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1 INTRODUCTION

1.1 THE SEVERN ESTUARY COMMISSION AND WESTERN GATEWAY PARTNERSHIP

1.1.1. The Western Gateway Partnership comprises 28 Local Authorities, one Mayoral Combined Authority in England, and two Corporate Joint Committees in Wales, representing over 4.8 million people. The Severn Estuary sits at the heart of Western Gateway's geography and has long been recognised for its potential to generate renewable electricity.

1.1.2. The Partnership launched the Severn Estuary Commission to consider the feasibility of developing tidal range energy. Chaired by Dr Andrew Garrad CBE FREng, the Commission comprises experts in science, engineering, finance, sustainable development, and environmental disciplines.

1.1.3. The Commission will provide their findings and recommendations to the Western Gateway partnership Board on, or shortly after, March 2025 through undertaking the following tasks:

- Review and update the evidence base in its broadest form;
- Understand and assess:
  - the physical and ecological characteristics of the estuary, especially the importance of its unique environment and the potential impact of climate change;
  - the relevant policy and legislation;
  - the current and potential future uses of the estuary.
- Collate and consider past tidal energy initiatives and the lessons learned from them;
- Review the different methods of generating electricity from the tidal energy resource and their contribution to a future energy system;
- Identify the key socio-economic and environmental challenges and opportunities of developing tidal energy schemes; and
- Identify means of financing and regulating potentially very long-term projects.

1.2 PROJECT CONTEXT

1.2.1. As part of the broader work that the Commission will report on, the content of this environmental report will be integrated with the social, energy and financial workstreams (produced by others) within the final report produced by the Commission.

1.2.2. This report considers the Estuary's tidal resource, its capacity and potential to support tidal energy projects with regards to the environment and environmental impacts associated with a tidal range scheme, with a view to providing conclusions and recommendations on the Estuary's capacity, existing knowledge gaps and legislative considerations relevant to decision making on any future proposals.

1.2.3. The environmental workstream has **four** key objectives focused on seeking to establish:-

1. Whether there has been any materially significant new evidence, information or data related to the health and condition of the environment, supported species and integrity of designated sites and of relevance to consideration of a tidal range scheme in the future.
2. The extent to which effects from climate change (e.g. higher rainfall, more frequent flooding, rising water temperature, salinity etc…) are currently affecting the Estuary and

what the future impacts may be under current climate projections on the condition of designated sites, features, species, habitats and the estuary ecosystem more widely.

3. The extent to which the environmental impacts associated with a tidal range energy project in the estuary may vary spatially, using reference locations and projects as a benchmark and what considerations arise that should be factored into future decisions on tidal schemes.
4. How current environment policy and legislation may impact on the consideration of any future tidal range scheme, what future legal and policy changes might mean in the context of a tidal power project and whether further legislative changes may be needed to support delivery of a future scheme, if deemed acceptable.

2 EXECUTIVE SUMMARY

2.1 THE CURRENT ESTUARY ENVIRONMENT

2.1.1. The Severn Estuary is a large area of semi-natural habitat comprising approximately 55,684 hectares, of which approximately 9,971 hectares represent intertidal habitats (JNCC, 1993) and 6,275 hectares comprise sub-tidal habitats (Severn Estuary Partnership, 2011). The Estuary is fed by the catchments of several major rivers and the diversity of habitats is reflected in the assemblage of species in the Estuary, with substantive areas being protected by a range of national and international designations including National Nature Reserves and Sites of Special Scientific Interest (SSSIs) alongside Special Areas of Conservation (SACs), Special Protection Areas (SPAs) and Ramsar wetlands.

2.1.2. The unique geography and coastline of the Severn Estuary has generated the third highest tidal range in the world and its tidal power potential, which has been studied since the mid-19th Century, is representative of conditions that are both rare and desirable from a power production perspective. The Estuary has been subject to significant historical pressure of balancing human habitation with environmental diversity and its current condition reflects impacts of human settlement, ports, manufacturing, and energy generation along the shoreline. Further development of the Estuary in the context of tidal power would build upon this historical use providing further importance for the region to the UK's energy security.

2.1.3. Climate change and the nature crisis are already influencing both natural and human developments within the estuary. One of the biggest threats to the Estuary is from rising sea levels which, coupled with significant storm events, exacerbate the effects of coastal erosion and flooding (Severn Estuary Partnership, 2011), prompting ongoing investment (and likely future investments) in coastal and fluvial flood defences. Whilst changing conditions may in the future present an opportunity for new species, our incomplete understanding of the future baseline makes scientifically accurate predictions on which to base key decisions around further exploitation of the potential for tidal power challenging. Decision-makers will benefit from further work at a more precise scale if accurate judgements are to be made in the context of consenting a future tidal power project.

2.2 THE FUTURE SEVERN ESTUARY

2.2.1. Being home to unique plant and animal species that have adapted to an ever-changing salinity regime, estuaries are delicately balanced dynamic ecosystems that are especially vulnerable to future changes in climate variables such as rising sea-levels, increases in storm surge heights, changing precipitation and temperature patterns.

2.2.2. Projected sea level rise will alter the habitat availability in the Estuary, particularly that of intertidal habitats such as mudflats but also coastal margins, saltmarsh as well as low-lying land. In future climate scenarios, this will be particularly impactful on areas where habitat is unable to migrate inland due to existing sea defences and land-use (coastal squeeze). Such changes and losses will directly impact on the flora and fauna which has adapted to this environment and, in particular, loss of intertidal habitat will present a significant impact for the Estuary's bird assemblage, which rely on the rich and exposed feeding grounds and the vegetative grassy cover for protection.

2.2.3. Storm surges and sea level rise, coupled with changes to winter and summer precipitation patterns will increase the risk for erosion of riverbanks and coastlines, and likely change sediment transport regimes (volume as well as erosion/deposition patterns). These changing processes affect not just habitats themselves, but also the species that depend on them.

2.2.4. Climate change impacts are and will continue to alter the environmental conditions in freshwater and at sea which are likely to affect the life history variables[1] of different fish species (i.e. in different ways from direct mortality to more subtle physiological responses). Changing oceanographic conditions including current systems and production cycles are expected to alter feeding and migration patterns of many types of marine fauna. In freshwater, the effects of climate change are likely to be due to increasing water temperature, lower flows in summer, greater variation in flows and related environmental factors. The anticipated increase in winter flooding intensity may change the morphology of the Severn's rivers, further impacting life history of migratory fish species with the destruction of egg laying sites for migratory salmonids

2.2.5. Impacts on the fish assemblage will indirectly challenge the future ornithology of the Estuary alongside climate change through changes in food webs across the Estuary which are yet to be fully understood. Intertidal habitat loss to waterbirds including the loss of roosting locations at mid- and low-tide is anticipated to increase with development pressure. Furthermore, alterations to prey-species distribution and abundance in areas where there is not total habitat loss may result in fewer waterbirds utilising the intertidal zone.

2.2.6. Observable changes which are likely to continue or worsen in response to climate change include the short-stopping[2] of migratory species. Short-stopping of Siberian and Fenno-Scandian waterfowl is already notable with fewer Bewick's swans and white-fronted geese reaching the Estuary.

2.2.7. For the historic environment, impacts from extreme weather events and warming waters will raise sea levels and temperatures around archaeological assets as well as present increased erosion risk of assets, whether known or unknown. The influence of increased future wave scour in the intertidal may hasten the destruction of such features. Warming waters may result in the northward migration of invasive species which threaten the integrity of assets (e.g. pre-industrial shipwrecks). Furthermore, ocean acidification may lead to increased rates of degradation of metallic heritage assets (e.g. piers) across the Estuary.

2.2.8. More intense and regular storm events, particularly at soft sediment coastlines like beaches and saltmarsh alongside cliff retreat as undercutting increases will likely increase sediment volumes in the Estuary. The increased sea level and storminess may combine to increase

[1] Life history variables are the characteristics that describe how fish grow, survive and reproduce and include growth, survival and mortality rates, reproduction, maturation, distribution and abundance and are used as a basis to understand how fish populations change over time and how environmental factors impact fish.

[2] This is where migratory species either do not begin their migration or do not fulfil their journey to their final intended destination because their current and temporary stop-overs can fulfil their needs in terms of food, roosting and breeding needs over the winter.

rates of wave overtopping and erosion of current sea defences; in combination with increased precipitation, flooding of coastal communities is expected to increase. Further siltation of the estuary from increased runoff is also expected, degrading the water clarity and quality with additional sediment and potentially nutrifying the water from pollutant loading including from urban and agricultural landscapes. These changes in river and estuarine turbidity are likely to impact species predominantly reliant on hunting prey using visual means, including raptors.

2.3 KEY TIDAL ENERGY CONSIDERATIONS

2.3.1. The analysis and review of information undertaken in this study relating to the Estuary's environmental features points to **three primary considerations** when considering the development of a tidal range energy scheme; (1) the nature of the environmental impacts, (2) the location of the proposed asset and (3) the scale, technology and design. Policy and legislative framework considerations are also important factors in the context of tidal range power development.

NATURE OF THE ENVIRONMENTAL IMPACTS

2.3.2. Of the ecological receptors, the designated sites in the northeast of the Estuary present a significant challenge to any development due to the level of legal protections and requirements for demonstrating no likely significant impact on their conservation objectives (targets for the species and/or habitats for which sites for nature conservation are designated). This challenge is felt more significantly for barrage type developments given the impoundment of significant volumes of water north and east of any development. Lagoon type developments have the possibility of locating outside of these designated sites and impounding less water, therefore limiting direct impacts upon them.

2.3.3. Consideration is also required to the presence of both near-field and far field effects, with some species (such as migratory fish and other aquatic life) being impacted directly by near-field effects from the tidal power structures, including passage, collision and entrainment and the presence of a static impediment to movement. Far-field effects can be felt much more widely and include changes in the levels of water, current/flow rate, sediment loads, and turbidity. Such changes have the potential to alter the finely balanced conditions that exist in the estuarine environment.

2.3.4. Both tidal barrages and lagoons are likely to have significant adverse impact on the specific habitats and species associated with the estuary. The exact scale of the impact is hard to quantify given uncertainty over the level of impacts on habitats and the effectiveness of potential mitigation measures, which are largely derived from untested models, leading to lower confidence in tidal power technologies from key stakeholders. However, there is the potential for the operational mode of a tidal range project to unlock opportunities for mitigation and compensation through compensatory habitat measures within lagoons and provide an increased control over water flow within the estuary, which may offer future protection of intertidal habitats in the face of rising sea levels, coastal squeeze and more frequent storm events. The precise extent of this control will be determined by the tidal project selected, with significant differences in terms of scope of control for barrage and lagoon developments.

2.3.5. Barrages are likely to be more ecologically damaging and lagoons less so, with any site within the SAC designation more impactful. Any proposed environmental mitigation measures underpinned by engineering design at a landscape level are untested. Scenarios that require compensation (in form of habitat) is very unlikely to be deliverable at the prescribed ratio for the entire estuary in-situ, and other approaches would need to be explored and agreed. In today's legislative context, this means within the rules of the Habitat Regulations (2017) and any different approaches would need stakeholder buy-in.

2.3.6. If the climate status quo were to remain, then a red status for barrages and an amber for lagoons in this area would be envisaged for their direct impacts on key features. However, the expected impacts of climate change are predicted to significantly alter estuary conditions, which will directly impact the bird, fish and sub-tidal species assemblage along with the area and balance of intertidal and coastal habitats in the next 60 years. Invariably, we are likely to need to review and potentially strengthen existing flood and sea defences alongside building new defences and this may create further pressures on estuarine and coastal habitats. The nature and significance of these changes in environmental baseline conditions may support the case to proceed with a tidal range development with innovative mitigation measures at landscape scales. The level of uncertainty at present makes this a difficult but perhaps not insurmountable prospect, particularly for a well-considered lagoon.

2.3.7. Mitigation and compensation for likely environmental impacts needs to be considered further on a location basis and with reference to the project design specifications as these are developed. The requirements for habitat compensation and mitigation are complex, underpinned by strong legislation frameworks such as the Habitats Regulation Assessment (HRA) as well as Biodiversity Net Gain (England) and Net Benefit for Biodiversity (Wales) and with the likely amount of compensatory habitat and species mitigation required increasing within designated sites such as the SPA/SAC/Ramsar. The volume of this requirement is unprecedented for the space available within the Severn Estuary, or even nationally.

LOCATION

2.3.8. The suitability assessment carried out through spatial multi-criteria analysis using publicly available GIS datasets gave a good indication of the potential suitability of locations within the Estuary for a tidal energy project. The analysis showed that the existing protected areas, as shown in Figure 2-1, were the most sensitive from an environmental perspective with that environmental sensitivity reducing the further west you go. However, the tidal range reduces (and thus potential for tidal power) as you move west and so this becomes an immediate trade-off consideration.

2.3.9. Any tidal project will still need to be assessed for its impact and effect on the environment through its design process. Careful assessment and consideration of suitability during project siting and location selection, which includes consideration of mobile features such as fish and birds within designated sites, can reduce or avoid impacts on internationally designated sites, their features and species. Such considerations can lessen the scale and requirements for compensation and mitigation from the outset (area and complexity of habitat creation). Ultimately any siting assessment requires a series of trade-offs between optimal conditions for power production, engineering design challenges and cost alongside environmental impact and scale of mitigation for a variety of environmental sensitivities. However, this study concludes that the middle estuary could offer the best combination of tidal range potential and environmental sensitivity, particularly on the northern shoreline provided full account is made of the requirement to avoid impounding existing rivers which would otherwise affect the passage of migratory fish to or from their natal rivers.

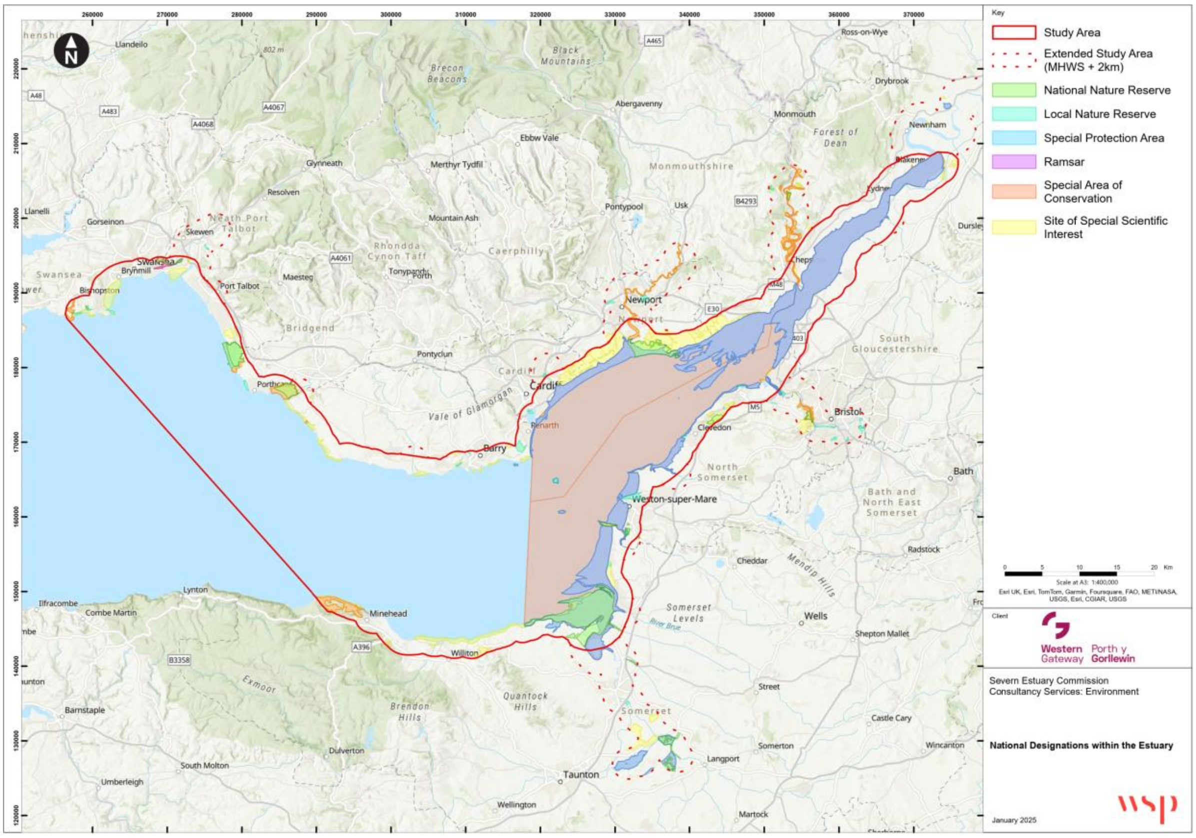

Figure 2-1 – Study area and designated sites within the Severn Estuary

2.3.10. Given the significance of proximity to protected areas in terms of both near and far-field effects from tidal power assets, siting a project outside the SAC designations and ensuring far-field effects are minimised on the protected habitats and species is recommended through siting, detailed modelling, asset size and configuration assessment and effective design. Such effects include not only changes in intertidal levels and durations but also risks from erosion of estuarine, coast and riverbanks and risks of tide-locked outlets leading to upstream flood and land drainage issues. As barrage structures impound far greater volumes of water, both near and far-field effects are more substantive, whereas lagoons (with lower impoundment levels and reduced far-field effects) may be sited closer to protected areas at reduced relative environmental impacts.

TECHNOLOGY & DESIGN

2.3.11. It has been widely modelled, studied and is recognised that the modes of operation of a tidal range power project have a significant influence on the intensity, scale and nature of impacts felt in both near and far-field locations. This is due to different levels of water being impounded throughout a tidal cycle which in turn directly impacts the surrounding intertidal environment, with greater or lesser changes in impounding water volumes and for different lengths of time being materially correlated to the change (and therefore potential impact) felt by the receiving habitats and species.

