sector within a specific target area).
IMADP	Interim Marine Aggregates Dredging Policy.
FOE	Friends of the Earth.
LBAP	Local Biodiversity Action Plan.
LNR	Local Nature Reserve.
NNR	National Nature Reserve.
NR	National Rail
RSPB	Royal Society for the Protection of Birds.
SAC	Special Area of Conservation.

SEA	Strategic Environment Assessment.
SDC	Sustainable Development Commission.
SPA	Special Protection Area.
SSSI	Site of Special Scientific Interest.
STP	Severn Tidal Power.
STPG	Severn Tidal Power Group.
TAN	Technical Advice Note.
WHS	World Heritage Site.
WWF	World Wildlife Fund.