TIDAL LAGOON SWANSEA BAY

Environmental Statement
Chapter 3. Site Selection and Option Appraisal

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Contents

3.0 Site Selection and Option Appraisal

3.1 Introduction

3.1.0.1 The objective of this Chapter is to set out the option assessment stages which have been undertaken for the Project. This has been an iterative process, from site selection through to the development of the overall design of the tidal lagoon and onshore infrastructure as presented in Chapter 4, Project Description.

3.1.0.2 The following sections will present the iterative processes which have been undertaken including:

a) Marine renewables and wider site selection ("why Swansea Bay?");

b) Positioning the Lagoon within Swansea Bay;

c) Option assessment for Lagoon design;

d) Turbines and sluice gates;

e) Construction method choices;

f) Grid connection options;

g) Water quality optimisation applications;

h) Decommissioning options; and

i) Project infrastructure – including sports and recreation, mariculture opportunities, education and art.

3.2 Marine renewables and wider site selection

3.2.0.1 In order to capture energy from the sea there are three marine renewable options that are being progressed in the UK: wave power, tidal stream and tidal range.

3.2.0.2 Wave power is dependent on the movement of the sea surface and the use of swell or large moving offshore waves to generate energy. The devices used to capture wave power tend to be large floating pontoons located off the coast. They are dependent upon weather conditions, which affect wave energy.

3.2.0.3 Tidal stream power is focused on capturing the energy from the flow of currents during the ebb and flood tides. These devices are like underwater windmills (turbines) which turn with the flow of the current. Each turbine can be placed on freestanding foundations or a number can be grouped on a single foundation frame. Good locations for these devices are in high tidal flow areas, such as where flows are channelled between landforms and hence the currents increase.

3.2.0.4 Tidal range power requires an area where there is a large difference (range) between high and low water caused by tides. The technology works by holding back the tide in a lagoon or other impoundment (such as in an estuary) for a short period of time, thereby creating a difference in water level inside and outside the structure (called head). When the water is released, energy is generated. This technology has been used in estuarial barrages for many years (e.g. at La Rance in France, which has operated since 1966).

3.2.0.5 The tidal range of a particular location is dependent, in part, on its position relative to the equator, but more on other physical factors in the area e.g. topography, water depth, shoreline configuration, size of the ocean basin etc. The highest tidal range in the world can be found in the Bay of Fundy in Nova Scotia (>11m), and this is closely followed by Swansea and the Bristol Channel, UK (>9m).

3.2.0.6 Figure 3.1 below illustrates the areas around England and Wales where particularly high tidal ranges are found (coloured yellow/orange). This, combined with the fact that the time of high tide varies around the coast of the UK, gives the potential to produce base load electricity, around the clock, from a reliable, renewable resource.

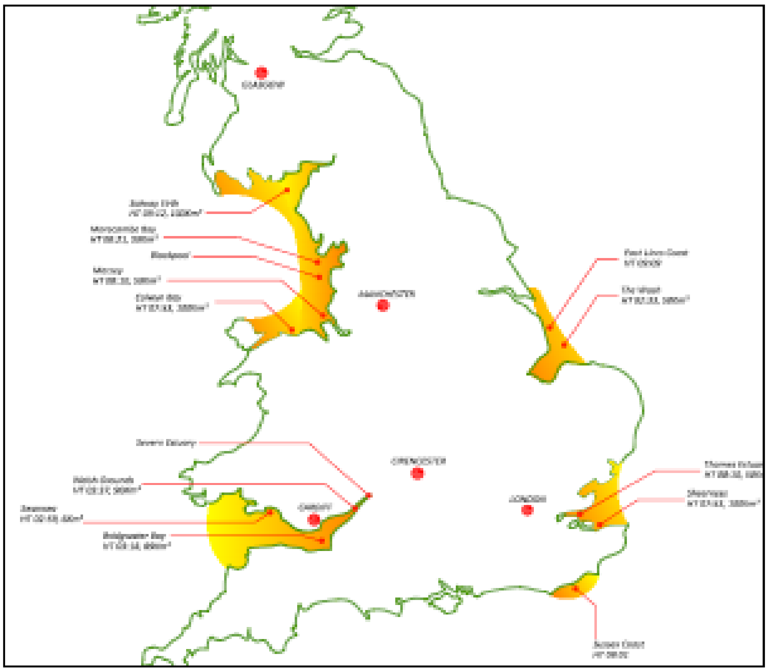


Figure 3.1 Areas of high tidal range around England and Wales

3.2.0.7 In addition to a good tidal range, a gently-sloping seabed (as found in Swansea Bay) is also required for building lagoons. Finally, economies of scale apply, with bigger tidal lagoons making cheaper electricity than smaller ones, which enhances the attractiveness of larger bays.

3.2.0.8 To achieve the objective of constructing the first, purpose-built, tidal lagoon in the world, a balance was sought between optimum tidal range, an appropriate scale, and opportunities for providing additional benefits to the local area (e.g. recreation and regeneration). Swansea Bay provides all of these key elements.