2.3.12. The six example projects reviewed had an associated mode of operation applied to understand likely impact on water levels, as follows:

- Cardiff Tidal Lagoon – ebb and flood
- Cardiff – Weston Barrage – ebb only or ebb and flood
- Shoots Barrage – ebb only
- Stepping Stones Tidal Lagoon - ebb and flood
- Swansea Bay – ebb and flood (with pumping)
- West Somerset Tidal Lagoon – ebb and flood (with pumping)

2.3.13. For ebb only modes, the rate of water level reduction is lower than natural tide. For ebb and flood generation, this results in a lower high water mark level and a higher low water mark level than what currently exists, with a period of static water remaining before the tide turns. In an ebb and flood mode with pumping, the tide levels are almost at the natural levels and therefore from an environmental perspective this is preferable and less impactful given the reduced losses on intertidal habitats. It should be noted that dual operation and pumping does present potential additional impacts from increased flow and localised currents and increased periods of turbine operation which may exacerbate entrainment of fish and other marine life within the turbine housings.

2.3.14. The water level changes have implications for the area of habitat exposed or wetted in a tidal cycle, bringing changes to the sediment transport within the Estuary, and influence therefore on rivers and other wet environments. A larger structure (such as a barrage or larger lagoon) has a likely correspondingly larger impact on the hydrodynamic characteristics of the Estuary, though this will need to be considered alongside location and consequently may offer a greater degree of influence and control over the water flow and levels. Sediment and water level changes (either through operation or through the structure itself) has an impact on the habitats lost, created, or just changed due to a water level change, which then will impact both flora and fauna to a greater or lesser extent.

2.3.15. Turbine design, the impoundment structure design as well as operation needs to be studied further to minimise or remove impacts on affected habitats and species, and to better model sediment transport and changes to tidal and fluvial flood risk. Given the typical predicted service time of 100 years or more, any design will need to ensure the structure and components can be serviced with minimal disruption to the ecosystems which may form around them over time and in particular decommissioning plans will need to fully account for what is likely to be an “environmentally integrated” structure by the cessation of power production. Post generation repurposing should be considered at an early stage to ensure opportunities are taken for long-term nature positive design features to be realised.

2.3.16. To enable the study to judge the significance of these considerations, six representative project examples were used to test, through spatial analysis, the relative influence they exert on the likely acceptability of any scheme when taken through the consenting frameworks that are presently available to developers of a tidal range power project. The summary of these is shown in Table 2.1.

Table 2.1 – Potential magnitude of impact for six example projects in the Severn Estuary

Reference Example Project	Installed Capacity (MW)	Mode of Operation	Within an SSSI, SPA, SAC, or Ramsar? (Y/N)	Scale of Compensatory Habitat Potentially Required	Risk for Fish	Risk for Birds	Risk for Archaeology* *Notwithstanding the potential for unknown finds	Sedimentation Risk	Flood / Coast Protection from Sea Level Rise	Land Drainage Mitigation Requirements
Shoots Barrage	1,050	Ebb only	Yes	Large	High	High	High	High	Coastal communities North of M4	High
Cardiff Weston Barrage	8,640	Ebb only or ebb and flood	Yes	Large	High	High	Medium	High	Coastal Communities to the North, Gwent and Somerset Levels	High
Cardiff Lagoon	2,000	Ebb and flood	Yes	Medium	Medium	High – but spatially constrained	Low	Medium	Cardiff Bay but already protected by barrage	Medium
West Somerset Lagoon	2,000	Ebb and flood	No	Medium	Medium	High – but spatially constrained	Low	Medium	Coastal protection to the coastline and flood defence for Minehead	Low

Stepping Stones Lagoon	600	Ebb and flood	No	Small	Medium	High – but spatially constrained	Low	Low	Glamorgan's Heritage Coast	Low
Swansea Bay Lagoon	320	Ebb and flood	No	Small	Low	High – but spatially constrained	Low	Medium	Swansea Bay low lying areas	Low

Table Notes

Impact Magnitude Definition

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

Compensatory Habitat Scale

- **Large**:- Greater than 1,000 hectares predicted to be required
- **Medium**:- Between 250 and 1,000 hectares predicted to be required
- **Small**:- Less than 250 hectares predicted to be required

2.4 STAKEHOLDER PERSPECTIVES

2.4.1. During the three elements of stakeholder engagement carried out for this project (and discussed more fully in **Appendix E**), clear sentiments arose under five overarching themes:

1. **Understanding the Estuary** – this is an internationally important, dynamic and protected ecosystem, and a product of human activity as well as its biological and physical processes. We don't know as much as we should about it, nor completely understand how its habitats and species and processes will change because of climate change. Growing our understanding (by surveying key areas and key topics and agreeing datasets to better inform marine/estuarine spatial planning) will improve decision-making for all development in the Estuary.
2. **Data** – Estuary data is collected and stored on many different web portals, often on a project basis and are recorded differently between devolved administrations. Longer term data is often patchy and using differing methodologies. By using existing partnerships and data storage options, which are publicly available, data confidence and availability is increased and a whole Estuary approach to protection and development can emerge. Governance arrangements and resourcing/funding will need to be explored further.
3. **Strategic Planning and Policy** – Existing partnerships for the Severn Estuary should be used to strengthen and agree cross-border priorities and needs. This needs to be a devolved and democratically accountable regional planning structure. A greater steer is needed on Government priorities and the relative weighting and importance of national significant environmental action plans – the biodiversity crisis needs to be balanced against the climate crisis.
4. **Perception** – Tidal barrages are not a viable option with what we currently know and protect about the Severn Estuary, and with current known technologies, lagoons are more acceptable even if concerns remain on their long and short-term impacts. Stakeholders are generally supportive of a pilot project. Tidal power could be more acceptable if strategic ecological regeneration was being considered at local, regional and national scales. A tidal project in the Estuary will be a first-of-its-kind development and developing a complete understanding of its impacts and effects (with levels of scientific accuracy and using assessment methodologies acceptable to stakeholders) whilst also encouraging community and stakeholder buy-in is key.
5. **Stakeholder Involvement –** Organisations with an interest in the Estuary have a large amount of scientific expertise and knowledge and should remain part of the conversation around its future. They would like to do more but are often limited by resources and funding and want to see real progress made given Government commitments to both biodiversity and climate targets.

2.4.2. The conversation around tidal power in the Severn Estuary has been in existence for many years, with stakeholders (in both regulatory and non-regulatory capacities) asked to comment and advise on other developments as well as the possibility of tidal power. There is a risk of stakeholder fatigue and significant challenges without clear commitments made from Government that account for the sentiments and concerns as above. As pressures on this environment increases (natural or human changes), maintaining engagement and dialogue is crucial in aiding our understanding of the Estuary's value and the place that tidal power may have in it.

2.5 CONCLUSIONS

Baseline data and assessment of estuarine impacts

2.5.1. The natural features and species of the Severn Estuary are outstanding examples in a European context (JNCC, 2015). The Estuary is protected for good reason as a diverse, productive and rare environment and an ecosystem that is sensitive to pressures from both human development and climate change. Many of the bird and fish species present are at population levels of international importance (JNCC, 2015).

2.5.2. The study acknowledges that whilst the Estuary conditions that we see today are because of both natural and human impacts, pressures and stressors from in-combination effects and impacts will continue to threaten the delicate balances established in many of the important protected sites, features and habitats within the estuary. It also recognises that baseline conditions within the Estuary are representative of a degraded ecosystem, where simple protection of the status quo is not addressing the need to enhance the estuarine environment, not only to counter existing impacts, degradation and stressors but also address the wider nature and biodiversity crisis.

2.5.3. Therefore, the study concludes there are strong fundamental drivers to take a precautionary approach to protecting against significant in-combination impacts on the integrity of important sites and features and such considerations need to sit at the centre of a more strategic decision-making framework for how we use the Estuary in the future, whether a tidal scheme or other development.

Conclusions on environmental decision-making

Strategic management of the Estuary and leadership of the work programmes is needed to bring together all necessary elements from an environmental, data and stakeholder perspective across the consenting process to adequately assess, understand and manage the risks from a future tidal power project:

- Management of the estuary with attention to the ecological features and impacts over administrative borders needs to be employed to offer the best outcome for nature conservation and attainment of stakeholder buy-in to any tidal energy project in the Estuary
- Continued stakeholder engagement at a strategic level, in particular to ascertain the extent of Environment Agency’s, Natural England’s and Natural Resource Wales’s requirement for Habitat Regulations compensation to address coastal squeeze and investigate to what degree Biodiversity Net Gain (England) and Net Benefits of Biodiversity (Wales) would apply to a project straddling tidal, intertidal and terrestrial habitats.
- An updated technical opinion on what type of project may be able to secure consent under the Habitats Regulations. This would have to consider whether functional compensation is achievable, both practically and technically; whether out-of-kind compensation could be acceptable; and whether out-of-region compensation might be tenable.

2.5.4. From an environmental perspective, all tidal range projects will have an impact and an effect as they change, to a greater or lesser extent, the finely balanced intertidal dynamics upon which fish, birds, invertebrates and plant life has come to adapt to. Whilst the nature of such impacts is broadly understood within a baseline context, the significance and scale vary depending on location, project size, technology selection and mode of operation.

2.5.5. Whilst we are already in possession of a wide range of data from existing baseline datasets, many of the datapoints represent a snapshot in time of individual receptors and therefore our complete understanding of the complex interrelationships is lacking when it comes to making strategic decisions at the whole Estuary level. Furthermore, the cross-border nature of the data available leads to challenging international comparison, given variable sampling across devolved administrations. A key example is the UK Priority Habitat Layer containing higher granularity in England than Wales.

Conclusions on data gathering and assessment

Further strategic data collection is required to assess the Estuary holistically, independent of administrative borders, funding, or project level study area, focused on provided levels of detail and granularity that directly support the understanding needed to effectively assess impacts and support determination of the scheme through established consenting regimes, which includes:

- Consolidation of respective data sources into a common data environment (akin to the MDE) to allow more rapid identification of the interrelationships between environmental receptors
- Continuing to build our knowledge on the impacts of tidal developments on fish population/stock size and behaviour, movement and habitat utilisation within the Estuary and Bristol Channel to help inform how fish will interact with a project and potentially be impacted by it.
- Acknowledging modelling will be required to inform any future impact assessment. Model approaches should be agreed through technical dialogue in advance of a tidal project development and modelling approaches should advance with guidance provided to developers by statutory authorities. Ensuring assessments are streamlined and align with expectations of regulators.
- Reaching agreement on the basis for considering the fish assemblage as a sub-feature of the Severn Estuary SACs when undertaking Habitats Regulations Assessments, the scale at which harm to fish populations should be assessed and the most appropriate way of estimating future harm caused to fish populations the applicability of adaptive management.
- Building on baseline hydrodynamic modelling to better understand the Estuary's sediment transport regime, and tidal and fluvial flood risk, particularly impact of tide locking and erosional changes.
- Commissioning a deeper understanding of the Estuary's paleo-landscape and also how its various habitats and biological and physical processes contribute to its unique characteristics
- Building on baseline ornithological data and recent studies for the Hinkley Point C project and to gain a more complete understanding of how bird populations might continue to use the estuary, studies that identify the future constraints on bird populations such as foraging areas and roosting locations in an unaltered baseline and incorporating the climate modelling would be useful alongside considering how mitigation at a landscape scale could be used advantageously to support future use of the estuary by bird populations.

2.5.6. The study concludes that there are several knowledge gaps that remain, such as up-to-date fish and bird population/stock size, especially in the middle (offshore) part of the Estuary. These data gaps would limit confidence in the assessment of tidal development in the Severn Estuary and would make consenting challenging and/or extend mitigation and compensation requirements. Decision-makers will benefit from collection of additional evidence on how the impacts from a tidal power project together with human-driven changes, ecosystem evolution over time and how predicted impacts from climate change are likely to interact in combination with each other. This will support determination with greater scientific certainty exactly what is likely to occur in the future and, based on how the Estuary has changed at a strategic level over the previous 15 years, what we can expect to see if the decision is made to move forward with a tidal power project development.

Impacts of climate change on the estuarine conditions

2.5.7. Climate change impacts on salinity, water temperature, sea level and coastal and river flooding are likely to alter the composition of intertidal and coastal habitats/ecosystems and affect the distribution of different habitat types, the composition of animal and plant species in those habitats, and/or the diversity and abundance of winter and summer migrant species. From an environmental perspective, the projections suggest a reduction in the suitability of the Estuary over time to support the current assemblage of both fish and birds and threaten intertidal habitats and plant species but an acknowledgement that future baseline conditions may support a different assemblage of species. The climate driven changes on the Estuary's intertidal environment of greatest importance to any development are likely to be sea level rise and increased coastal and river flooding.

- Sea level rise against hard engineered coastal defences around the estuary (coastal squeeze) could further erode intertidal habitats. This would exacerbate any habitat loss as the resource of that habitat could already be depleted by coastal squeeze before being further impact by any consented development. A large development may be able to act alongside a coastal squeeze compensation project to deliver a 'bigger, better' area of habitat. However, if the activities of any future development and those of the regulatory agencies are not aligned effectively, there could be competition for the limited area of suitable land where coastal habitat creation can be carried out.
- Increased coastal and river flooding could render coastal farmland 'unfarmable' or increase the need for nature-based flood alleviation schemes (e.g. coastal wetlands). Both these factors may create opportunities to compensate for habitat loss associated with a project. Equally if the Severn Estuary becomes a more erosive environment, this may create greater pressure on existing intertidal habitats, making them more sensitive to further impact by a development.

2.5.8. The evidence and understanding of how climate change will affect the Estuary and the marine environment is growing, but there are still many complexities and uncertainties. While there is robust data and consensus around general trends, particularly land-based climate variables, the specific impacts on estuarine systems can vary widely depending on local conditions and the interplay of various environmental and human factors. At present there is a lack of available localised data on the projected climatic changes and their impact on the Severn Estuary presenting a challenge to draw robust conclusions as to how the hydrological, ecological, geomorphological and human systems in the Severn Estuary will respond and function in the future.

Conclusions on Climate

As with the Baseline Data conclusions above, further strategic data collection is required to assess the Estuary holistically in a climate change context, focused on provided levels of detail and granularity that directly support the understanding needed to effectively assess the effects of a changing climate on the Severn Estuary and support determination (and engineering), which includes:

- Maintaining measurements at existing locations, while also incorporating new site locations to undertake measurements;
- Data gathering on water temperature at depth, salinity, dissolved oxygen, pH levels and sea surface temperatures across the estuary; and
- Undertake new studies to determine current patterns in turbidity, sedimentation and nutrient levels and what potential land use and management practices may influence them.

There are also wider gaps in the data on: compound events, cascading impacts, interdependencies, extreme events and return periods. To fill these gaps, it is recommended that:

- Further climate modelling and analysis is undertaken
- Dynamic models are used and advanced to better predict estuarine change, coupled with climatic changes to simulating environmental stress to support future modelling
- Comparisons are made with similarly positioned habitat conditions globally and those representative of future climatic conditions in the estuary

Several technical deep dives are recommended which are discussed further in Section 4 and **Appendix D**.

Significance of project location and technology

2.5.9. Given the designated sites and protections afforded to the key estuarine habitats, features and areas, the study concludes that the northeast of the Estuary, and proximity between the northern and southern coastlines make the upper Estuary unsuitable for tidal range development with what we know of the Estuary environment today. Tidal range development in the upper Estuary will create significant impacts and correspondingly larger significant effects on the Severn Estuary Ramsar/SPA/SAC, a host of SSSI and other local designations, ecological receptors in the intertidal zone, cultural heritage assets at the coast, and terrestrial flood zones within it.

2.5.10. Although impacts further west (after Barry on the Welsh coast and Bridgwater on the English coast) still need to be assessed, understood and mitigated for, the risk profile for a tidal project is correspondingly lower and therefore the conclusion is that environmental impact significance on key estuarine habitats diminishes the further west you go.

2.5.11. In terms of the predicted environmental impacts from the six example projects, barrages have a more significant set of near and far-field effects and are less suitable in the Severn Estuary due to the extent of these effects on the designated sites. It is unlikely that design of a barrage would overcome such significant environmental impacts to a satisfactory conclusion for consenting. This position also holds true for the larger lagoon within the designated sites.

2.5.12. Different operational modes, turbine design, and impounding structure design all need further study and modelling to understand how key species behave around these structures, what habitats could be created within the impounding area itself (as well as structure), how sediment transport will be altered, how known and unknown archaeology and heritage assets will be affected and what will happen to tidal and fluvial flood risk through a tidal cycle, storm surges and other likely climate changes for the Estuary.

Consenting, mitigation and compensation

2.5.13. Mitigation of impacts – the mitigation hierarchy needs to be followed, which states that impacts are best avoided through appropriate siting and design before they are to be mitigated for (and as concluded above). Key impacts beyond that that will require environmental mitigation are likely to be:

- Impacts to ecological features (habitats, species, functional ecosystems, and far-field effects);
- Impacts to sediment transport, scouring and erosion, tidal locking regimes and tidal and fluvial flood risk changes both upstream and downstream of an impounding structure;
- Impacts to known and unknown heritage and archaeological features; and
- Cumulative impacts (of any other tidal developments as well as other proposed development within Estuary).

2.5.14. Mitigation will likely take the form of habitat creation, recording of heritage features, potential strengthening of other embankments, species-specific changes to the project's design (such as behavioural deterrents or turbine design changes or operating periods) amongst other elements. These need to be studied further on an individual project basis to best inform adaptive mitigation strategies.