Other studies

3.2.0.9 The UK Government has also considered marine renewable energy in its rounds of Strategic Environmental Assessments (SEA) to inform licensing and leasing of the seabed for energy uses. In SEA8 (2007), the Government considered the strategic use of the southwest waters of England and Wales, including the Bristol Channel, for oil exploration and renewable energy (such as wind). The conclusion of SEA8 states that the area has not seen a large amount of development in relation to oil exploration or renewable energy in the offshore zones, but that significant infrastructure development has taken place in the densely populated coastal zones.

3.2.0.10 Offshore Energy Strategic Environmental Assessments 2 (OSEA2) is currently being undertaken by the Department of Energy and Climate Change (DECC) to supersede the assessment undertaken in SEA8 (and other) SEAs, and to inform the granting of leases and licences in relation to territorial waters and the Renewable Energy Zone (of which the Bristol Channel and Swansea Bay form a part). The assessment covers tidal range development and defines its impacts. The consultation SEA (OSEA2) sets out how the activities that follow the adoption of a plan or programme to license or lease tidal range technologies will have certain broad impacts on the environment, which should be considered in an environmental impact assessment.

3.2.0.11 OSEA2, once completed, will provide the assessed basis of a program for the licensing and leasing of territorial sea in England and Wales. This includes tidal range technologies aside from the Severn Barrage.

3.2.0.12 Further understanding of the potential size and distribution of wave and tidal resources has been developed in a study by The Crown Estate (2012). The objective was to look at the future potential for wave and tidal project development around the UK coast. The study concluded that there are opportunities for tidal range schemes that can contribute to the UK's energy needs. In addition, the study noted that England and Wales share the largest single area of tidal range resource, namely the Bristol Channel and Severn Estuary.

3.3 Positioning the tidal lagoon within Swansea Bay

3.3.0.1 A number of key factors were used to select the position of the Project within the Bay. These are described below.

3.3.0.2 **Beach profile and depth of water:** In order to minimise various environmental and economic impacts, shallower water depth is preferred for lagoon development. Shallow waters with gentle beach slopes are found at a number of areas in the Bay, including off the Swansea Port and between Mumbles Headland and Singleton Park.

3.3.0.3 **Beach recreational quality:** As shallow water depth is preferred, this tends to occur nearer to the shore and, as such, there is scope for material impacts on existing beach uses. Within Swansea Bay there are two designated bathing beaches (Aberafan Sands and Swansea Bay), and these have been avoided so as to preserve these amenities. The site selected for the Project is on an intertidal area, which is not a designated bathing area, and which is predominantly backed by the Swansea dockland.

3.3.0.4 **Landfall:** To construct landfalls for the seawalls of a lagoon (if it is land-attached - see 3.4.2 below), suitable sites are required. Some of the key elements of a good landfall would include: minimising disruption to existing users of the land; the presence of good local and wider transport infrastructure; availability of space for onshore facilities; and the opportunity to provide additional regeneration and/or recreational opportunities to the local area. Suitable shore profiles are also necessary.

3.3.0.5 **Navigation:** Positioning the lagoon such that it did not interfere with the operation of the three ports in Swansea Bay (Swansea, Neath and Port Talbot) was a key factor. The location between, but not affecting, the dredged approach channels of the ports of Swansea and Neath was selected to minimise disruption to shipping.

3.3.0.6 **Turbine depth:** The marine turbines required for power generation have to be positioned in sufficiently deep water to be permanently submerged. On current turbine dimensions this requires 7m of permanent depth below Chart Datum, which can be achieved by seabed excavation.

3.3.0.7 **Conclusion:** Taking all the factors above into consideration, the selected area for the Project is located off Swansea Port. Here, the seabed is gently-sloping offshore, up to the outer reaches of this area which achieve the required water depth for the turbines. The use of western landfall point in an area of existing industrial/port uses provides significant benefits in terms of: minimising impacts during construction; assisting with transport logistics (i.e. supporting delivery of materials by sea); and providing space for supporting facilities during construction and operation. The site also provides a relatively simple electrical grid connection. During operation there would be potential for onshore facilities with opportunities to enhance the local area. In terms of minimising disruption to navigation, this can be achieved by siting the Project between, but not affecting, the dredged approach channels of the ports of Swansea and Neath.

3.4 Option assessment for the Lagoon design

3.4.1 Introduction

3.4.1.1 The lagoon design has changed throughout the evolution of the Project to find the best solution with regards to energy generation, environmental considerations and cost viability. This section describes how the lagoon design has changed, and what has led to the proposals presented in Chapter 4, Project Description.

3.4.2 Evolution of the Lagoon shape

3.4.2.1 At the early stages of the Project, the initial idea was for an entirely offshore lagoon impounding structure, without any landfall (Table 3.1). It was thought that this design would create enough energy for viability, and would be beneficial to coastal processes and sediment transport by allowing flows around the landward perimeter of the lagoon.

3.4.2.2 However, preliminary energy and cost modelling showed that the offshore lagoon option was not commercially viable, as the ratio of wall length to enclosed area was too low. In addition to this, initial high level (low resolution) coastal process modelling showed that significant current movement would occur on the landward side of the lagoon as a result of tides, potentially significantly increasing scouring.

3.4.2.3 This resulted in a change to a land-attached lagoon design. By becoming land-attached, the lagoon was more economically viable, as approximately 30% of the impounding wall comprises existing land, instead of manmade seawall. This also provided a simple, protected cable route within the seawall, and easier access to the lagoon for both the construction and operation purposes.

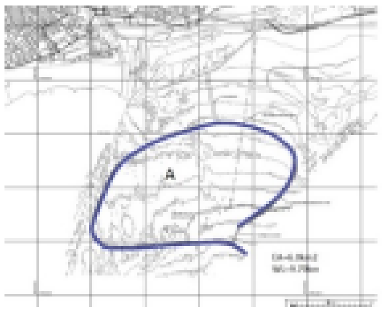
3.4.2.4 This necessary design change not only made the lagoon viable, but also completely changed the vision of what the lagoon could achieve. The land attachment meant that the lagoon could now, not only provide reliable renewable energy, it could also provide a potential recreational and sporting resource as well as other opportunities. These opportunities are discussed further in Section 3.10

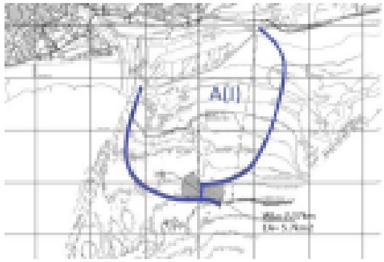
3.4.2.5 The lagoon shape has evolved throughout the preliminary design process, as the understanding of the energy modelling, turbines, cost modelling and environmental constraints has grown. Approximately 20 different lagoon layout options have been considered ranging from a small, 6.0km^2, offshore lagoon (A) to a very large, 17km^2, land-attached lagoon (L). The main designs that were considered are presented in Table 3.1.

3.4.2.6 As part of the selection process, the chosen layout, Option (J3), was optimised based on potential energy production and also took into consideration preliminary water quality modelling, initial high level coastal processes modelling (including changes in current movement), navigation risk, geotechnical issues, engineering (in terms of wall design), wall depth and overall cost.

Table 3.1 Tidal Lagoon Swansea Bay, lagoon design iterations

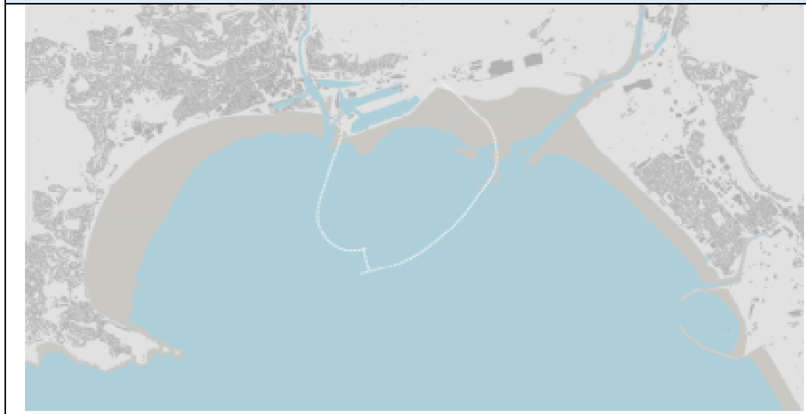
LAGOON DESIGN	CONSTRAINTS SUMMARY
All lagoon design options	The design iteration process ran from December 2011 to July 2013, encompassing 15 main lagoon options shown below. Constraints applying to all options can be summarised as follows: - Energy output – primarily driven by the volume of captured water: more water provides more power - Viability – primarily driven by the ratio of the length of seawall to the area of seabed (and therefore the volume of water) enclosed. Elongated lagoon shapes have a less efficient ratio than rounded shapes - Bathymetry – deep water requires a higher seawall, with a greater associated cost - Construction method – use of Geotubes® in the seawall was preferred from the start, but the method of building the turbine housing changed from floating pre-cast caissons into position, to building a cofferdam within which to construct the turbine housing *in situ*. This change influenced some aspects of lagoon design detail as set out below - Dredged channels – providing access to Swansea Docks (via the River Tawe) and Neath Harbour (via the River Neath) - Crymlyn Burrows SSSI – requiring protection NOTE: Each lagoon option has been reviewed below with reference to the most relevant constraints only.

LAGOON DESIGN	DESIGN DATE & RATIONALE	CONSULTEE / EIA FEEDBACK & DECISION
CONSULTATION PHASE: “Early project definition and informing the EIA”		
	**December 2011 - April 2012** Option A. Offshore lagoon, similar to proposals initiated by Tidal Electric Ltd (2002-2006) on the assumption that an offshore lagoon would have lower impact on coastal processes compared to a land-attached lagoon by allowing water flow between the landward wall of the lagoon and the port. Ratio of seawall to enclosed area – 1:0.6 Easterly turbine alignment. Lagoon below 100MW installed capacity and not an NSIP.	High level coastal process modelling suggested significant increase in currents between the rear wall of the lagoon and the shore adjacent to Swansea Port at certain states of the tide, which would have significant erosion potential behind the lagoon. Water quality modelling indicated that under heavy rainfall conditions the reduced water quality in the River Tawe would be entrained behind the lagoon keeping it inshore for an increased period of time. In addition, the easterly discharge position of the turbine house would result in the storm water from the outfall affecting Aberafan beach. Inadequate viability ratio of seawall to enclosed area. Option rejected.