2.5.15. To gain a better understanding of some of these impacts and efficacy of mitigation, robust datasets are needed for the Estuary, more detailed modelling, and the potential for these things to be tested in a practical trial project or living lab scenario. A digital twin could be considered, though should be noted that these require a lot of data to present realistic outcomes, and if this is to be considered, robust, consistent datasets are even more critical ahead of any operational project.

2.5.16. The policy and legislative frameworks comprise different administrations and focus across the study area which reflect additional complexity as outlined below:

- Current policy and legislation have different priorities between devolved administrations, with a strong focus on future generations present in Wales over England. Applying a regional spatial lens to the Estuary as a whole, with agreed compromises, could overcome this.
- Marine spatial planning is an emerging field of planning policy, and existing spatial plans for the Estuary focussed on gathering evidence for marine development to inform better decision-making. There is recognition that future policies need to be more spatial and climate adaptable than current policies.
- A tidal project in the Estuary would most likely be submitted as a Nationally Significant Infrastructure (NSIP) project and applied as a Development Consent Order, with a decision made by the Secretary of State. The priorities between the devolved nations need to be balanced, and given the fluid nature of the marine space, the Estuary needs to be reviewed as a strategic whole.

- A regional, strategic plan for the Estuary should therefore be developed, using existing partnerships and supported by comprehensive data to best ensure that policy and projects both align to its complex environment, and be better able to support its future changes. This should be aligned to enhance the UK's commitment to both reversing biodiversity loss and move to net zero.

Conclusive summary

2.5.17. The Severn Estuary is a complex environment undergoing changes from both human and natural pressures. Conclusions indicate that based on the current understanding of the Estuary, there is not likely to be sufficient space in the estuary (intertidal, coastal, terrestrial) to accommodate further expansive development in an environment which is already degraded, and degrading, due to its current use and the impacts from global-scale climate change that are projected.

2.5.18. Where space can be portioned to accommodate a tidal range project, the direct and indirect impacts on the Estuary's environmental characteristics will require careful assessment and a joined-up approach across the relevant stakeholder groups to ensure these impacts can be avoided, mitigated and/or compensated for in what is already a pressured environment with many cumulative pressures.

2.5.19. The concept of a trial project to create a living/practical lab in a location of compromise where impacts are generated in sufficient severity to be studied for mitigation whilst not undermining the environment of the Estuary, will likely present a clearer understanding of the Estuary's ability to cope with further development on the scale of a tidal range generation project.

3 BASELINE SUMMARY

3.1 SCOPE OF ASSESSMENT

3.1.1. To address the above requirements of the work package, the project team has conducted a strategic review of the existing environmental designations, knowledge and data gaps based on the 2010 Strategic Environmental Assessment (SEA) Tidal Energy Review, the information supplied in the Commission's 2024 Call for Evidence, the 2016 Hendry Review, and publicly available evidence from projects including the Hinkley Point C development. The full suite of sources consulted for this review are listed in **Appendix A**, notwithstanding contributions from stakeholder knowledge gathered as part of the work package.

3.1.2. To provide focus for the environmental study, five specific topics associated with the physical and environmental characteristics of the Severn Estuary have been selected as representative markers of the biodiversity, human and natural characteristics. These are: (a) the estuarine habitats, (b) fish species and assemblage, (c) bird life, (d) marine archaeology, and (e) flood risk and geomorphology.

3.1.3. The review of environmental information has been supported by stakeholder engagement with experts and organisations who have an interest in, and knowledge of, the Estuary, its characteristics and related environmental objectives. Many of these stakeholders will be key consultees as part of any future tidal range project development process and therefore understanding viewpoints and concerns has formed an integral part of this work package. Further details are presented in **Appendix E.**

BIODIVERSITY FEATURES

3.1.4. This section identifies key biodiversity features in the Severn Estuary. Fish and birds are dealt with in a separate chapter. It highlights the main factors driving change in the ecology of the Estuary and identifies a selection of uncertainties in the baseline data.

3.1.5. The Estuary contains the largest aggregation of saltmarsh habitat in the south and south-west. Mudflats, which typically occur within the middle reaches of the Estuary, comprise a large proportion of the Severn Estuary's intertidal habitat, and can be found alongside intertidal sandflats. Combined, they cover around 20,300ha of the Severn Estuary intertidal area (Severn Estuary Partnership, 2011).

3.1.6. Subtidal sandbanks are permanently submerged features of soft sandy sediments which exist in relatively shallow depths of less than 20 metres. The sandbanks of the Severn Estuary support a distinct invertebrate community, including notable species such as crustaceans, echinoderms (such as starfish) and polychaetes (such as lugworms).

3.1.7. Intertidal rocky shores along much of the Estuary are typically comprised of hard substrate such as rocks, boulders, mussel/cobble scars, rocky pools and shingles.

3.1.8. Seagrass habitats of the Severn Estuary are made up of eel grasses (*Zostera* sp.). These occur extensively on the more sheltered mixed substrates around the Welsh side of the Second Severn Crossing. The Severn seagrass beds are unique. They occur amongst mixed substrates of cobbles, sands, muds and large boulders; whereas elsewhere such beds are generally associated with mudflats. Two species of eel grass are present compared with most other sites where it is more normal for only one species to occur.

3.1.9. Biogenic reefs in the Severn are constructed by tube-dwelling polychaete worms, commonly known as honeycomb worms (*Sabellaria* sp.). Studies have revealed extensive biogenic reef systems in the intertidal and subtidal zones of the Severn Estuary, distinguishing the region from other estuaries in the south-west of the UK, where such reefs are largely absent. Intertidal reefs can be found at locations such as Redcliff Bay near Portishead, south of Severn Beach near Avonmouth; and at Goldcliff near Newport.

3.1.10. Data on the distribution and extent of estuary habitats is provided by Natural Resource Wales and Natural England and is available from both organisations as GIS data, downloadable from their websites. It is apparent that other organisations have published data on the distribution of marine habitats, including The Crown Estate (e.g. the Marine Data Exchange), the Joint Nature Conservation Committee and organisations such as EMODnet. It is also apparent that there is a degree of overlap between different datasets, and they may not extend to the full extent of the Estuary. To inform a robust assessment of the possible impact of a tidal energy project, there is a need to generate a consolidated and rationalised set of habitat data for the Estuary, taking the most reliable data sets from the varied sources available.

FISH

3.1.11. Over 100 fish species have been recorded within the Severn Estuary and form part of the Ramsar fish assemblage designation (JNCC, 1995). Included within this fish assemblage are a number of internationally and nationally designated estuarine and migratory fish species. These species collectively fall into the range of international designations within the Severn Estuary and its tributary rivers; in particular the Rivers Usk and Wye. In addition to Habitats Directive designated migratory fish species, the internationally protected catadromous European eel (*Anguilla Anguilla*) and the highly protected sturgeon (*Acipenser sturio*) require consideration within any future assessment of development within the Estuary or Bristol Channel.

3.1.12. The Estuary has benefited from long-term fish datasets dating back to the 1970s from entrapment studies at the power stations that have historically operated around the Estuary, in particular Hinkley Point B and Oldbury. These datasets have enabled analysis of changes to the fish community and correlations with potential climate change effects such as changes to water temperature, salinity, the North Atlantic Oscillation (NAO)[3] and river flow.

3.1.13. In general, conclusions of previous studies relating to the feasibility of a tidal range power project, whether a lagoon or a barrage in the Severn Estuary and Bristol Channel, have recognised that impacts are likely to be unprecedented. The impacts arise in what is a heavily designated area and there is significant uncertainty in how the regulatory framework would apply to and be managed around a large-scale marine power project. Application of the mitigation hierarchy, in particular embedded mitigation in any scheme design and

[3] This weather phenomenon determines the strength of westerly winds across the Atlantic as a result of the differences in atmospheric pressure between Iceland (which is low) and Azores (which is high).

operating regime, will be important to avoid and minimise the impacts as far as possible, with location and consideration of proximity and interaction with the heavily designated tributary rivers being a key consideration. There is also existing ecological improvement requirements under the objectives of the various designated sites and existing conservation legislation that would need to be considered to ensure 'additionality' of proposed mitigation measures. These mitigation measures would need to consider the unique nature of estuarine migratory species, particularly noting that mitigation or compensation 'off-site' would be insufficient to maintain the integrity of designated features within individual tributaries to the Severn Estuary. For example, salmon and sea trout populations which return mostly to their individual natal rivers for spawning.

3.1.14. The Severn Tidal Power SEA and subsequent Swansea Bay tidal lagoon power studies as well as the Hinkley Point C permit variation inquiry have advanced the approaches that would be required to assess the impacts of a tidal power development on fish populations. A range of modelling approaches would be required to assess impacts at an individual and population/stock level as well as at an ecosystem level. To ensure confidence in assessments, known evidence gaps need to be filled and/or uncertainty within the model development and output interpretation managed.

3.1.15. Previous studies, in particular at a whole Estuary scale, such as the Severn Tidal Power SEA, highlight the potential impacts that would require assessment for the fish assemblage as a whole and for the individual species; given the current condition of some populations and other pressures. There has been acknowledgement within the studies of the potential for local population extinctions and population collapses of some designated species such as Atlantic salmon and shad, if impacts are not successfully mitigated or compensated for. The more recent assessments of potential impacts of the Hinkley Point C power station development have further highlighted the complexities of assessing impacts upon the fish assemblage.

3.1.16. Several knowledge gaps are known which impact the confidence in required modelling outputs and assessment requiring significant management of uncertainty which can inflate impact severity consideration and required mitigation/compensation considerations. This is confounded in some instances by the fact that evidence which assessments have previously been made on have been dependent upon data that may be 20-30 years old. Despite the benefits of long-term fish datasets for the Estuary, the nature of these datasets, which are largely dependent on power station entrapment studies, limits the understanding of fish movement and migration within specific areas of the Estuary, as well as habitat utilisation.

3.1.17. Effort has been made since the 2010 SEA study and subsequent Swansea Bay studies as well as the Hinkley Point C development assessment to progress filling some of these key data and knowledge gaps, in particular by organisations such as Swansea University, Cefas, NRW, the Environment Agency (EA) and through the Welsh Government's Tidal Lagoon Challenge.

3.1.18. Since some of the earliest studies, the fish assemblage of the Severn Estuary has seen changes both positively and negatively and significant updates have been made to tidal range power technology (for example turbine design) with the intention of improving the environmental impact position, in particular in terms of fish passage. Any future project assessment would, therefore, require consideration of such data and modelling improvements to ensure a realistic assessment position with reduced uncertainty management through increased assessment output confidence.

ORNITHOLOGY

3.1.19. The Severn Estuary is an internationally important site for birds, particularly wintering waterbirds, for which it is designated as an SPA, SAC, Ramsar and SSSI. It is also likely to be functionally linked to a range of further designated sites for ornithological features. The baseline conditions of the estuary for waterbirds have changed over time and the composition of the assemblage has changed in line with underlying national trends driven by climate change and habitat use (Sustainable Development Commission, 2007). This has been marked by the arrival of little, cattle and great egrets from Southern Europe into northwest France and then into southwest England (BTO, 2024).

3.1.20. Short-stopping of white-fronted goose and Bewick's swan are leading to a decline in numbers within the Estuary, with an increase in the North Sea basin, particularly in the Netherlands. This is likely happening for a range of wildfowl of eastern origin in winter.

3.1.21. Despite these species' changes, the total assemblage number has remained stable at approximately 73,000 birds. This consists mostly of dunlin, grey, golden and ringed plovers, knot, shelduck, wigeon, teal, curlew, bar-tailed and black tailed godwits, black-headed, common, herring, lesser black-backed, great black-backed and black-headed gulls.

3.1.22. There is likely to be functional linkage from all SPAs with wetland features within 10-15km of the Estuary as birds interchange between the sites. For the Estuary, this is likely to be the Somerset Levels and Moors SPA which lies near to Bridgwater Bay. At the western end of the study area, Burry Inlet and Carmarthen Bay are both likely to be connected. The vast areas of mudflat within the Estuary, and the saltmarsh that fringes it, are crucial habitats for birds, with the former particularly important for foraging, and the latter for roosting and to a lesser extent foraging.

3.1.23. All proposed tidal range schemes from the 2010 SEA are likely to have significant adverse effects on the baseline waterbird populations, although the scale of the impact is hard to quantify given uncertainty over the level of impacts on habitats and the effectiveness of potential mitigation measures. Impacts are derived from untested models, and this leads to low confidence from key stakeholders (RSPB, Wildlife Trusts). The level of impact is not well quantified, with number of species expected to have significant impacts in each scenario the only metric presented with total habitat loss ranging from 5-50% and declines in 9-30 species.

3.1.24. There is good baseline data at high tide for the Estuary from coastal vantage point surveys, collated by the British Trust for Ornithology (BTO, 2024). Extensive study would still be needed to quantify usage by waterbirds through the tidal cycle to identify key areas of change. Bridgwater Bay has already been well covered through the Hinkley Point C project, and further data may be available to inform a baseline data collection approach. Both RSPB and the Wildlife Trusts have negative attitudes toward the 2010 SEA, with uncertainty on effects underpinning this. Natural Resources Wales (NRW) is more positive, however outlines that a strategic approach would be needed to maximise output from a tidal range development whilst not compromising the needs of the environment. Natural England's position is not recorded regarding birds and would need establishing, as well as any changes in the position of other stakeholders in the interim

3.1.25. In the interim period since the 2010 SEA, there have not been significant developments regarding the bird assemblage knowledge, however intertidal surveys at a granular project level have continued. These may support future regional assessment of the bird assemblage to identify patterns of change

3.1.26. The expected impacts of climate change are anticipated to significantly alter the bird assemblage of the estuary in the next 60 years. The uncertainty in the modelling is likely to lead to pessimism in stakeholders but the direction of travel is clear, with changes in assemblages already evident. Due to these factors, there may be potential to proceed with a tidal range development with innovative mitigation measures at landscape scales. The level of uncertainty makes this a difficult but perhaps not insurmountable prospect, particularly for a well-considered lagoon. For ornithology features, when considering climate impacts over the lifetime of a project, an amber status is considered appropriate. There would be many complex hurdles with regard minimising impact but there would be an opportunity to create a development that futureproofs the estuary. Identification on future constraints on the population such as foraging areas and roosting locations in an unaltered baseline without a barrage but incorporating the climate modelling would be useful.

MARINE ARCHAEOLOGY

3.1.27. The Severn Estuary and Bristol Channel are noted for their significant archaeological record and potential for future discoveries. The Bristol Channel has been through significant environmental changes over the glacial and inter-glacial periods. The current sub-tidal and intertidal area of the Bristol Channel was terrestrial in the Late Pleistocene and Early Holocene periods, and the landscape would have been suitable for human exploitation and habitation. By the Neolithic period (4000–2200 BC), sea-level was near modern levels and the coastline had retreated to near its current position.

3.1.28. Along the coast and within the intertidal, the Estuary has potential for the remains of prehistoric and historic landscapes. The prehistoric landscapes are likely to preserve Late Glacial to Early Holocene archaeological features and paleoenvironmental remains. The historic landscapes are likely to be more limited as the land reclamation activities have moved the coast further into the historic estuary footprint.

3.1.29. Identified terrestrial receptors are presented in **Table 3.1**

Table 3.1 – Coastal designated assets in the Severn Estuary study area

Asset designation	Quantity in England	Quantity in Wales	Total assets identified
Scheduled Monuments	167	228	395
Listed Buildings	5016	1979	6995
Conservation Areas	91	-	91
Registered Parks and Gardens	67	21	46

3.1.30. The United Kingdom Hydrographic Office (UKHO) has recorded numerous assets or anomalies within the Severn Estuary which have varying or unconfirmed historical significance. These assets may remain of unconfirmed significance until investigated further as part of wider works within the Severn Estuary. The assets identified by the UKHO are described in **Table 3.2.**

Table 3.2 – UKHO identified cultural heritage assets

Asset designation	Total assets identified	Comments
Unknown wrecks	172	-
Named wrecks	107	-
Unspecified obstructions or foul ground	60	10 of which are named wrecks
Aircraft remains	5	-
Structures	1	A pier

3.1.31. There is substantial potential for unknown heritage assets to exist. The known heritage assets exist across the Estuary study area, with concentrations of wrecks to be found around ports and around headlands and given the longevity of human presence within the Estuary, unknown heritage potential could exist within all elements of the Estuary.

GEOMORPHOLOGY

3.1.32. The Severn Estuary, due to its size, importance and long history of human activity, is one of the most studied estuaries in the UK. A significant bibliography of academic, consultancy, public sector and private sector research exists detailing its geomorphological and hydrological environment.

3.1.33. The Estuary's hydrodynamics are complex and heavily influenced by its geographical positioning and morphological features. While the adjacent Bristol Channel is shaped by both tidal currents and Atlantic swell waves, the Severn Estuary is more protected due to its northeast-southwest orientation, making it predominantly governed by tidal forces. Its funnel shape and shallow water depths result in tidal asymmetry, where the flood tide, despite being stronger, is shorter than the ebb tide. This tidal imbalance plays a critical role in sediment transport within the Estuary, as flood tides push saline water and sediment upstream, while the ebb tide carries them back towards the sea, creating a very dynamic environment.

3.1.34. Its high suspended sediment concentration is maintained at capacity, a state supported by tidal asymmetry and the lack of natural sediment sinks due to historical land reclamation. Seasonal variations also affect sediment dynamics; for instance, summer months see lower suspended sediment levels due to reduced river discharge and calmer weather conditions, allowing for sediment deposition that is later eroded during winter storms. Fine sediment is primarily deposited in low-energy areas like intertidal mudflats and salt marshes, with key sinks located in Newport Deep and Bridgwater Bay.