	**December 2011- April 2012** Option A1. First land-attached option reviewed in parallel with offshore Option A, above, to compare and contrast potential impacts. Approximately 30% of the impoundment made up by land instead of seawall, reducing length of seawall (and cost) accordingly. Seawall now provides a grid connection route within the wall structure (instead of on the seabed), as well as easy access during the construction and operation periods. Ratio of seawall to enclosed area – 1:0.77 Easterly turbine alignment. 'Lip' at turbine housing designed to protect the housing from prevailing weather/seas during both construction (of a caissons-based housing) and operation. Lagoon below 100MW installed capacity and not an NSIP.	High level coastal processes modelling suggested a reduced overall coastal process impact relative to offshore Option A. Water quality modelling indicated that the easterly discharge position of the turbine house would result in the storm water from the outfall impacting on Aberafan beach. Inadequate viability ratio of seawall to enclosed area. Option rejected. However, land-attached lagoons identified as the preferred option for development and further consultation on the grounds of: reduced environmental impact; increased viability; simpler grid connection; ease of access; recreational opportunities created by that access.
	**March 2012 – April 2012** Option B. Exploration of larger land-attached options, aiming to improve ratio of seawall to enclosed area, and enhance viability from greater energy output. Ratio of seawall to enclosed area – 1:0.98 South easterly turbine alignment. Lagoon below 100MW installed capacity and not an NSIP.	Early water quality modelling suggested intermittent storm water from sewage outfall, in combination with south easterly turbine alignment, would have potential to adversely affect Aberavon bathing beach. Inadequate viability ratio of seawall to enclosed area. Option rejected. Land-attached, west to southerly facing lagoon design confirmed as preferred option.

	**March 2012 – April 2012** Option C. Alternative land-attached option, considered at the same time as Option B, but with slightly smaller enclosed area and different shape. Ratio of seawall to enclosed area – 1:0.95 South-easterly turbine alignment. Lagoon below 100MW installed capacity and not an NSIP.	Water quality issues the same as Option B, above. Inadequate viability ratio of seawall to enclosed area. Option rejected. Land-attached, west to southerly facing design for turbine housing confirmed as preferred option for further design development.
 Lagoon design D is shown here set against selected larger options, described below, for scale.	**April 2012 – April 2013** Option D. Similar in scale to Option B but with turbine housing facing southwest to reduce adverse effects on water quality. Initial modelling demonstrated that a turbine housing with a west to southerly alignment would not affect the designated bathing beaches. Ratio of seawall to enclosed area – 1:0.99. Energy outputs good, and in excess of 100MW (qualifying the project as an NSIP, inside the DCO process), initial costs estimates positive. Lagoon design D was used for the EIA Scoping Report (October 2012) and subject to 'Issues and Options' consultation (November 2012 to April 2013, below).	This option was identified in April 2012, and informed a more detailed period of cost, viability, baseline EIA assessment and informal consultation with key stakeholders. During this period, it was established that lagoons below 100MW (and outside the DCO process) were not viable and should be rejected. Detailed cost figures raised questions over viability from January 2013, and larger lagoons began to be explored by TLSB engineers, with an improved viability ratio and hence greater potential energy output, as set out below. (Option finally rejected in May 2013).

EIA SCOPING REPORT: lagoon design Option D, submitted to the Planning Inspectorate in October 2012, response received in November 2012



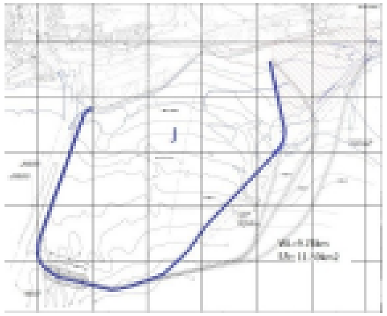
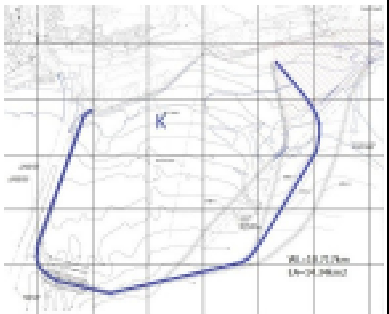
Wall length	9.4km
Area	9.4km^2
Installed capacity	250MW
Annual output (gross)	400GWh
Design life	50-100yrs
Height of wall	11-19m
Wall above low water	11.3m
Wall above high water	2.8m

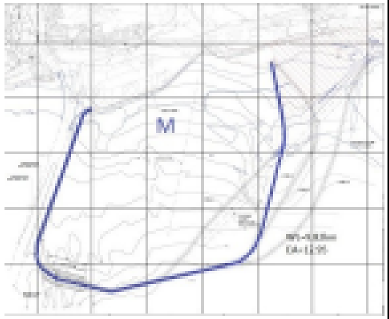
From January 2013, as concerns over the ‘viability ratio’ were raised about Option D, the options E to M described below were investigated. The process also addressed the height of the seawall in response to wave data. Various of options E to M were presented as alternatives to design D through:

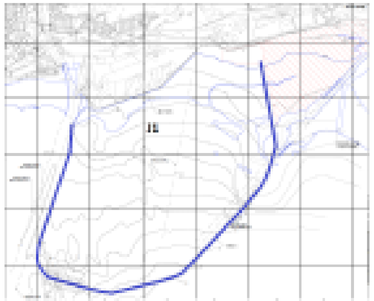
CONSULTATION PHASE: “Issues and Options phase 2, lagoon design D with emerging alternatives E-M as set out below

	**January – June 2013** Option E. Similar in form to Option D but larger and without the turbine house 'lip'. As noted above, the lip was intended to protect the turbine house from prevailing weather/seas during both construction and operation, but was proven un-necessary by (i) wave modelling and, (ii) the shift from a caisson-based construction method to the more cost-effective use of a cofferdam for construction. To increase the lagoon size, the walls for Option E have extended south and east, with a new eastern landfall outside Swansea Docks. Ratio of seawall to enclosed area – 1:1.16	Lagoon design E and a number of larger options (below) were explored in parallel, based on various engineering requirements and desired energy yields. The options raised key issues, including the lagoon's relationship with Crymlyn Burrows SSSI and the Neath dredged channel. Stakeholders queried whether building the lagoon wall outside the SSSI would cause more or less impact than crossing, or even encompassing, the SSSI and requested that modelling should inform the decision. In response, additional, high level modelling was conducted on key options selected from emerging designs E to M in order to test design assumptions about the lagoon's relationship with the SSSI which could then be applied to other design iterations as required. The options/relationships tested were: - Option J – avoid the SSSI - Option K – cross the SSSI - Option L – encompass the SSSI Option E was ultimately rejected due to due to potential adverse impact on Crymlyn Burrows SSSI.
	**January – June 2013** Option F. Similar to Option E but fully encompassing the SSSI with a view that this may offer protection to the dune area. Ratio of seawall to enclosed area – 1:1.30	Concerns were raised by multiple stakeholders (e.g. EA/CCW, which subsequently became NRW) about encompassing Crymlyn Burrows and preventing sand feed to the SSSI. Eastern landfall is in an isolated location for masterplanning and recreational ambitions. Option ultimately rejected after significant concerns raised by stakeholders over encompassing Crymlyn Burrows SSSI.

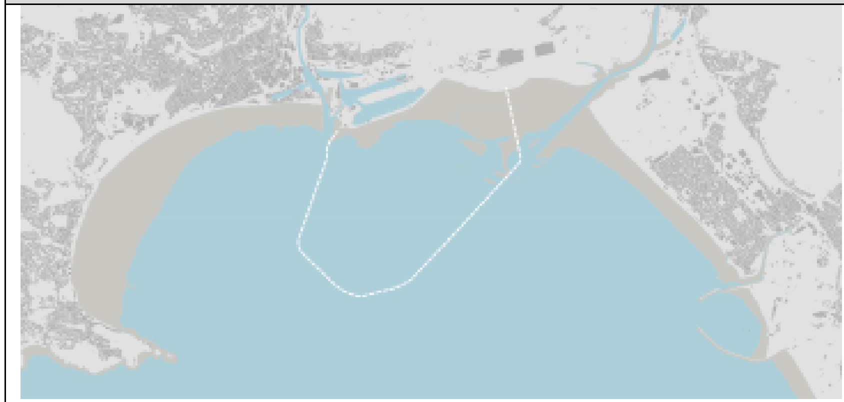
	**January – June 2013** Option G. Large lagoon avoiding the SSSI while maximising impounded area, with good wall to area ratio and high potential energy output. First options to explore relocation of Neath dredged channel (along with H, below). High capital cost due to extended wall length and deep water at southeast corner. Ratio of seawall to enclosed area – 1:1.32	Neath Port Authority (NPA) raised objections to the relocation of the dredged channel. Also, water quality modelling showed that channel relocation had the potential to reduce water quality at Aberafan beach during wet weather (concerns raised by multiple stakeholders). Option rejected.
	**January – June 2013** Option H. Large lagoon encroaching on SSSI with good wall to area ratio and high potential energy output. First options to explore relocation of Neath dredged channel (along with G, above). High capital cost due to extended wall length and deep water at southeast corner. Ratio of seawall to enclosed area – 1:1.51	As above, Neath Port Authority (NPA) raised objections to the relocation of the dredged channel. Also, water quality modelling showed that channel relocation has the potential to reduce beach water quality at Aberafan during wet weather (concerns raised by multiple stakeholders). High level coastal process modelling (on Option K, below) showed potential increased adverse impact on Crymlyn Burrows SSSI relative to designs (Option J) which avoid the SSSI. Option rejected.
	**January – June 2013** Option I. Very large lagoon encompassing SSSI, with good wall to area ratio and high potential energy output. Relocation of Neath dredged channel necessary. Very high capital cost due to extended walls. Ratio of seawall to enclosed area – 1:1.52	High level coastal process modelling (on Option L, below) indicated a higher level of impact on Crymlyn Burrows SSSI relative to Option J (avoiding the SSSI). Relocation of the Neath Channel also had potential to reduce water quality at Aberafan Beach during wet weather. Lagoon design also assessed as having a significantly higher environmental, ecological, visual and navigation impact – concerns raised by multiple stakeholders. Isolated eastern landfall threatens masterplanning and recreational ambitions. Option rejected.

	**January – June 2013** Option J. Good wall to area ratio, good potential energy output. Avoids encroachment onto SSSI and Neath Channel. Both walls located 100m from dredged river channels. Wall depth reasonable so capital costs acceptable. Ratio of seawall to enclosed area – 1:1.18	High level coastal process modelling carried out on this option to assess impact of lagoon designs avoiding the SSSI. The results indicated reduced potential impacts on coastal processes compared with options which cross into the SSSI (represented by option K) or encompass the SSSI (represented by option L). No encroachment onto SSSI and lagoon wall set back 100m from Neath Channel. Potential synergies and design opportunities created with new Swansea University Bay Campus (SUBC) at eastern landfall. Water quality modelling also demonstrated no adverse impact on Aberafan Beach from the River Neath. Informal discussions with NPA and CCW/EA indicated this design was viewed as a good compromise layout, falling between design D and larger options F, H, I, K, L and M. Option taken forward for refinement – see J1 through to J3 below.
	**January – June 2013** Option K. Variation of Option J, extended eastwards to increase energy output, crossing the SSSI and requiring re-alignment of Neath dredged channel. Energy modelling and cost modelling very positive: indeed, this was TLSB's preferred lagoon design from a value for money and engineering perspective. Ratio of seawall to enclosed area – 1:1.34	High level coastal process modelling was carried out on this option to assess impact of lagoon designs encroaching into the Crymlyn Burrows SSSI. Results showed this option has higher potential coastal process impacts compared to Option J. Option also affected the alignment of the Neath channel and as such water quality at Aberafan would be at greater risk during wet weather. Concerns raised by multiple stakeholders. Option rejected.

	**January – June 2013** Option L. Extreme variation of design J, extended eastwards to increase energy output, encompassing the SSSI and requiring re-alignment of Neath dredged channel. Energy modelling and cost modelling positive. Ratio of seawall to enclosed area – 1:1.51	High level coastal process modelling carried out on this option to assess impact of lagoon designs encompassing the SSSI. This option would also require the realignment of the Neath Channel. Option was rejected due to potential water quality effect on nearby Aberafan and coastal process effects on Crymlyn Burrows SSSI. Concerns raised by multiple stakeholders. Option rejected.
	**January – June 2013** Option M. Further variation of Option J, extended eastwards without encroaching on the SSSI and reducing change required to Neath dredged channel. Energy modelling and cost modelling very positive. Ratio of seawall to enclosed area – 1:1.31	NPA objected due to anticipated problems for pilots approaching the Neath Channel. Option rejected as additional impacts in terms of water quality and coastal processes outweighed the benefit of increased generation capacity.

Refinement of lagoon design J – June 2013		
	Option J1 was slightly enlarged (compared to Option J) in order to incorporate training walls for the Neath Channel, also to give an improved wall to area ratio and greater potential energy output. Ratio of seawall to enclosed area – 1:1.28	Rejected following further consultation with NPA about crossing of training walls to Neath Channel and because the option required a change in alignment to the Neath Channel.
	Option J2. Positioned the eastern lagoon wall 100m from the Neath channel and moved the turbine housing into shallower water to reduce construction cost. The western lagoon landfall was linked into the existing Tawe eastern approach wall to remove/replace derelict infrastructure and thereby improve visual appearance from land. Ratio of seawall to enclosed area – 1:1.19	NPA requested: a) relocation of eastern lagoon seawall to form the western training wall of the dredged channel b) widening of the eastern wall of the approach to the Neath channel Further discussions with NPA allowed final adjustments to incorporate the training wall into the design of the channel. The result was option J3.
	Option J3. Refinement of design J to incorporate all improvements identified above, and establish an appropriate compromise design, balancing environmental and navigational impact with technical requirements and responding to stakeholder comments. Ratio of seawall to enclosed area – 1:1.21	Identified as Preferred Option for formal consultation and reference design for EIA purposes.

CONSULTATION PHASE: Statutory s42 and s47 – Preferred Option and the PEIR, July 2013 onwards



Wall length	9.5km
Area	11.7km^2
Rated capacity (@4.5m head)	240MW
Annual output (gross)	400GWh
Design life	up to 120yrs
Height of wall	5-20m
Wall above low water	12m
Wall above high water	3.5m

TLSB engineers investigated requirements for the height of the seawalls in parallel with the above work on lagoon size and layout. Wave data indicated that the initial identified requirement (Option D) for a seawall of 11-19m (2.8m above high water and 11.3m above low water) was incorrect. Close to shore, the seawall could be lower, but offshore more height was required for structural integrity and operational/visitor safety, with a new range identified for lagoon option J3 as: 5-20m (3.5m above high water, and 12m above low water).