FLOOD RISK

3.1.35. The tidal floodplain of the Severn Estuary is currently protected from flooding by extensive tidal defences on both banks. These protect existing property, infrastructure and agricultural land. Some 90,000 properties and commercial assets are at risk of flooding in over 500 km^2 of low-lying tidal floodplains of the Severn Estuary (approximately 35,000 properties in Wales and 54,000 properties in England) with high concentrations in the urban centres of Cardiff, Newport, Burnham on Sea and Weston-super-Mare.

3.1.36. The December 2010 Severn Estuary Shoreline Management Plan Review (SMP2) Indicates that Hold the Line (HTL) is in general the preferred draft policy to protect urban areas to the current level of protection. There are many non-urban areas where the preferred draft policy is Non-Active Intervention, where no maintenance, repair or replacement of existing defences will take place.

3.1.37. In the tidal floodplain, property and infrastructure assets are protected in general to a standard of at least 2% (1 in 50) annual exceedance probability (AEP). In some rural areas the standard is as low as 20% (1 in 5) AEP. Defence overtopping can therefore take place, with potential catastrophic consequences should overtopping result in the weakening and breaching of the defences. The tidal influence restricts upstream fluvial flows and therefore fluvial flood risk is indirectly influenced by downstream tidal conditions.

3.1.38. Coastal erosion with the potential for undermining defences and affecting infrastructure is a potential risk in the Severn Estuary. For example, along the coastline from Hinkley Point to Minehead, emergency works were initiated in 2023 at Blue Anchor, to protect the coastline and B3191 road at a cost of £3.8m.

CURRENT CLIMATE

3.1.39. The climate within the Severn Estuary, along with much of the UK, is classified as an 'Oceanic' climate within the Köppen-Geiger Climate classification system. This system defines different climate zones across the globe, for example, tropical, arid, polar and continental. Characteristics of the Oceanic zone (Cfb) include cool winters and warm summers, with year-round rainfall.[4]

3.1.40. There are multiple drivers which influence the weather in the UK, this includes warmer tropical air meeting colder arctic air in the air mass resulting in large changes in weather and intense severe storms.

3.1.41. The latest State of the UK Climate Report 2023 indicates UK's climate is changing, with recent decades warmer, wetter, and sunnier than the 20th century on a national and local

[4] Severn Estuary Partnership. (n.d.) Weather and Climate [Online] Available at: https://severnestuarypartnership.org.uk/the-estuary/environmental-quality/weather-and-climate-change/

scale. UK land temperatures have warmed by 1.25°C compared to 1961-1990, which is at a broadly consistent, though slightly higher, rate than the observed change in global mean land temperatures (1.15°C).

3.1.42. The Hadley Centre Central England Temperature (HadCET) dataset is the longest instrumental record of temperature in the world. The mean, minimum and maximum datasets are updated monthly. These temperatures are representative of a roughly triangular area of the United Kingdom enclosed by Lancashire, London and Bristol and provide context to the changing UK climate (**Figure 3-1**).

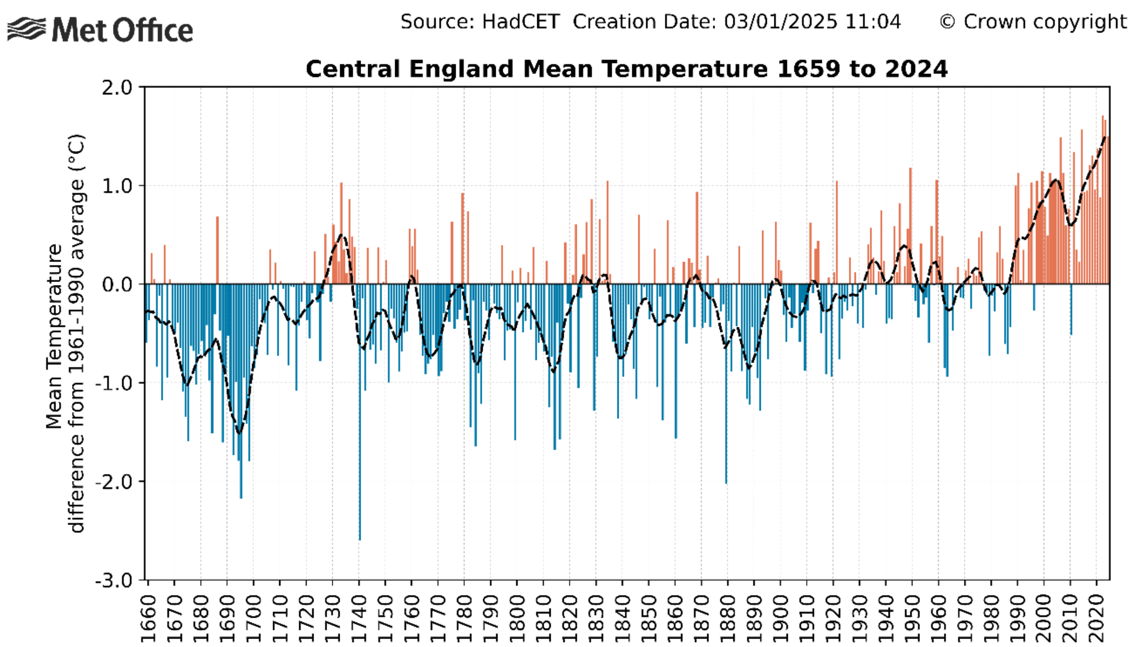

Figure 3-1 – HadCET dataset mean temperature 1659 to 2024

3.1.43. As per IPCC's WGI Interactive Atlas, the long-term average sea surface temperature for the region corresponding to Severn estuary is 7.7°C over the baseline period of 1995 to 2014. These temperatures are higher upstream than they are downstream (e.g. ranging between 11-13.5°C in 2006).

3.1.44. South-west England is one of the more exposed areas of the UK, with wind speeds on average only greater in western Scotland. The strongest winds are associated with the passage of deep depressions close to or across the British Isles. The frequency and strength of depressions is greatest in the winter months and this is when mean speeds and gusts are strongest. Across the UK there is a marginal downward trend of annual mean wind speeds, falling from ~18.5km/h in 1970 to ~17km/h in 2023.

4 FUTURE TRENDS

4.1 CLIMATE PROJECTIONS

4.1.1. Being home to unique plant and animal species that have adapted to brackish water, estuaries are delicate ecosystems. Estuary communities are especially vulnerable to future changes in climate variables such as rising sea-levels, increases in storm surge heights, changing precipitation and temperature patterns and others.

4.1.2. The environment of the Severn Estuary is one of the most dynamic in the UK, with changes in sea level, waves and storms all playing their part in shaping the coastline. Historical records show that severe storms have caused coastal erosion and flooding, however, extreme weather events are becoming more and more frequent. One of the biggest threats to the Estuary is from rising sea levels which, coupled with significant storm events, exacerbate the effects of coastal erosion and flooding (The Severn Estuary Partnership, 2025).

4.1.3. These climate change effects are already impacting the Estuary with sea level rise, storm surge, coastal flooding, warmer air/water temperatures and increased precipitation being amongst the most significant. The impact from these changes is likely include acidification of waters, changes in river flows, with increased pathogens from run-off affecting water quality and altered environmental cues affecting biological cycles such as feeding, reproduction and migration patterns.

4.1.4. The UK climate baseline as outlined in **Section 3** shows that a warmer, wetter climate is already happening. The UKCP18 (UK Met Office, 2018) projections are the most recent scenarios, produced by the Met Office, of what will likely happen to the UK's future climate and looks at a range of rising temperature scenarios and land-based projections arising from this (RCP4.5, the moderate emissions and RCP8.55, the high emissions scenarios).

4.1.5. The UKCP18 probabilistic projections have been used to infer future changes in a range of climate variables that may affect the Severn Estuary. The UKCP18 considers land-based datasets to develop these projections. The Climate Risk Indicators (CRI) (Arnell, 2025), developed as part of the UK Climate Resilience Programme have been used in this assessment.[6] The CRI utilises the UKCP18 projections and allows for a range of climate related indicators (including but not limited to, Met Office Heatwaves and heat stress). Data has been extracted from the CRI Explorer for two representative local authority areas of

[5] Representative Concentration Pathways (RCP) are climate change scenarios to project future greenhouse gas concentrations. RCP4.5 is described by the IPCC as an intermediate scenario. RCP 4.5 IS likely to result in global temperature rise between 2°C and 3°C. RCP8.5 is generally taken as the basis for worst-case climate change scenarios with global Severn Estuary Partnership (2015) Climate Change Report Card 1 [Online] Available at: https://severnestuarypartnership.org.uk/wp-content/uploads/sites/2/2015/10/ClimateChangeReportCard1.pdf temperatures likely to rise by over 4°C.

[6] There are inherited limitations and uncertainties within the data. Further information on the methodology used to produce this data can be found in Arnell, et al., (2021) Changing climate risk in the UK: a multi-sectoral analysis using policy-relevant indicators. Climate Risk Management 31, 100265 10.1016/j.crm.2020.100265

'Forest of Dean' and 'West Somerset' corresponding to the time periods of 2030s (2021-2050), 2050s (2041-2070) and 2080s (2071-2100) for RCP4.5 and RCP8.5. Additionally, a summary of relevant UKCP09 climate projections has been included in this report. However, it should be noted that much of this data was not incorporated into the most recent climate projections (UKCP18).

4.1.6. The UKCP09 climate projections indicate an increase in both winter and summer mean air temperature across the Severn Estuary. Marine air temperature for the Severn Estuary is projected to rise in line with land air temperature (The Severn Estuary Partnership, 2015). It is estimated that by 2080 sea levels will be 30-40cm higher than they are at present based on a medium greenhouse gas emissions scenario. The UK's estimate[7] for sea level rise by 2100 at Cardiff, lies between 0.27m to 0.69m (low global temperature rise scenario) to between 0.51m and 1.13m (high global temperature rise scenario).

4.1.7. Projections of storm behaviour used by the UKCP09 wave model show storm tracks moving south, resulting in lower wave heights to the north of the UK and slightly larger wave heights in some southerly regions, especially the southwest. Models suggest that coastal squeeze, habitat loss, coastal erosion and steepening of beach profiles will all increase in the future because of further sea level rise and possible changes to wave conditions.

4.1.8. Around the UK the size of storm surge expected to occur on average about once in 50 years is projected to increase by less than 0.9 mm/year over the 21st century. For the Severn Estuary, an increase in the 50-year skew surge[8] return level of around 0.8 mm/year is anticipated. Storm surge events are difficult to predict beyond a few days ahead as they are controlled by various interlinked weather and marine factors, and this is why much uncertainty remains in future projections (Holt, et al., 2009).

4.1.9. Both the RCP4.5 and RCP8.5 climate change scenarios predict a steady rise in the occurrence of heatwaves (defined as over a threshold of 25°C). This is also reinforced by the predictions for increasing heat stress, more significantly in the RCP8.5 scenario, predicting a stark increase from the 2050s to the 2080s.

4.1.10. Overall, precipitation patterns are likely to increase in the winter and decrease in the summer. This could influence the temporal length and scale of mixing which is critical for water quality. In addition, changes in flows (seasonally and due to drought/high rainfall events) are likely affect levels of nutrients in the estuary and lead to more frequent and severe eutrophication, hypoxia, sedimentation and harmful algal blooms.

4.1.11. The decreased rainfall associated with droughts is anticipated to lead to increasing salinisation of freshwater habitats in upstream tidal rivers during periods of low rainfall, thereby threatening freshwater habitats and placing estuarine habitats under stress. The increased number of dry days and decreased precipitation (usually in summer months) are

[7] https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Marine-report.pdf

[8] According to UKCP09, a skew storm surge is a way of calculating the height of a storm surge and is the height difference between a predicted astronomical high tide and the nearest (in time) observed or modelled high tide.

anticipated to result in baked soils and a decrease in infiltration rate, increasing surface runoff and sedimentation of the Estuary during periods of rain immediately following drought conditions.

4.1.12. Based on the current climate baseline and the future climate projections, the climate trends for the Severn Estuary are summarised in Table 4.1, though it should be noted that this is based on land projections and modelled data. The level of confidence in the climate science and projection data is provided for each time period. It would be expected that the trend and hazards identified would be amplified for each RCP scenario (i.e. RCP4.5 or RCP8.5) as described above.

Table 4.1 - Climate trends and land-based hazards for the Severn Estuary

Climate Parameter	Climate Trend	Data Confidence			Hazards
		Conf 2030s	Conf 2050s	Conf 2080s	
Sea Level Rise	Increased mean sea level and high tides	High	High	High	Coastal and inland flooding
		High	High	High	Coastal erosion
		High	High	High	Higher water table
		High	High	High	Saline intrusion and/or salt spray exposure
Precipitation	Increased number of dry days and decreased precipitation (summer)	Moderate	Moderate	High	Dry soil hardening, cracking and destabilisation
		High	High	High	Heatwaves
		High	High	High	Wildfire
		Moderate	Moderate	High	Reduced water availability
	Increased frequency, volume and duration of extreme precipitation events (winter)	Moderate	Moderate	High	Heavy Rainfall
		Moderate	Moderate	High	Soil destabilisation, landslips, landslides or subsidence
		Moderate	Moderate	High	Surface water flooding (and standing water)

Climate Parameter	Climate Trend	Data Confidence			Hazards
		Conf 2030s	Conf 2050s	Conf 2080s	
Wind	Increased intensity of wind and storm activity	Low	Low	Low	High winds
		Low	Low	Low	Lightning and lightning strikes
Temperature	Increased frequency and intensity of hot spells (summer)	High	High	High	Hot days (and nights)
	Decreased frequency, volume and duration of cold days/snow/ice events (winter)	High	High	High	Low temperature days (with snow/ice)

4.1.13. Evidence and understanding of how climate change will affect estuaries and the marine environment is growing, but there are still many complexities and uncertainties. While there is robust data and consensus around general trends, particularly land-based climate variables, the specific impacts on estuarine systems can vary widely depending on local conditions and the interplay of various environmental and human factors. Ongoing research and monitoring are essential to continue to build and further refine analysis of climate change risks to estuaries.

4.1.14. This section has been informed partly by the Climate Change Technical Note (WSP, 2024). Available for review in **Appendix D** where a more detailed review of the climate projections for the UK and the Severn Estuary is presented.

4.1.15. At the time of writing, there is a lack of available localised data on the projected climatic changes and their impact on the Severn Estuary. As such, it is challenging to draw robust conclusions as to how the hydrological, ecological, geomorphological and human systems in the Severn Estuary will respond and function in the future. Preliminary conclusions and recommendations for further study are discussed within each respective topic section of Section 4.2.

4.2 ENVIRONMENTAL TOPICS

BIODIVERSITY FEATURES

4.2.1. Key factors affecting change in coastal habitats include across the Estuary include climate change, toxic and nutrient pollution from agriculture and sewer discharges, development agriculture; and recreational use of coastal and shallow water habitats.

4.2.2. Climate change effects on salinity, water temperature, weather, sea level and coastal and river flooding are likely to alter the composition of intertidal and coastal habitats/ecosystems. Ecological changes may include those affecting the distribution of different habitat types, the composition of animal and plant species in those habitats, and/or the diversity and abundance of winter and summer migrant species. The climate driven changes on the Estuary's intertidal environment of greatest importance to any development are likely to be sea level rise and altered coastal and river flooding (e.g. the magnitude, severity and frequency of flood events).

4.2.3. Sea level rise against hard engineered coastal defences around the Estuary (coastal squeeze) could further erode intertidal habitats. This would exacerbate any habitat loss arising from tidal energy development, as these habitats could already be depleted by coastal squeeze before being further impact by any consented development.

4.2.4. Increased coastal and river flooding could render coastal farmland 'unfarmable' or increase the need for nature-based flood alleviation schemes (e.g. coastal wetlands). Both these factors may create opportunities to compensate for habitat loss associated with a project. Equally if the Severn Estuary becomes a more erosive environment, this may create greater pressure on existing intertidal habitats, making them more sensitive to further impact by any development.

FISH

4.2.5. Climate change will alter the environmental conditions in freshwater and at sea which may affect the life history variables of different fish species in different ways from direct mortality to more subtle physiological responses. Changing oceanographic conditions including current systems and production cycles are expected to alter feeding and migration patterns of many types of marine fauna. In freshwater, the effects of climate change are likely to be due to increasing water temperature, lower flows in summer, greater variation in flows and related environmental factors.

4.2.6. These effects could result in changes to:

- river carrying capacity;
- juvenile production;
- life history variables; and
- population features of fish.

4.2.7. In addition, changing ecosystems in both freshwater environments and transitional waters may introduce alterations from indirect effects of changing trophic dynamics, new competitors, predators and pathogens.

4.2.8. Life history theory and observations indicate that the variety of interactions and correlations that occur amongst traits that drive population size may alter under different climate scenarios e.g. growth, survival, age at maturity etc. Long-term adjustments in life history characteristics are seen in fish and may be responses to a range of environmental changes, of which climate is one.

4.2.9. The long-term fish datasets for the Severn Estuary from power station entrapment monitoring demonstrate alterations to the assemblage over a period of decades and potential links to changes to environmental parameters such as temperature, salinity, the North Atlantic Oscillation and river flow have been reported on. The effect of climate change has the potential to be significant, even major, however the processes are complex and uncertain including a lack of data. The immediate factors and their responses to climate are therefore, not sufficiently understood to confidently be able to model predictions of population/stock change.

4.2.10. Predicted population/stock changes in response to climate driven environmental alterations will differ between species making assessment over a 100+ fish assemblage complex.

4.2.11. For migratory fish species their production is the combined outcome of their ecology in freshwater and at sea. A combination of increasing temperature and more erratic and higher peaking river flows and greater incidences of drought may gradually reduce the availability of optimal habitat in rivers for key species such as Atlantic salmon, trout and lamprey. There is potential that contraction of habitat and affected habitat connectivity could reduce the overall production capacity of the Severn Estuary rivers. It may also result in reduced survival of juvenile shad through flushing out of rivers into the Estuary earlier in their lifecycle.

4.2.12. For Atlantic salmon (a cold water species), effects from climate change are likely to be negative rather than positive. The European eel stock has shown a strong decline, and recruitment is as low as 1% of historic levels. Climate change is likely to have significant effects on the life-history parameters of eel, in particular; rate of maturation, size at maturation, life-cycle length and recruitment/yellow eel population size. Changes in these parameters, either solely or in conjunction with each other, may have significant effects on the size of the silver eel population within UK rivers. Conversely changes to the spawning schedule of shad, potentially reduced adult longevity and decreased mortality rates could result in an increase in population size.

4.2.13. The impacts upon fish are summarised in **Table 4-2**

Table 4-2 – Predicted changes in Severn Estuary Fish Populations

Environmental Stressor	Fish Receptor	Effect	Impact
Increasing temperature and erratic and higher peaking river flows or droughts.	Migratory Fish (e.g. salmon, trout lamprey)	Reduction in availability of optimal habitat in rivers. Increased flushing rate of rivers into the Severn Estuary	Reduction in overall production capacity of the Severn Estuary rivers. Reduced survival rate of juvenile shad. Destruction of salmonoid redds in tributary rivers
	European eel	Changes in rate of maturation, size at maturation, life-cycle length, and recruitment/yellow (mature) eel population size.	Changes and likely reduction in silver eel populations in UK rivers. Changes and likely reduction in yellow eel populations in UK rivers.
	Shad	Changes in spawning schedule, potentially reduced adult longevity, and decreased mortality rates.	Increased population size in UK rivers

4.2.14. The sea level rise, warming, increased storm intensity and alterations in precipitation and wind speed associated with climate change are projected to significantly alter the bird assemblage of the estuary in the next 60 years. It is likely that short-stopping of Siberian and Fenno-Scandian species will exacerbate. It is presumed that conditions in the Baltic and North Sea estuaries will be more suitable for waterfowl, and as these will be less exposed to prevailing south-westerly winds and extreme storm events, so may be selected over the Severn Estuary.

4.2.15. Alongside coastal squeeze from sea level rise, this may reduce the effective availability of foraging and roosting habitats in the Severn Estuary. However, there is the potential for a tidal range project to unlock some of these opportunities through compensatory habitat measures and increased control overflow rates within the Estuary and its intertidal habitats.

4.2.16. The climate predictions will reduce the potential suitability of the Estuary to support the current assemblage, and whilst gains in Lusitanian breeding and wintering species are expected, it is unlikely that these would offset the losses of short-stopping birds. As these effects materialise, this may alter the current position of many stakeholders on the acceptability of tidal range developments on the Severn Estuary should the current assemblage be significantly altered by climate change in the Severn Estuary.

MARINE ARCHAEOLOGY

4.2.17. For the historic environment, the key climate changes that may affect marine and terrestrial archaeology relate to extreme weather events (and therefore increased wave action and scour) as well as warming waters which will raise sea levels as well as temperatures. The influence of increased future wave scour (climate-induced) would primarily affect heritage receptors (known or hitherto unknown) located in the intertidal areas or at shallower water depths (<20m water depth) by erosion and/or destruction of such features.

4.2.18. Underwater cultural heritage is also under threat from warming waters, resulting in sea level rise that affects tidal activity, consequently impacting on the heritage assets within and adjacent to the intertidal zone. Warming waters further result in the northward migration of invasive species like blacktip shipworm (*Lyrodus pedicellatus*), which threatens the integrity of wooden wrecks and other wooden structures. Ocean acidification that can adversely affect the metal (particularly ferrous) elements of wreck sites. Any intertidal and marine projects within the Estuary will all have the potential to cause adverse direct impacts on heritage assets or contribute to beneficial impacts.

GEOMORPHOLOGY

4.2.19. It is likely that predicted climate effects such as sea level rise, warming, increased storm intensity and alterations in precipitation and wind speed will impact the coastal processes occurring within the Severn in the following manner:

- Increased storminess may lead to increased erosion along the coast, particularly of soft-sediment coastlines (beaches, etc). Cliff retreat may increase as wave undercutting increases.
- Sea level rise will increase the risk of wave overtopping in the short term, and increased erosion in the longer term as land behind the current shoreline becomes exposed to coastal processes.

- Alterations in precipitation (e.g. heavier rainfall) may lead to more siltation within the Estuary due to increased runoff from land.

FLOOD RISK

4.2.20. The flood risks identified in the present-day baseline will increase significantly because of climate change over the next 50-100 years. The risk will be primarily induced from sea level rise, increasing the baseline from which extreme events occur.

4.2.21. It is important to note that, although the Hold The Line draft policies of the SPM2 recommend that the standard of protection should be maintained, there is no financial guarantee that these will be raised to counteract climate change. Therefore, business cases with partnership funding (potentially from a tidal barrier or several tidal lagoons) are likely to be required to fund highly expensive climate change solutions.

4.3 UNCERTAINTY IN FUTURE PREDICTIONS

4.3.1. Evidence and understanding of how climate change will affect estuaries is growing, but there are still many complexities and uncertainties. While there is robust data and consensus around general trends, particularly land-based climate variables, the specific impacts on estuarine systems can vary widely depending on local conditions and the interplay of various environmental and human factors.

4.3.2. There is a need for further detailed work to provide information on how the habitats are changing across the Estuary. This doesn’t necessarily need primary research. It could include compiling information from available academic studies and studies undertaken to inform the impact assessment of development projects in the Estuary. Modelling work may be available from flood risk management assessments undertaken by Natural Resources Wales and the Environment Agency. These may provide information on future water levels, storm characteristics and the responses of Estuary habitats to these external pressures.

4.3.3. At the time of writing, there is a lack of this available localised data on the projected climatic changes and their impact on the Severn Estuary. As such, it is challenging to draw robust conclusions as to how the hydrological, ecological, geomorphological and human systems in the Severn Estuary will respond and function in the future.

5 DATA MANAGEMENT

5.1 CURRENT DATA AVAILIBILITY

5.1.1. Through the GoldSET process (detailed in **Appendix B**) and in consultation with specialist teams, a host of conclusions were able to be drawn out of the deep dive into data available for the Severn Estuary and the limitations on analysis which were encountered.

5.1.2. Several knowledge gaps remain which, unless filled, would limit confidence in the assessment of a tidal power project in the Severn Estuary and would make consenting challenging and/or extend mitigation and compensation requirements. It is recommended that further studies are undertaken to fill some of these key gaps, particularly fish and bird population/stock size, and behaviour of those species benefitting from the Estuary. Movement, and habitat utilisation will also help to inform interactions with a tidal project and potential impacts from it.

5.1.3. Data on the Severn Estuary is also not consolidated to support ease of planning across the devolved administrations. For example, data on the distribution and extent of estuary habitats is provided by Natural Resources Wales and Natural England and is available from both organisations as GIS data, downloadable from their websites. Other organisations have published data on the distribution of marine habitats, including The Crown Estate (e.g. the Marine Data Exchange (MDE)[5]), the Joint Nature Conservation Committee and organisations such as EMODnet[6]. It apparent that there is a degree of spatial overlap between different data sets and there may be spatial data gaps remaining once all data sets are assembled. To inform a robust assessment of the possible impact of a tidal energy scheme, there is a need to generate a consolidated and rationalised set of habitat data for the estuary, taking the most reliable data sets from the varied sources available.

5.1.4. This data is often collated on a project basis and are recorded differently between devolved administrations, likely due to the varying guidance documents and levels of protection afforded by devolved nations.

5.1.5. Other areas where data and/or uncertainties exist include mitigation measures for safe fish passage, efficacy of habitat creation, the effects of cumulative sedimentation and the impact, if any, of changes in water temperature, salinity and turbidity.

5.1.6. Longer term data is often patchy and collected using differing methodologies. By using existing partnerships and data storage options, which are publicly available, data confidence and availability is increased and a whole Estuary approach to protection and development can emerge. Governance arrangements and resourcing/funding will need to be explored further.

5.2 INCREASING DATA USABILITY

5.2.1. Building upon the concerns with current data availability raised in **Section 5.1**, consolidation of data sources into a common data environment akin to the MDE would allow more rapid identification of the interrelationships between environmental receptors.

5.2.2. Any data consolidation exercise such as this should seek to centralise available data and highlight gaps in knowledge about environmental condition (e.g. habitat condition) as well as extent. For examples, receptors in poor/degraded condition may be less resilient to environmental change than habitats in good condition.

5.2.3. Without a robust understanding of the Estuary's baseline environmental receptors and their interrelationships and conditions, the accuracy of shadow impact assessments required for permitting tidal developments is diminished to the extent that applications for development may be rejected on the premise of further assessment required. This further assessment may be required to confirm either the baseline environment, or that significant impacts are reduced to acceptable levels.

5.2.4. Through involvement of stakeholders, early identification of this requirement becomes simpler, acknowledging requirements before identification in the latter part of the planning process. For example, the requirement for further confidence in assessment of fish mortality rates for the Swansea Tidal development meant that the Marine License could not be agreed. Similar situations may be identified early in the development process through this collation of data, in consultation with stakeholder and regulatory organisations, before it is too late in the engineering design.

5.3 RECOMMENDED FURTHER STUDY

5.3.1. The current data availability discussed has highlighted topic specific needs for further assessment. Common themes have been identified and consolidated in Section 8, whilst more specific recommendations are captured here.

5.3.2. The identified data and knowledge gaps for biodiversity features, alongside their recommendations for further study include the following:

- An updated technical opinion on what type of project may be able to secure consent under the Habitats Regulations. This would have to consider whether functional compensation is achievable, both practically and technically; whether out-of-kind compensation could be acceptable; and whether out-of-region compensation might be tenable.
- Consolidation and review of the various sources of baseline evidence on coastal and marine habitat distributions and agreement on which data sources remain the most representative of the Estuary's baseline conditions.
- Consolidation of available information on coastal realignment opportunities in the Severn Estuary. Such an assessment would need to review the socio-political feasibility of creating new coastal habitat, the engineering feasibility and cost of creation/maintenance. The latter point needs to be considered a potentially significant part of overall project viability.
- Consultation to ascertain the extent of Environment Agency's, Natural England's and Natural Resource Wales's requirement for Habitat Regulations compensation to address coastal squeeze. This must cover what land is needed and where each organisation is seeking to create new coastal habitat.
- Consultation to investigate to what degree Biodiversity Net Gain (England) and Net Benefits of Biodiversity (Wales) would apply to a project straddling tidal, intertidal and terrestrial habitats. This will be a major driver for the quantum and type of compensation land required.

5.3.3. In regard to the fish assemblage of the Severn Estuary, the below are key recommendations for future assessment:

- It will be important to better understand the potential future state of the fish assemblage and key fish species populations in relation to climate change and knowledge of this remains a gap.
- Upon consideration of fish status/condition an understanding/agreement will be required on what would be deemed an 'acceptable loss' in population/stock percentage terms and how this may differ between different species and status/conditions. The extent and nature of evidence that would be required to enable a consenting decision with 'no reasonable scientific doubt' to be determined also needs to be explored.

5.3.4. Cultural heritage in the Estuary should undergo a regional level assessment, undertaken prior to any project specific assessment. This would be akin to Marine Aggregate Industry Regional Assessments (MAREA) (British Marine Aggregate Producers Association, 2008) which would provide the information required to better target proposed surveys. A regional environmental assessment as either a standalone cultural heritage and archaeology assessment or as a multi-disciplinary study (known as a Regional Environmental Characterisation) is recommended.

5.3.5. It is acknowledged that modelling will be required to inform any future development impact assessment upon environmental receptors, with climate change risk being a key impact model requirement for ecosystem wide models to assess impact significance. Model approaches should be agreed at an early stage of the project and in advance of a development advancing alongside input parameters and output requirements. Guidance to developers on these modelling requirements will ensure assessments are streamlined and align with statutory authority expectations.

5.3.6. Overall, a consolidation and review exercise of the various sources of baseline evidence on coastal and marine datasets is needed. This will support stakeholder engagement and provide a mechanism for agreement on which data sources remain the most representative of the Estuary's baseline conditions, thereby streamlining and supporting stakeholder engagement requirements for future tidal development.

5.3.7. To increase understand the climatic changes that could cause the most significant impact to the Severn Estuary in the future, more climate projection data is required. The key data gaps include quantifiable climate projection data for the Estuary on (not exhaustive):

- water temperature,
- turbidity,
- salinity,
- pH level,
- storm surge,
- storminess, and
- wind.

5.3.8. These data should cover the whole of the Estuary and be at a resolution of 50km2 or finer. In order to obtain these projections, further climate modelling will be necessary; however, it is noted that current climate science and modelling might not have the capacities yet to do this level of analysis. There are also wider gaps in the data on: compound events, cascading impacts, interdependencies, extreme events and return periods. To fill these gaps, it is recommended that:

- Further climate modelling and analysis is undertaken
- Dynamic models are used and advanced to better predict estuarine change, coupled with climatic changes to simulating environmental stress to support future modelling
- Make comparisons with similarly positioned habitat conditions globally and those representative of future climatic conditions in the estuary.

5.3.9. Finally, to effectively understand climate change impacts on the systems of the Severn Estuary, several technical deep dives are recommended. These, where possible, should be underpinned by quantifiable climate projection data. However, where climate data is not available, qualitative assessments, for instance using a climate story-line approach, could help further explore the complexities and uncertainties of the impacts of climate change. Ideally, these studies will be specifically for the Severn Estuary; however, it is also noted that it might not be possible in all cases where studies from other estuaries could be used as a proxy. The topics of the technical deep dives include:

- Nutrient Cycling and Water Quality: Investigating how climate change influences nutrient loading (e.g., nitrogen and phosphorus) from surface runoff and its effects on water quality. This should include research into the links between climate change and harmful algal blooms and eutrophication.
- Hydrodynamics and Salinity: Research on how changes in precipitation and freshwater flow regimes affect estuarine hydrodynamics and salinity levels.
- Sediment Dynamics: Assessment of sediment transport and deposition processes under changing climatic conditions with a focus on projecting changes in estuarine morphology and habitat availability.
- Ecosystem Resilience and Adaptation: Studies on the resilience of estuarine ecosystems to climate-induced stressors, such as increased salinity and temperature, and the effectiveness of habitat restoration efforts.
- Biodiversity and Species Distribution: Research on how climate change affects the distribution and abundance of estuarine species, including birds, fish and invertebrates.
- Maritime Archaeological impacts: Researching how climate change can affect preservation and rates of deterioration of underwater and coastal archaeological sites.
- Socioeconomic Impacts: Assessing the socioeconomic dimensions of climate change on estuarine communities, including the impacts on fisheries, tourism, and coastal livelihoods

5.3.10. Once authoritative data is identified for these environmental receptors, and data gaps filled, the confidence in impact assessments throughout the planning process can be improved. Without an increase in the level of confidence for conclusions made in Environmental Impact Assessments, Habitats Regulations Assessments, and similar permitting requirements of tidal schemes, there is a distinct possibility of rejection during application, and contest from stakeholders, both regulatory and non-governmental, due to flaws in the underlying data upon which the assessments were conducted.

6 IMPACTS ON THE ENVIRONMENT FROM SIX EXAMPLE PROJECTS

6.1 INTRODUCTION

6.1.1. The first step in assessing how the Severn Estuary's natural environment could be impacted by tidal range projects is to identify example projects that can be used to demonstrate, in practical terms, the effects of development and potential mitigation and compensation measures. Given the nature of the Severn Estuary's tidal capabilities and in light of existing technologies, those projects are tidal range in nature over tidal stream.

6.1.2. The example projects in this case comprise two barrages (a small barrage adjacent to the Prince of Wales M4 bridge known as the **Shoots Barrage**, and a larger barrage further downstream and often referred to as **The Cardiff - Weston Barrage**) and four lagoons.

6.1.3. The tidal lagoons are all located downstream of The Severn Barrage and comprise two large examples – **Cardiff Lagoon** and **West Somerset Lagoon**, a smaller lagoon close to the recently closed Aberthaw power station is included, called **Stepping Stones** and a very small lagoon similar to the proposals for **Swansea Bay** which received a Development Consent Order in 2015 (**Figure 6-1**).