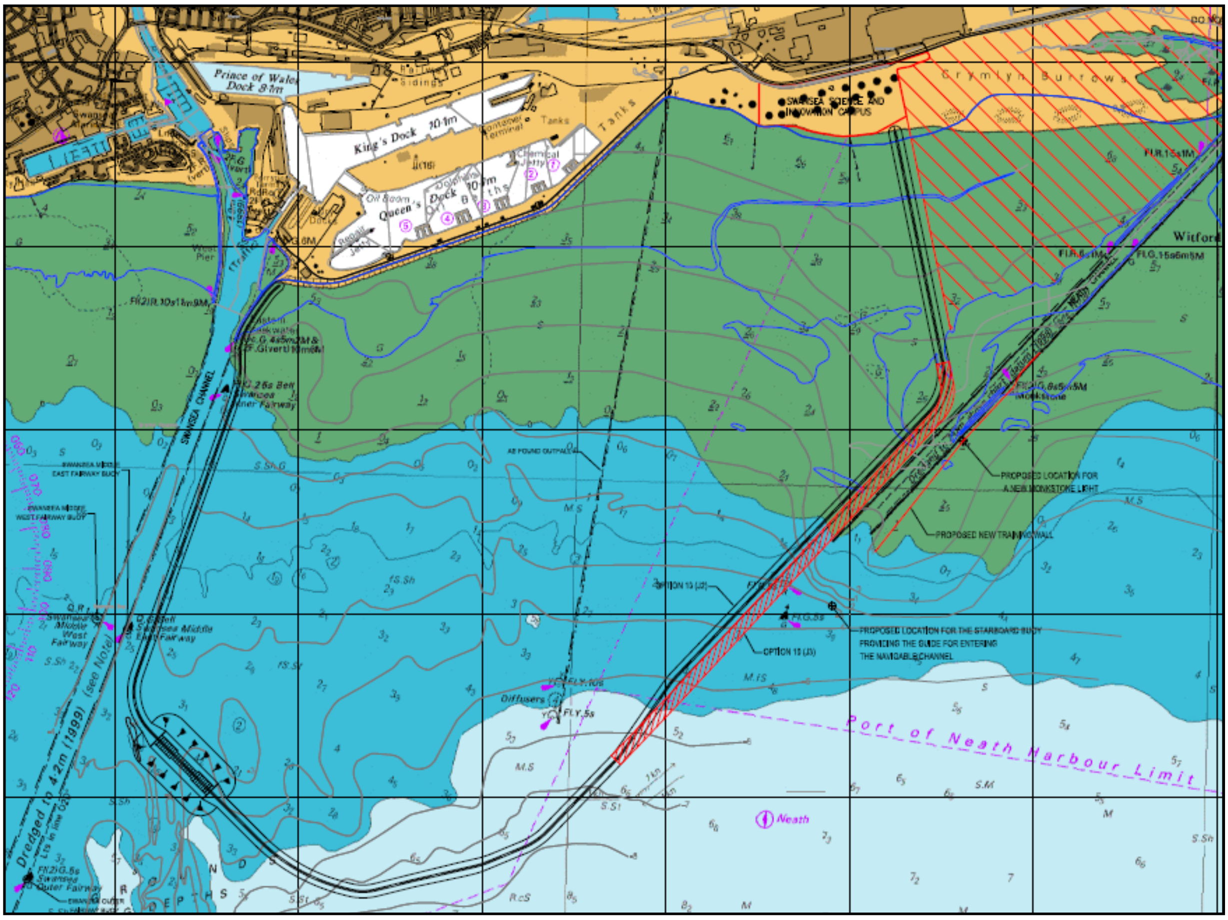


Figure 3.2 Key difference between Lagoon layout options J(3) and J(2)[1]

3.5 Turbines and sluice gates

3.5.1 Introduction

3.5.1.1 In order to optimise output from a tidal range power project there are a number of factors to consider, including:

a) type of turbine (single or bi-directional flow);

b) the size and number of turbines; and

c) the number of sluice gates.

3.5.1.2 An overview of the selection of these elements of the Project is presented in the sections below.

[1] The options for lagoon design in respect of the location of turbine and sluice gate housing that are comprised within the Project are presented in Section 4.3.3 of Chapter 4, Project Description.

3.5.2 Turbines

Single (ebb tide) or dual generation (ebb and flood tide)

3.5.2.1 Low head bulb turbines have been used for the generation of electricity in river and dam projects for well over 50 years. As such, they are a tried and tested technology. For the purpose of the Project, a variety of existing conventional hydro technologies were investigated further during the preliminary stage.

3.5.2.2 Options considered at an early stage looked at whether the Project would only generate on the ebb tide, or whether the Project could generate on both the ebb and flood tides (dual generation).

3.5.2.3 Early energy modelling suggested the maximum achievable output from ebb-only generation would be approximately 25% of the lagoon impoundment's potential energy. However, in order to make lagoons commercially viable, approximately 35% of the potential energy output is necessary. To achieve this, dual generation (on ebb and flood tide) is essential.

3.5.2.4 The energy outputs for a number of dual design turbines were very positive showing greater than 40% of the potential energy output was possible. Further engineering design, and understanding of lagoon operations from the turbine manufacturers, along with reliable performance data, all pointed towards bi-directional turbines being the optimum solution for the Project.