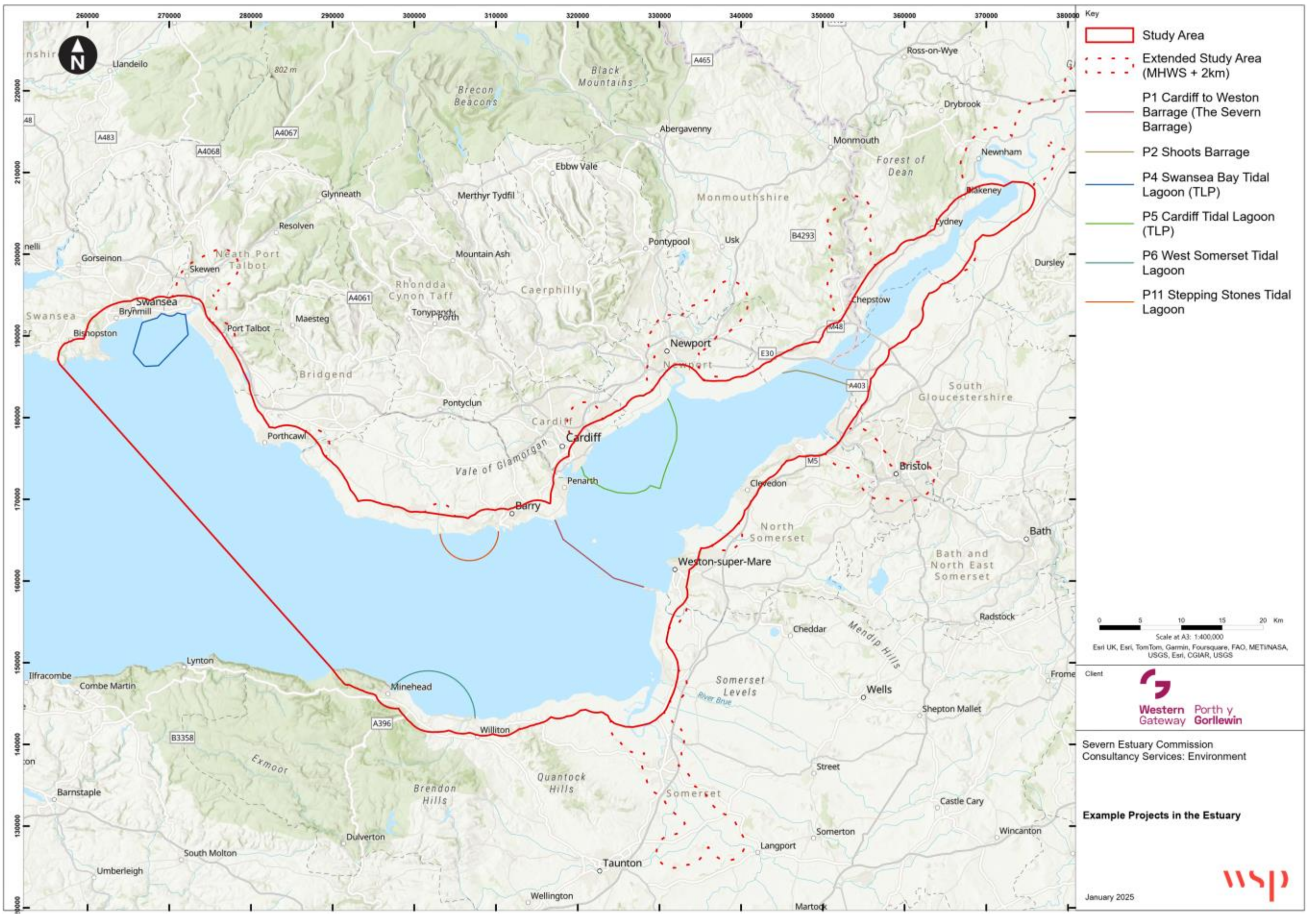

Figure 6-1 - The Severn Estuary Six Example Projects for Review

6.2 TIDAL PROJECT DESIGN AND DECOMMISSIONING

6.2.1. Tidal power projects, when in operation, will change tidal levels upstream of the marine wall (the structure forming the barrage or lagoon). A tidal power project can operate in a number of different ways to maximise the amount of energy generated in any given 24-hour period depending upon a project's configuration be it barrage or lagoon and its size.

6.2.2. The six example projects reviewed had an associated mode of operation applied to understand likely impact on water levels, as follows and explained in **Table 6-1**:

- Cardiff Tidal Lagoon – ebb and flood
- Cardiff – Weston Barrage – ebb only or ebb and flood
- Shoots Barrage – ebb only
- Stepping Stones Tidal Lagoon - ebb and flood
- Swansea Bay – ebb and flood (with pumping)
- West Somerset Tidal Lagoon – ebb and flood (with pumping)

Table 6-1 – Operating modes of tidal range power projects

Mode	Description	Effect on Water Levels
Ebb only	The flood tide fills the basin through sluice gates. Generation begins 1 to 2 hours after the tide ebbs	The high-water mark is close to the natural tide level and there is a period after the tide turns where water levels are static. When generation begins, the rate of reduction in water level is lower than the natural tide and the low water mark rises to the mid-point of the tidal prism.
Ebb and Flood	Generation occurs both on the flood and ebb tides	The high-water mark is reduced whilst the low water mark is increased by around the same amount (around 1 to 2m). A period of static water occurs each time the tide turns.
Ebb and Flood with sluicing	As ebb and flood mode but sluicing is used to reduce water levels in the basin towards the end of the generation cycle	Similar to the Ebb and Flood mode but the low water mark is closer to the natural tide low water mark.
Ebb and Flood with pumping	As ebb and flood mode but pumping is used as the tide turns to increase or reduce the water levels in the basin to increase energy production. Sluicing can also be used to reduce water levels in the basin towards the end of the generation cycle	Similar to ebb and flood but the water levels return to close to (but not equal to) the natural tide level

6.2.3. There are three principal options available when a tidal power plant reaches the end of its life:

- Wholesale demolition of the structures and equipment so that the site is returned to its original condition;
- Retention of the structure itself but removal of all mechanical and electrical equipment
- Retention of the structure but incorporating water level control elements to provide the same level of flood protection as existed during operation.

6.2.4. There are few precedents for decommissioning of tidal power projects – Annapolis Royal in the Bay of Fundy being one of the few and the most recent. This was a 20MW ebb only operated plant constructed in 1984 and decommissioned in 2019. The assets were transferred from the operator to the local government authority at the time of decommissioning. The impounding structure existed before the construction of the tidal power plant and was installed in 1960 to prevent sea water ingress into the marshlands behind. As control of water levels existed before the construction of the tidal power facility, it is likely that the only elements to be removed will be the Straflo turbine-generator and the powerhouse control room. A requirement for decommissioning was to leave the substation and grid connection in place to allow connections from other projects.

6.2.5. The wholesale removal of a tidal impoundment structure, which is likely to have been in-situ for a century or more, risks removal of a significant number of colonised habitats established over the lifetime of the asset. The decommissioning plan for the Swansea Bay Lagoon acknowledged this challenge and established long-term utilisation of the tidal generation asset for leisure and amenity services under ownership of a Community Interest Company predominantly run by local council administration who would fund maintenance works to the asset through ground rent and the Maintenance Reserve Fund collated over the operational lifetime of the scheme.

6.2.6. It is anticipated that works to maintain the integrity of any tidal structure would also be required to also maintain the integrity of any compensatory habitats linked to the project. These would require ongoing monitoring and adaptive maintenance to reflect potential ecosystem changes over the decades post operation. It is assumed the Best Practicable Environmental Option (BPEO) (E.ON, 2018), at the time of decommissioning will be chosen to minimise the impact on the environment at an acceptable cost to a Maintenance Reserve Fund.

6.3 TIDAL POWER IMPACTS

6.3.1. Tidal power projects change water levels and the length of time by which areas are either under water or not. This sits at the heart of likely impact and strength of effect that is felt within a tidal environment such as the Estuary, and the expected changes upstream and downstream of an impounding structure upon habitats, designated features, sediment transport and flood risk. These water level changes have corresponding implications for species present in the Estuary in terms of available habitat for feeding birds, or where fish can move and at what times of the tidal cycle.

6.3.2. A tidal power project (whether barrage or lagoon) consists of an impounding structure, turbine house and the turbines themselves to capture energy on each tidal cycle. The water level changes associated with a tidal project will change depending on the mode of operation for that development, and whether pumping or sluicing will be used. These modes change the high and low water marks compared to the natural tidal cycle. A general trend is that the larger the project type, the greater the likely environmental impact but it should be noted that needs to be considered alongside operational mode and location to gain a holistic view of likely environmental impacts and strength of effects.

6.4 IMPACTS IN THE CONTEXT OF THE CASE STUDY PROJECTS

6.4.1. This review provides a summary of the potential environmental impacts (loss as well as for improvement) of various types of potential tidal energy schemes in the Severn. Working with the environmental baseline data and evidence of potential ecosystem and habitat changes, conclusions on the impact of the six case study projects have been made with reference to their environmental impact and suitability to the estuary environment. Development pressures are also significant in the tidal Estuary and these need to be considered as potential beneficiaries from a tidal project.

6.4.2. Given the environmental baseline is complex and some data and trends indicate further detailed reassessment is required, a qualitative approach has been used to extrapolate what is currently understood to be the environmental baseline into a long-term view. Aiming to be representative of the significant lifetime of a major tidal scheme and externalities such as climate change impacts.

BARRAGE DEVELOPMENTS

6.4.3. Barrage developments by virtue of their size, proposed location and impoundment potential are considered to have the greatest environment impact of the six example projects studied. This is reinforced with the GoldSET analysis ranking both barrage developments as the least suitable options. Further embodied by the location of both barrages within SAC and SPA designated areas, it is therefore extremely difficult to envisage a tidal range barrage development gaining consent on the Severn Estuary due to potential impacts on designated bird populations.

6.4.4. Fish passage through tidal power projects is also a challenge for those which bisect the Estuary, with rotating turbines likely to be the primary source of fish injury and mortality. If injuries are not immediately lethal, fish could suffer delayed and indirect mortality. Not all fish species and life stages would suffer injuries, and the extent of injury sustained would differ. There is potential for impacts to have permanent, long-term effects which could affect the extent / integrity of the population or assemblage and could threaten their sustainability / conservation status.

6.4.5. These developments have a significant effect on the tidal prism, which is reduced, primarily by the water level in the impounded basin being retained at a higher level than a natural low tide. This occurs over a significant swathe of intertidal habitat upstream of barrages. However it is worth noting, the loss of tidal prism at the lower end of the tidal spectrum could be reduced through the use of parallel sluicing towards the end of the generation cycle.

6.4.6. Changes in the tidal prism and subsequent sedimentation patterns in the subtidal zone could lead to the covering of archaeological assets on the seabed or the reduction in access to the intertidal zone which would result in a loss/reduction in the opportunity to gain knowledge. Changes in sedimentation patterns may also result in the protection/preservation of the historic environment beneath deposition zones or uncovering of assets in areas of scour downstream.

6.4.7. Due to the parting of the Estuary and presence of a hard engineering upstream, tidal flood risk may be reduced through the barrier effect of the barrage, whilst downstream this may be increased through tidal rebound. In some cases, this rebound may be experienced well beyond the Estuary and within other estuaries across the Welsh and English coastlines. Upstream developments would also be at increased risk of fluvial flooding from tidal locking of outfalls across the entirety of the impounded basin.

6.4.8. In the context of climate change these impacts are expected to be compounded from the stressors placed upon environmental receptors as described in **Section 4.1.** The extent to which these impacts effect environmental receptors is hard to quantify, the unknowns in both regional climate modelling and future environmental baseline of the Estuary are too vast to allow accurate assumptions of effect. Confidence can be held in the current observed trends of decreasing environmental integrity of the Estuary, and increased climatic change, both compounding any anticipated impacts generated by a tidal barrage.

Cardiff - Weston Barrage

6.4.9. The Cardiff – Weston Barrage would directly impact SAC, SPA, and SSSI designations due to its location in the middle to upper estuary. There is potentially a large loss of inter-tidal habitat estimated in the region of 14,000ha. Finding land to compensate for this extent of habitat loss is likely to be extremely difficult in situ, with compensation expected to be required outside the Estuary, or with agreements needed on what biodiversity value such compensatory will have once mature.

6.4.10. There is potential for population collapse and extinction of Atlantic salmon and Twaite shad populations across the genetically distinct rivers of the Estuary upstream of the structure. Sea lamprey, river lamprey and eel are likely to decrease in population size but may not be susceptible to local extinction. The outputs of silver eel from tributaries of the Severn could reduce significantly whilst local extinction is uncertain. An Adaptive Environmental Management Plan (AEMP) will be important and the process of implementation, securement and monitoring of such a Plan should be agreed and understood at an early stage, as well as actions required if monitoring determines impacts differ to those assessed.

6.4.11. Construction and operational impacts on birds would include total habitat loss to waterbirds reliant on intertidal habitats upstream of the barrage, where inundation throughout the tidal cycle occurs, including the loss of roosting locations at mid- and low tide. Furthermore, alterations to prey-species distribution and abundance in areas where there is not total habitat loss may result in fewer waterbirds utilising the intertidal zone both upstream and downstream of the barrage. During the construction phase, temporary habitat loss would be more extensive due to the footprint of the development and disturbance effects, both visual and noise derived.

6.4.12. The Cardiff - Weston Barrage passing in proximity to the Flat Holm and Steep Holm islands increase the potential for changes in the setting of the historically significant assets present on the islands. Compounded by the changes in sedimentation and tidal prism throughout the upper Estuary east of the barrage, cultural heritage receptors are a challenge to the development of the Barrage, although direct effects may be more manageable than impacts upon estuarine ecology.

6.4.13. The upstream extent of the barrage, totalling approximately 372km of coastline, will see reduced drainage performance and an increase in potential erosion of 1m to 3m over the next 120 years. The extent of affected coastline is the largest for any of the proposed example projects and although the project may provide some upstream flood defence capabilities, the tidal rebound from such a large structure may pose significant risk to estuaries north and south of the barrage which required further detailed modelling to precisely predict and mitigate.

6.4.14. The location of the Cardiff – Weston Barrage leads to a significant challenge in terms of climate change impacts. The westerly location of the barrage impounds greater volumes of water upstream, and a wetter and warmer UK climate increases the risk of flooding and tidal locking of outfalls. The development's impacts upon intertidal habitats may further synergise with climate change induced surface runoff effects to generate a more significant level of impact on habitat loss than previously anticipated. For example, the increased over-land drainage may increase sedimentation, decrease water quality, and decrease integrity of habitat features in the Estuary to a greater extent than the barrage alone.

Shoots Barrage

6.4.15. The Shoots Barrage is the most upstream of the example options considered and has been included to review the relative performance of a small barrage, ebb only generation mode and the upstream environmental impacts. It was one of the recommended options for further study in the STPFS. It comprises two rockfill embankments connecting the Welsh and English shorelines to concrete structures housing the sluices and turbines. The powerhouse and turbines are located over the deep Shoots channel with a navigation lock to allow shipping to pass through the barrage to Sharpness Docks and Canal.

6.4.16. Fish would be able to pass through the sluice gates in the barrage as they travel upstream in the Estuary. There is uncertainty as to whether fish swimming downstream would pass through the turbines deep in the Shoots channel or would prefer to use a fish ladder or wait for the sluice gates to open at the end of the ebb tide. Due to the high tidal exchange at this point in the Estuary, there is also the potential for multiple scheme passages during both up and downstream migration. Due to straying and searching behaviours of a number of fish species, there is also potential for fish destined for other rivers such as the Usk and Wye to pass through the scheme. The STPFS identified that there was the potential, without mitigation, for population collapse of Atlantic salmon, Twaite shad, sea lamprey, and a reduction in population of eel. The STPFS SEA noted that "fish would be affected by alterations to migratory cues (sensory stimulants that trigger and/or direct fish migratory activity; e.g. freshwater discharge, light intensity and water temperature) and disruption to route of passage. Fish may also be affected by habitat change and/or loss, changes to water quality and anthropogenic noise disruption.

6.4.17. The impounded area upstream of the barrage with reduced drainage performance includes approximately 97km of coastline with potential erosion of 1m to 3m over 120 years. There is also the potential for 7m of sub-tidal accretion as a result of the development (DECC, 2010) (Hammond, Jones, & Spevack, 2014). The upstream location of the Shoots Barrage increases its relative risk of sedimentation. To reduce this risk, the large number of sluice gates, combined with a relatively high sill level, would allow only the finer silts in the upper part of the water column to pass through the barrage

6.4.18. The upper Estuary will undergo similar environmental changes to the middle Estuary where the Cardiff - Weston Barrage is located. The more eastern location of the Shoots Barrage however may promote use of the project for flood defence and tidal control inland. Subject to detailed modelling, it is anticipated the reduced impoundment at Shoots Barrage may negate many of the tidal rebound flood concerns associated with the employment of a barrage in the west. The development is, however, likely to increase the stress placed on ecological receptors in the upper estuary which are already subject to climate change impacts as described in **Section 4.1.** Migratory fish for example will be compounded with climate change driven alterations in physiological and behavioural patterns, alongside the impediment of a tidal barrage and navigation of turbine structures during periods of electricity generation.

LAGOON DEVELOPMENTS

6.4.19. The impact risk profile of a lagoon type development is more spatially constrained than that of a barrage. Common themes across the four example projects include a reduction in impacts the further west from the upper estuary and its many environmental features, designations, and sensitivities, alongside increased impact when increasing scale of intertidal land take due to the succeeding effects on ecological receptors.

Cardiff Lagoon

6.4.20. The Cardiff Lagoon was considered by the STPFS in 2010 and again in 2015 by Tidal Lagoon Power who produced outline designs and submitted a Scoping Report to the Nationally Significant Infrastructure Project division of the Planning Inspectorate. It has been included to assess the relative performance of a large lagoon on the Welsh coastline and its potential effects on the environment with its ebb and flood generation plus pumping mode.

6.4.21. This scheme would directly impact European designations from near-field effects such as land take and could indirectly impact more distant designations via far field effects like noise and vibration disturbance or changes in tidal behaviour elsewhere in the estuary. The lagoon was scored as wholly unsuitable (0.00) by GoldSET (**Appendix B**) in the context of SAC features due to its location well within the Severn Estuary SAC. Simultaneously, the site will impact one or more SSSIs including the Severn Estuary SSSI and the Severn Estuary Ramsar's intertidal habitats. The scope of potential loss of inter-tidal habitat is unknown for this scheme but is assumed to be significant given the designated sites surrounding it.

6.4.22. Construction and operational impacts on birds would include total habitat loss to waterbirds reliant on these intertidal habitats, including the loss of roosting locations at mid- and low-tide. Furthermore, alterations to prey-species distribution and abundance in areas where there is not total habitat loss may result in fewer waterbirds utilising the intertidal zone. During the construction phase, temporary habitat loss would be more extensive due to the footprint of the development and disturbance effects, both visual and noise.

6.4.23. The encircling of the Taff and Rhymney watercourse could result in changes to the fish assemblage of both watercourses which requires further investigation to determine the extent of such impacts in light of developments in mitigation technologies since the 2010 SEA. The proximity of the lagoon impoundment to the mouth of the River Usk also has the potential to pose a risk to migratory fish features destined for this SAC River. Any lagoon development in this area would have to consider this within its design and minimise fish injury features such as turbines at the Eastern end of the impoundment, which may reduce energy generation potential.

6.4.24. This same encirclement could result in increased flood risk to property, whereby mitigation will be required in the form of flood defences and/or flood resilience measures at increased cost to local regulators. Furthermore, the lagoon area will lead to tidal locking of drainage systems due to impoundment which may require pumping or higher pumping capacity due to climate change.

6.4.25. In terms of flood risk as with any smaller scale project, all impacts (positive or negative) for this lagoon option are much lower when compared to the Cardiff – Weston Barrage as a narrower width of the Severn does not create a barrier to flooding conditions upstream or downstream of the development. For example, there will be a reduction in tidal flood risk for properties located within a smaller impounded area, as the lagoon slows down extreme tidal events

6.4.26. The larger scope of the Cardiff Lagoon leads to increased tidal flood risk from the reflection effect caused by the tidal barrier, which will need to be mitigated with raised flood defences or flood resilient measures, to ensure no increase in flood risk outside of the development.

6.4.27. The historic environment resource within the vicinity of the coastal 21km long marine structure was assessed to be the most suitable from GoldSET analysis, scoring highly in comparison to other schemes when assessed in the context of impacts on nearby listed buildings and marine archaeological assets, resulting from the loss of known assets. Sedimentation patterns in the lagoon may preserve archaeology in situ, whilst simultaneously archaeological assets on the seabed whilst restricting in access to these and resulting in a loss/reduction in the opportunity to gain further historical and cultural knowledge.

West Somerset Lagoon

6.4.28. The West Somerset Lagoon was first proposed after publication of the STPFS in 2010 to consider whether a more downstream location offered less constraints than those considered in the STPFS. It has been pursued since then by different developers including Balfour Beatty in 2013 and more recently by TEES. It has been included to assess the relative performance of a large lagoon on the English coastline and its potential effects on the environment with its ebb and flood generation plus pumping mode.

6.4.29. This project would not directly impact European designations from near-field effects such as land take. Being situated outside of many designations, the site scored as more suitable for development in the context of direct impacts on Ramsar and SPA designations, but it could indirectly impact them via far field impacts, although these effects are anticipated to be limited given the approximate 11km distance from the Severn Estuary SAC they will require further study to determine no significant impacts in the context of the Habitats Regulations explained in **Section 7.1.**

6.4.30. The West Somerset Lagoon does not impound any significant tributary watercourses in the context of the Severn Estuary and therefore the development was deemed most suitable for transitional and coastal fish species out of the six example projects by the GoldSET tool. The location of the site in the west of the Estuary does mean many species will transit past the project and may be subject to far-field impacts. There is a notable presence of freshwater fishing rivers near the coastline of Minehead requiring further study to determine the use of these watercourses by transiting migratory species. At this stage the impact on fish is deemed low, subject to further study.

6.4.31. The Blue Anchor to Lilstock Coast SSSI is located within the footprint of the scheme. The site is designated for its internationally significant geology along much of the English Severn coastline (Natural England, 1986) and consideration of impacts upon this, both within the SSSI and across the wider Minehead coastline setting during construction will be required.

6.4.32. Driven by the landing points of the lagoon in Minehead and Watchet, the unsuitability ranking for West Somerset Lagoon in terms of archaeological assets was second only to Stepping Stones Lagoon. Both Minehead and Watchet host significant concentrations of Grade II Listed Buildings which would be subject to changes in setting and construction-based impacts from the project.

6.4.33. Flooding impacts both positive and negative for this option are predicted to be much lower when compared to a barrage, there will be a reduction in tidal flood risk for properties located within a smaller impounded area, as the lagoon reduces the risk to local propertied from extreme tidal events. There is however still the risk of impounding watercourses such as the Avil which could result in increased flood risk to property. The tidal flood risk due to the reflection effect caused by the barrier, which although reduced compared to other options, will need to be mitigated with raised flood defences or flood resilient measures, to ensure no increase in flood risk.

Stepping Stones Lagoon

6.4.34. The Stepping Stones Lagoon was also first proposed after publication of the STPFS in 2010 to consider whether a more downstream location offered less constraints than those considered in the STPFS. It was proposed by the STPFS consultants to assess whether a smaller project, with a location more remote from the environmentally protected areas further upstream and improved ground conditions could reduce development risks and unit costs. It has been included to assess the relative performance of a small to medium sized lagoon on the Welsh coastline and its potential effects on the environment with its ebb and flood generation plus pumping mode and rocky foreshore.

6.4.35. This scheme would not directly impact European designations due to its location near the western extent of the Estuary, but it could indirectly impact them. No significant areas of intertidal habitat are anticipated to be lost because of this Scheme. However, coastal habitat may be impacted, especially that within the East Aberthaw Coast SSSI. This SSSI is designated for its small stretch of coastline supporting a range of habitats that make it one of the richest coastal wildlife sites in the county of South Glamorganshire (Countryside Council for Wales, 1965).

6.4.36. Construction and operational impacts on birds would include total habitat loss to waterbirds reliant on intertidal habitats within the lagoon, including the loss of roosting locations at mid- and low-tide. Furthermore, alterations to prey-species distribution and abundance in areas where there is not total habitat loss may result in fewer waterbirds utilising the intertidal zone. During the construction phase, temporary habitat loss would be more extensive due to the footprint of the development and disturbance effects, both visual and noise.

6.4.37. The Stepping Stones Lagoon does not impound any significant tributary watercourses and is in an area of reduced siltation on the rocky shore of the Severn's northern coast. The location of the site in the west of the Estuary does mean many species will transit past the scheme and may be subject to far-field effects. is the lagoon is in the immediate vicinity of the Thaw Estuary less than 1km west. The proximity to this estuary has led to a GoldSET unsuitability score off 75.6 reflecting the possible usage of the river by migratory fish.

However further assessment of this heavily modified watercourse for impacts on ecology will be required to assess the likely degraded environment in this tributary.

6.4.38. Although the lagoon is distant from many urban areas and usual conglomerations of listed buildings within, the proximity to The Bulwarks Came Scheduled Monument has heavily influenced the suitability score for the Stepping Stones Lagoon in the context of archaeology. The site comprises the remains of a hillfort, which probably dates to the Iron Age period (c. 800 BC - AD 74, the Roman conquest of Wales) (Cadw, 2025). Complementing this location, further Scheduled Monuments in the vicinity of the lagoon include Westward Corner Round Barrow and the Site of Medieval Mill & Mill Leat Cliffwood. These locations are Scheduled under the Ancient Monuments and Archaeological Areas Act 1979 and hold significant national importance to Wales historic value (Cadw, 2019).

6.4.39. There is a relatively small, localised scour risk on the coastline and seabed outside of the lagoon by isolation of sediment within, reducing sediment budget due to physical barriers hindering normal sediment transport patterns. The exclusion of significant tributaries to the Severn in this location reduces the effects of sediment capture by the lagoon in comparison to developments impounding tributaries which contribute significantly to the Estuary's overall sediment budget.

6.4.40. Flooding impacts both positive and negative for this option are predicted to be much lower when compared to a barrage, there will be a reduction in tidal flood risk for properties located within a smaller impounded area, as the lagoon reduces the risk to local propertied from extreme tidal events. There is a reduced relative risk from impounding of watercourses due to the lack of significant river mouths in the footprint of the lagoon. The tidal flood risk due to the reflection effect caused by the impounding structure, which although reduced compared to other options, will need to be mitigated with raised flood defences or flood resilient measures, to ensure no increase in flood risk.

Swansea Bay Lagoon

6.4.41. The Swansea Bay Tidal Lagoon was also first proposed in 2011 by Tidal Lagoon Power who developed a detail design, undertook an environmental assessment and submitted an application for a Development Consent Order in 2014. This was awarded in 2015 but a marine licence was withheld and ultimately not awarded as the developer and regulator could not initially agree on fish modelling matters. It was subject to a joint BEIS and Welsh Office Select Committee Inquiry in 2018. The DCO lapsed in 2020 and the project has failed to progress although Swansea City Council and new developers have been working on how they could resurrect the project. It has been included to assess the relative performance of a small lagoon on the Welsh coastline and its potential impacts on the environment with its ebb and flood generation plus pumping mode in a location that has little impact on the designed SPA and SAC areas of the Estuary.

6.4.42. This project would not directly impact European designations, but it could indirectly impact them. One or more SSSIs could be directly impacted, including the Crymlyn Burrows SSSI within the lagoon's footprint. This site is designated due to it being one of last remaining sections of the Swansea Bay coastline which has remained substantially unmodified by industrial development (Swansea University, 2018). No intertidal habitat is likely to be lost though needs to be confirmed. However, coastal habitat may be impacted in the vicinity of the marine construction works.

6.4.43. There is a total loss of habitat for foraging waterbirds within the footprint of the lagoon during the operational phase of the project whilst a loss of habitat for foraging waterbirds in the construction phase is also expected, including a buffer caused by disturbance. The potential loss of mid and low-tide roost locations due to inundation is expected and the forecast but uncertain sea level change upstream and downstream may lead to habitat loss and change with potential to impact birds via access and availability of prey.

6.4.44. Swansea Bay scored the lowest suitability in terms of river mouth exclusions integrated into the GoldSET analysis (74.7). This low (relative) suitability score is guided by the impoundment of the River Neath and immediate proximity of the River Tawe. Impacts on migratory fish species using these rivers will be substantial during construction, whilst those transiting to the River Neath and navigating further into the Severn Estuary will require mitigation of any impacts from marine infrastructure during the operational phase. The Marine Licence from NRW could not be ascertained for this development primarily due to concerns regarding fish mortality modelling.

6.4.45. Swansea Bay is located close to but not immediately adjacent to the Listed Buildings surrounding the project and therefore impacts on setting and direct impacts on assets are expected to be limited. The development ranked second highest in terms of suitability in the context of Listed Buildings (65.3) due to this distance from assets. The concentration of Listed Buildings and Conservation areas in Swansea will present a small challenge to development, however these impacts can likely be mitigated through the course of project development.

6.4.46. Situated in the outer Estuary the geomorphology of the area leads to a reduced potential for tidal power generation. Therefore, any impacts derived upon ecological and physical parameters of the surrounding environment must be considered with relative risk in terms of generation potential.

6.4.47. Flooding impacts both positive and negative for this option are predicted to be much lower when compared to a barrage, there will be a reduction in tidal flood risk for properties located within a smaller impounded area, as the lagoon reduces the risk to local properties in Swansea from extreme tidal events. There is however still the risk of impounding watercourses such as the Neath which could result in increased flood risk to property along its banks. The tidal flood risk due to the reflection effect caused by the barrier is reduced compared to other options due its smaller scale and location in the pouter estuary.

6.5 CONCLUSIONS

6.5.1. The Severn Estuary is a sensitive marine and terrestrial environment, with swathes of the Estuary hosting internationally important environmental features. These are embodied through designations at international, national, and devolved administration levels.

6.5.2. The impacts summarised above are from a rapid assessment of known environmental constraints, and subject to further investigation of indirect impacts and the interrelationship between receptors which current data availability does not allow. These impacts are presented in Table 6-2.

6.5.3. To aid interpretation of magnitude effects presented in Table 6-2, the following scales have been used.

Risks	*High*	*A permanent or long-term effect on the extent/integrity of a species population or assemblage. If adverse, this is likely to threaten its sustainability/ conservation status; if beneficial, this is likely to enhance its conservation status*
	Medium	*A permanent or long-term effect on the integrity of a species population or assemblage. If adverse, this is unlikely to threaten its sustainability/ conservation status, if beneficial, this is likely to be sustainable but is unlikely to enhance its conservation status*
	Low	*A permanent or long-term reversible effect on the integrity of a species population or assemblage whose magnitude is detectable but would not threaten or enhance its integrity*
	Very Low	*A short-term but reversible effect on the integrity of a species population or assemblage that is within the normal range*
Compensatory Habitats	*Large*	*Greater than 1,000 hectares predicted to be required*
	Medium	*Between 250 and 1,000 hectares predicted to be required*
	Small	*Less than 250 hectares predicted to be required*

Table 6-2 – Potential magnitude of impact for six example projects in the Severn Estuary

Example Project	Installed Capacity (MW)	Mode of Operation	Within an SSSI, SPA, SAC, or Ramsar?	Scale of Compensatory Habitat Potentially Required	Risk for Fish	Risk for Birds	Risk for Archaeology*	Sedimentation Risk	Flood / Coast Protection from Sea Level Rise	Land Drainage Mitigation Requirements
Shoots Barrage	1,050	Ebb only	Yes	Large	High	High	High	High	Coastal communities North of M4	High
Cardiff Weston Barrage	8,640	Ebb only or ebb and flood	Yes	Very Large	High	High	Medium	High	Coastal Communities to the North, Gwent and Somerset Levels	High
Cardiff Lagoon	2,000	Ebb and flood	Yes	Medium	Medium	High – but spatially constrained	Low	Medium	Cardiff Bay but already protected by barrage	Medium
West Somerset Lagoon	2,000	Ebb and flood	No	Medium	Medium	High – but spatially constrained	Low	Medium	Coastal protection to the coastline and flood defence for Minehead	Low
Stepping Stones Lagoon	600	Ebb and flood	No	Small	Medium	High – but spatially constrained	Low	Low	Glamorgan's Heritage Coast	Low

Swansea Bay Lagoon	320	Ebb and flood	No	Small	Low	High – but spatially constrained	Low	Medium	Swansea Bay low lying areas	Low

* Notwithstanding the potential for unknown finds

7 LEGISLATION AND CONSENTING ROUTE

7.1 MITIGATION HIERARCHY

7.1.1. The mitigation hierarchy is inextricably linked with the legislative and consenting frameworks, as detailed below, and should be considered alongside each other for any tidal power project.

7.1.2. The mitigation hierarchy is a widely used framework that developers follow in their efforts to avoid, minimise, restore or offset losses and captured within the EIA Regulations as an accepted framework for avoiding or minimising significant effects of a development. The hierarchy is stipulated as follows:

- **Avoid -** Avoid impacts entirely, such as by selecting a different site location based on environmental sensitivities
- **Minimise -** Reduce the impact of the project, such as by using more environmentally friendly construction methods, design choices
- **Restore -** Restore the affected area, such as by reseeding the land or creating a breeding programme for affected species
- **Compensate -** Compensate for any remaining impacts by restoring habitats elsewhere, such as by removing invasive species or restoring wetlands
- **Enhancement –** Seek to provide net benefits over and above requirements from above

7.1.3. Any measures used to inform the decision about the effects on the integrity of a project need to be sufficiently secured and likely to work in practice. Measures aimed at compensating for the negative effects of a project cannot be considered mitigation measures (Department for Levelling Up, 2019).

7.2 RELEVANT LEGISLATION AND POLICY

7.2.1. In the 15 years since the 2010 Severn Tidal Power Feasibility Study (STPFS), policy and legislation has changed. There has been increased emphasis on reducing greenhouse gas emissions, with a drive to net zero; the fundamental importance of the natural environment with the natural capital and ecosystems services approach; and the need to halt and reverse the decline in biodiversity.

7.2.2. A review of the existing policy base (**Appendix A**) for the Severn Estuary found that there is comprehensive and wide-ranging legislation and policy at international, national and devolved administration levels that apply to the Severn Estuary and that whilst most of these have remained the same since 2010, new regulations have come into force and the policy environment continues to be a dynamic one.

7.2.3. New plan-making, policy and consenting procedures for the marine environment reflects the increased importance of this resource. An increase in devolved powers means that there are more differences in the legislation and consenting framework between Wales and England. Despite the United Kingdom leaving the European Union ("Brexit"), other Regulations associated with environmental European Directives currently remain similar, with functions transferred from the European Commission to appropriate authorities in England and Wales and a creation of a national rather than European site network.

7.2.4. The Paris Agreement 2015 sets commitments for limiting global warming to well under 2ºC compared to pre-industrial levels and aiming for 1.5ºC to prevent catastrophic impacts. It also has resulted in the UK target of net zero by 2050. The Climate Change Act 2008 sets targets for UK greenhouse gas emission reductions of at least 100% by 2050, against a 1990 baseline[9]

7.2.5. Under the Well-being of Future Generations (Wales) Act 2015, public bodies need to make sure that the impact on future generations is considered. There are milestones for both net-zero emissions by 2050 and to reverse the decline of biodiversity, with an improvement by 2030 and clear recovery by 2050 (National Assembly for Wales, 2015).

7.2.6. The Environment Act (Wales) 2016 includes the Natural Resources Policy for sustainable management of resources to contribute to the Well-being of Future Generations Act 2015. Delivering nature-based solutions and increasing renewable energy and resource efficiency are priorities, in addition to the Section 6 duty to maintain and enhance biodiversity (National Assembly for Wales, 2016).

7.2.7. In England, the Environment Act 2021 sets out environmental targets, sets clear statutory targets for the recovery of the natural world in four priority areas: air quality, biodiversity, water and waste. This includes 10% biodiversity net gain (BNG) which is due to be applied to nationally significant infrastructure in late 2025 (UK Parliament, 2021).

7.2.8. There are a number of plans and policies associated with decarbonisation of energy, nature recovery and the marine environment, not all which are listed here (**Appendix A**). Net zero targets apply to policy in both Wales and England. and tidal power over 350 MW would be consented via the National Policy Statement for renewable energy infrastructure (EN-3, in conjunction with EN-1) (DESNZ, 2024). When Swansea Bay Tidal Lagoon received its DCO in 2015, the National Policy Statement at that time required any project over 100MW in marine waters to be determined using the national infrastructure planning system but in Wales, NRW were responsible for the separate marine licence. In 2017, the 100MW threshold was raised to 350MW but only in Wales. Projects also require consent to construct a cable connection onshore, an agreement to connect to the National Electricity Transmission System and an agreed decommissioning plan. Tidal range power has been excluded from the Energy Act 2023 and recent updates to the National Policy Statement for renewable energy infrastructure (EN-3) specify >100MW in England and >350MW in Wales for offshore wind and tidal stream only (DESNZ, 2024).

7.2.9. Nature Positive 2030 was produced in 2021 by the UK's five statutory nature conservation bodies and sets out how pledges to protect 30% of land and seas for nature by 2030 can be achieved (JNCC; Natural England; Natural Resources Wales; NatureScot; Northern Ireland Environment Agency, 2022). While biodiversity net gain/ net benefits is required by planning

[9] Previously 60%, then 80%, and was last updated to a net zero target in June 2019.

policy in both countries, any future marine net gain (MNG) requirement may need to use a whole ecosystem strategy due to the mobile nature of most marine environments.

7.2.10. The Marine and Coastal Access Act 2009 sets the framework for marine planning and marine licensing (UK Parliament, 2009). The UK Marine Policy Statement 2011 (DEFRA, 2011), led to development of the Welsh Marine National Plan 2019 (Welsh Government, 2019) and South West Marine Plan 2021 (MMO, 2024)[10].

7.2.11. In England, the Levelling-up and Regeneration Act 2023 (Part 6) (UK Parliament, 2023) includes provision for Environmental Outcome Reports (EORs) for plans and developments. EORs will require assessment against the Government's environmental objectives and targets. There will be forthcoming separate legislation for EORs, which would potentially replace EIA in England, when the legislation is passed and could mean a separate assessment process is undertaken in England than in Wales. Consultation on planning reform relating to development and nature recovery in England proposes that strategic level environmental assessment would be undertaken via Delivery Plans, with remaining impacts addressed by project level environmental assessment. This would potentially mean a separate assessment process is undertaken in England than in Wales.

7.2.12. Requirements for assessment under The Conservation of Habitats and Species Regulations 2017 (as amended) (UK Parliament, 2017) and The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (UK Parliament, 2017) which apply to Wales and England remain unchanged, except that the amended regulations make provision enabling the Welsh Ministers to carry out certain functions previously carried out by the UK Secretary of State in offshore waters adjacent to Wales, such as designation of protected sites and licensing for certain activities. The proposed Planning and Infrastructure Bill in England could change the way that legislative obligations under the Habitats Regulations are discharged. This means that there is potential for increased divergence between environmental consenting processes between the two nations in future.

7.3 RELEVANT CONSENTING CONSIDERATIONS

CONSENTING FRAMEWORK

7.3.1. The unique location of the estuary, spanning as it does two government administrative boundaries, taken together with the variant focus and objectives of the respective consenting and environmental assessment frameworks makes tidal power developments within the Estuary more complex to deliver, with any sufficiently sized project (100MW in England and 350MW in Wales) needing consent under:

- Development Consent Order (DCO) required from Secretary of State, following a recommendation from the National Infrastructure Planning Inspector (required by the Planning Act 2008); and

[10] Areas of coordination are set out in the cross-border marine planning guide (Welsh Govenment; MMO, 2023).

- Marine Licence (under the Marine and Coastal Access Act 2009) can be deemed as part of the DCO by the Secretary of State or developers can opt to apply for a separate license from NRW/MMO (these organisations also play a role in deemed licenses as part of the DCO) (Welsh Government, 2023).

7.3.2. In either case the MMO/ NRW acts as the discharging authority post-decision, meaning they are responsible for agreeing any specific provisions in the Order.

7.3.3. Timing is also a key consideration for tidal developers, where the pre- and post-application stages are likely to require allowances of a minimum of three years for the DCO pre-application period[11]. It can take a further 1.5 years for determination[12], with potential for Judicial Review following consent which would further delay the application and decision. There is no statutory period for determining marine license applications, online advice states a maximum of 25 months for offshore renewables[13]. However, as Swansea Bay Tidal Lagoon demonstrates, all pre-commencement conditions need to be discharged within five years of the DCO decision. The Government has recently consulted on a Planning Reform Working Paper with proposals to streamline Nationally Significant Infrastructure Projects to help reduce timelines.

7.3.4. For projects in Wales under 350MW, the elements of the process are similar, in terms of preparation of the application, need for stakeholder engagement, public enquiry and post-consent conditions. However, as well as a Marine License, a Section 36 Consent under the Electricity Act is needed from Welsh Ministers following a recommendation by a Planning Inspector.

7.3.5. There is also a substantive number of assessments, required by separate pieces of legislation, within the consenting process to review, assess and mitigate and compensate for environmental effects; the key ones being driven by three main pieces of legislation:

- Environmental Impact Assessment (EIA) under the Infrastructure Planning (EIA) Regulations 2017/ Marine Works (Environmental Impact Assessment Regulations 2007);
- Habitats Regulations Assessment (HRA) under the Conservation of Habitats and Species Regulations 2017 and The Conservation of Offshore Marine Habitats and Species Regulations 2017; and
- Water Framework Directive Assessment[14] (WFD) under the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017.

[11] The EIA (Scoping) process for Tidal Lagoon Swansea Bay started in early 2011 and application made in Feb 2014. This fits with other complex DCO projects.

[12] Approx 3 months review of application, statutory 6 months examination and 6 months decision.

[13] https://naturalresources.wales/permits-and-permissions/marine-licensing/applying-for-a-marine-licence/?lang=en. Note that in England the MMO aim to determine license applications within 13 weeks, but this is also unlikely.

[14] https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters

7.3.6. Key consenting risks associated with this legislation are set out in **Appendix C** and summarised below. There is some overlap between risks which can apply to multiple assessments:

- Gaps in environmental evidence and assessment knowledge – main topics comprise physical processes, fish, birds, marine mammals, habitats and climate change.
- Environmental mitigation or compensation where measures (e.g. amount of compensatory habitat proposed, or type of habitat) may be untested or deployed on a scale where it is uncertain whether they will be effective. Long-term monitoring and adaptive management plans are then relied on to mitigate impacts where outcomes are unknown and scope for changing engineered structures limited.
- Legal compliance with Habitats Regulations where derogations include no alternative solutions with a lesser (or no) effects on the Site and imperative reasons of public interest sufficient to over-rise the harm to the Site (IROPI) and compensatory measures are sufficient to ensure the coherence of the network.
- Legal compliance with the Water Framework Directive where derogations include over-riding public interest and/or benefits of the project outweigh the benefits of acheiving the objectives of the legislation, and these can't be achieved by a better environmental option.
- Uncertainty around decommissioning over long timescales (in terms of what elements of the tidal project is decommissioned as well as how the environment may have adapted to and what the new baseline is). For example, the Swansea Bay Tidal Lagoon had proposed part-decommissioning the energy generation elements, with structural elements remaining, but this was not signed off before the five-year permission period had lapsed.

7.3.7. There are a wide range of other legislated environmental requirements that will need to be demonstrated as part of consenting. In addition to compensatory habitat required under the Habitats Regulations referred to above, in England there is requirement for Biodiversity Net Gain (BNG) driven by the Environment Act 2021 and secondary legislation, and Net Benefits for Biodiversity (NBB) in Wales, rooted in the Environment (Wales) Act 2016 and driven by Planning Policy. While there are likely to be other compensatory requirements and mitigation, including protection of individual species and habitats, those relating to statutory protections for heritage, landscape and other aspects, these are not likely to be as extensive as habitat requirements. It should also be noted that while designated habitats may require compensation, loss of functionally linked habitat (i.e. outside site boundaries but important for species for which the site is designated (e.g. birds) would also need to be compensated. While BNG/NBB require an increase in biodiversity and benefits, there are no prescribed ratios, which can vary depending on factors such as the time period for creation, and likely effectiveness of proposals. As it currently stands, these requirements only apply to terrestrial and intertidal habitats, not the marine environment, and in Wales, species are also considered. **Appendix C** contains further information on the differences between these approaches and how they relate to HRA.

7.3.8. It is worth noting here that recent changes in policy are looking to make provisions for nature recovery and for ecosystems to evolve and adapt to climate change. This means that there is potential for future changes to legislation and consenting, including assessments such as EIA and HRA, for example Environmental Outcome Reports (EORs) and the proposed Nature Restoration Fund. This may take necessitate and evolution of the consenting framework and indeed the approaches take to assessment of environmental impacts, mitigation and compensation, particularly in light of climate change.

7.3.9. Tidal power projects in proximity to designated sites and at a scale that would create the most substantive habitat impacts are more likely to trigger consenting under the permitted derogation route, through assessment of any Imperative Reasons of Overriding Public Interest (IROPI) and through the demonstration that no reasonable alternatives exist. This is where the asymmetry of over-arching policy objectives within the relevant consenting frameworks, or cross-border priorities, are exposed and, through the legal processes, need to be balanced against each other.

7.3.10. Having particular consideration to the requirements under HRA, the fact that reasonable alternatives to a tidal range power project may not exist and noting that a tidal power project in the Estuary may have the potential to impact on the integrity of designated sites from habitat losses, there may be a requirement for potentially substantive compensatory habitat development of a scale that cannot be provided within the Estuary, indeed in some cases at a scale which may not be available nationally given the unique features and characteristics of the estuary environment.

CONSENTING CONCLUSIONS

7.3.11. It is acknowledged that any tidal range power project in the UK will face a dynamic and complex legislative framework, with uncertainties that translate directly to consenting risk. This is particularly so in the context of the Severn Estuary given its unique, rare and delicately balanced habitats. Whilst previous tidal schemes have tested the legislative and consenting frameworks (and from which lessons have been learnt), bringing forward a tidal range project in the Estuary is still likely to be considered to be first-of-a-kind (FoAK). We currently do not have the advantage of any real-world data sources from previous projects upon which to more accurately gauge how the potential environmental impacts have been realised through direct changes in habitat condition and species abundance. These consenting risks may in part be managed through a combination of three key actions:

- **Early stakeholder engagement –** our work within this study seeking, understanding and gauging the views of stakeholders shows a willingness for further engagement, alongside a frustration that we appear stuck in a "cycle of perpetual consideration" as projects are brought forward through existing regimes, ultimately unsuccessfully. Stakeholders recognise the legislative asymmetry and the risk this presents to developers and seek constructive dialogue through existing technical engagement mechanisms.
- **Clearer policy direction and more streamlined consenting processes –** consenting any future tidal scheme development is likely to require navigation of complex regulatory and legislative environments, however clearer policy direction on tidal power from Government, together with greater levels of support and coordination from statutory bodies will help address what has historically been legislative friction points and ultimately address the incongruence that is inherent within competing climate, societal and environmental priorities.
- **Development of a more strategic and holistic set of assessment approaches that increases confidence in the consenting pathway –** noting that tidal range projects will require a substantive number of assessments, judgement of unprecedented impacts on an uncertain future baseline and the compensation of habitat loss at scales that are not likely to be delivered on a like-for-like basis. By taking a more strategic view of the

management of the Estuary as a whole spatially and agreeing upfront on defined and acceptable assessment and modelling approaches (e.g. fish movement and collision, climate change scenarios), it is more likely that the wide-ranging priorities and objectives of stakeholders and the nation can be met whilst still preserving the functionality afforded by estuarine environments.

7.4 POTENTIAL FUTURE REQUIREMENTS

7.4.1. As the political and environmental landscape shifts over the coming decades, it becomes increasingly challenging to predict changes in environmental legislation and integrity. As aforementioned in **Section 4.1,** the climate is shifting more rapidly than initially predicted, this may increase as the earth reaches tipping points in its climate that trigger further feedback mechanisms of atmospheric change (Carbon Brief, 2024).

7.4.2. The political landscape of the 21st Century is equally unpredictable with some major economies distancing themselves from global efforts to curb emissions (BBC News, 2025). The UK has historically been at the forefront of global emission reduction (DESNZ, 2024) and in-line with the EU or better for environmental protection (UK Environmental Law Association, 2023). An assumption can be made that this will continue in isolation of global geopolitical challenges due to domestic pressure on environmental protection (YouGov, 2021) and therefore whilst legislation may evolve, it is unlikely to intentionally reduce in its ability to protect the UK's already protected environmental features.

7.4.3. The near-future requirements for a tidal energy project regarding navigation of policy instruments will likely involve a similar, if not a more stringent planning process. The implementation of BNG/NBB, Environmental Outcome Reports and Nature Restoration Fund, all focus on better outcomes for nature beyond that of the previous 'no net loss' (NNL) stance towards environmental protection in the UK.

7.4.4. In the context of climate change leading to deterioration of the UK's natural environment it will become increasingly challenging to implement a net gain approach to environmental protection. The added challenges from climate change impacts on the baseline environment which a development is situated within would likely increase the sensitivity of these environmental receptors and therefore increase the magnitude of effect.

7.4.5. There is anticipated to be a conflicting priority between the requirement for renewable energy fuelling the UK's projected 50% increase in energy demand by 2035 (Climate Change Committe, 2020), and the projected increase in environmental protection such as the recent 30by30 goal of the Environment Act (Defra, 2024).

8 CONCLUSIONS

8.1.1. The natural features and species of the Severn Estuary are outstanding examples in a European context (JNCC, 2015). The Estuary is protected for good reason as a diverse, productive and rare environment and an ecosystem that is sensitive to pressures from both human development and climate change. Many of the bird and fish species present are at population levels of international importance (JNCC, 2015).

8.1.2. The study acknowledges that whilst the Estuary conditions that we see today are because of both natural and human impacts, pressures and stressors from in-combination effects and impacts will continue to threaten the delicate balances established in many of the important protected sites, features and habitats within the estuary. It also recognises that baseline conditions within the estuary are representative of a degraded ecosystem, where simple protection of the status quo is not addressing the need to enhance the estuarine environment, not only to counter existing impacts, degradation and stressors but also address the wider nature and biodiversity crisis.

8.2 BASELINE DATA

8.2.1. There are a good range of existing baseline datasets in existence for the Estuary, but many represent either a temporal snapshot or a locational snapshot of individual species and habitats, heritage features, and likely geomorphology and flood risk impacts. Our understanding of the interconnectedness of the Severn Estuary is lacking and represents a barrier for the strategic decision-making that is needed here. This is amplified by the cross-border priorities which may be at odds or out of lockstep to one another, alongside other development pressures.

8.3 CLIMATE CHANGE

8.3.1. To effectively understand climate change impacts, and specifically those which will lead to significant impacts to the environment of the Severn Estuary, several technical deep dives are recommended, on a renewed set of quantifiable local climate projections. Where climate data is not available, qualitative assessments, for instance using a climate story-line approach, could help further explore the complexities and uncertainties of the impacts of climate change. Ideally, these studies will be specifically for the Severn Estuary; however, it is also noted that it might not be possible in all cases and studies from other estuaries could be used as a proxy.

8.4 TIDAL PROJECT CONSIDERATIONS

8.4.1. From an environmental perspective, all tidal range projects will have an effect and an impact as they change, to a greater or lesser extent, the finely balanced intertidal dynamics upon which fish, birds, invertebrates and plant life has come to adapt to. Whilst the nature of such impacts is broadly understood within a baseline context, the significance and scale vary depending on location, project size, technology selection and mode of operation. It can be broadly concluded that barrages present significantly larger impacts in the Estuary compared to lagoons and in terms of progressing tidal energy development, a lagoon (subject to size, location, design and operation and detailed study of the environmental impacts over the longer term) could be supported by the Estuary.

8.4.2. Ultimately any subsequent siting assessment will require a series of trade-offs between optimal conditions for power production, engineering design challenges and cost alongside environmental impact and scale of mitigation for a variety of environmental sensitivities. However, this study concludes that the middle estuary could offer the best combination of tidal range potential and environmental sensitivity, particularly on the northern shoreline provided full account is made of the requirement to avoid impounding existing rivers which would otherwise affect the passage of migratory fish species to or from their natal rivers.

8.4.3. Given the significance of proximity to protected areas in terms of both near and far-field effects from tidal power assets, siting a project outside the SAC designations and ensuring far-field effects are minimised on the protected habitats and species is recommended through siting, detailed modelling, asset size and configuration assessment and effective design.

8.5 CONSENTING & MITIGATION

8.5.1. There are strong fundamental drivers to take a precautionary approach to protecting the integrity of important sites and features and such considerations need to sit at the centre of a more strategic decision-making framework for how we use the Estuary in the future, whether a tidal scheme or other development.

8.5.2. The Estuary benefits from a number of important and internationally recognised designations on species, habitats and archaeological features, as well presenting a large area susceptible to tidal and fluvial flood risk, all which require some form of protection or compensation both now and in the future. The uncertainty around quantifiable climate modelling presents its own challenges around the severity and likelihood of impacts for the Estuary and need to be understood further to empower decision-makers and other stakeholders or users of the Estuary.

8.5.3. Furthermore, its current protections, and the requirements of such legislation, alongside the UK’s commitment to both biodiversity and net zero targets introduces a mosaic of competing priorities for any development within the Estuary.

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Appendix A

STRATEGIC BASELINE REVIEW SOURCES

Appendix B

GOLDSET METHODOLOGY

Appendix C

LEGISLATION, POLICY AND COMPENSATION FRAMEWORKS

Appendix D

CLIMATE CHANGE TECHNICAL NOTE

Appendix E

STAKEHOLDER ENGAGEMENT REPORT