3.5.2.5 The type of turbine to be used for the Project has been narrowed down, following detailed engineering input from the major turbine manufacturers. The preferred options are either: a slightly modified bi-directional double regulated bulb turbine; or a bi-directional variable speed bulb turbine. Ongoing detailed technical and commercial evaluation of both turbines is currently being undertaken to establish the best possible option for the Project. Further information on turbines is presented in Chapter 4, Project Description and the principle of the "Rochdale envelope", which has been applied to the EIA process, assesses the likely “worst case scenario” impacts for the use of either of these technologies in the relevant chapters of the ES.

Size and number of turbines

3.5.2.6 Energy modelling undertaken for the Project has focussed on the relationship between turbine diameter, discharge rate, power output, and the number of units. In this way the optimum size and number of turbines needed can be established.

3.5.2.7 Initial energy modelling looked at 2m and 3.3m units, as these were the largest unit size that could be installed with floating caissons and without bed excavation. However, once an "in-situ" turbine housing construction method was selected, larger turbine options could be considered. Using in-situ construction, with localised excavation, larger turbines 6m or 7m in diameter could be considered. These larger turbines are preferable as fewer units are needed, which is advantageous in terms of cost, manufacturing and installation lead times. Larger units generally have a slower rotational speed and higher flow rate and are therefore potentially less harmful to fish and other marine species when compared to smaller units.

3.5.2.8 Energy modelling has been undertaken to determine the optimum number of larger diameter turbines for the Project. The preferred design is presented in Chapter 4, Project Description.

3.5.3 Sluice gates

Number of sluice gates

3.5.3.1 Energy modelling shows that, in order to optimise electricity generation on each tidal cycle, the water level in the lagoon must return to as close to the water mark outside the lagoon as possible. In this way, the maximum head on the following tide is maintained. This balancing of water level and power generation is achieved by flow through the turbines and flow through the sluice gates.

3.5.3.2 The outputs for different combinations of turbines and sluice gates, and the sluice flows required have been modelled. Larger sluicing capacity gives higher energy outputs and more closely follows the natural tide in terms of foreshore exposure within the lagoon.

3.5.3.3 In bi-directional mode, sluicing (on the ebb and flood tide) at the end of the generation sequence allows an increase in head and thus more power from the next tide.

Type of sluice gates

3.5.3.4 Other projects, for instance the studies relating to the Severn Barrage, have considered numerous sluice gate designs. These were reviewed and it was decided to keep the Project's sluice gates as simple and robust as possible, with local fabrication being preferable.

3.5.3.5 Most of the standard gate designs were not suitable for bi-directional flow, so vertical lift roller gates have been selected. This is a simple, robust gate design, which is well proven in marine use. The proposed gates chosen have a large discharge capacity, are based on mature technology, are easy to maintain, and are capable of being manufactured locally.

Size of sluice gates

3.5.3.6 The larger the discharge capacity through sluice gates, the better in terms of energy production. However, there is a trade-off against an optimum point for size, cost and practicality of logistics and supply chain.

3.5.3.7 The sluice gate design has been obtained by examining the discharge capacity, cost and logistical practicality. The sluice gates can be easily fabricated in Wales by a number of companies and can be transported using standard low loaders and cranes.

3.6 Construction method choices

3.6.1 Turbine-housing construction

3.6.1.1 The turbine housing had two options for construction: a floating caisson; or an in-situ cofferdam technique.

3.6.1.2 The initial designs focussed only on floating caissons, as a marine cofferdam was viewed as too costly. It was also assumed that submerged excavation would be technically challenging, and so turbine size with a maximum diameter of 3.3m was assumed to avoid any need for excavation.

3.6.1.3 Later, with the involvement of a main civil engineering contractor, a more detailed cost and risk analysis was conducted, looking at various dry dock caisson options and cofferdam options including sand bund, Geotubes® and steel cellular cofferdam.

3.6.1.4 In-situ cofferdam construction is now the preferred option so that construction can take place in dry conditions. This is better in terms of cost, reduced weather risk, ease of bed preparation, access for equipment and larger sizes of turbines.

3.6.1.5 Further information is provided below on all the in-situ cofferdam construction options which have been considered during the Project development. For those not progressed, reasons are provided. Chapter 4, Project Description gives additional details of the cofferdam designs which are being taken forward and have been assessed in the EIA.

3.6.2 Offshore temporary bund

3.6.2.1 Once the method of turbine-housing construction had been decided as being built in-situ within a dry cofferdam, two approaches were analysed: a ‘soft’ option, using sediment as the main material; and a ‘hard’ option, using steel piles.

3.6.2.2 Each of the options has been progressed to a stage where the relative cost, duration, risk, buildability, and other impacts could be compared.

3.6.3 Soft options

3.6.3.1 Initially 3 ‘soft’ options of sand bund were considered, the first being made entirely of sand/sediment pumped into position by the dredging equipment. The second option was to create the bund with Geotubes® and a sediment core in a similar way to the permanent seawalls, but without the rock armour protection. The third option was to replicate the permanent lagoon seawall design, by creating a bund with Geotubes®, a sediment core and rock armour protection of the sea side of the bund.

3.6.3.2 The first option was rejected due to the large quantity of sand/sediment required and the vulnerability of a purely sand/sediment bund to sea conditions.

3.6.3.3 The second option was rejected due to vulnerability of the Geotubes® without any rock armour protection, as the temporary bund would need to be in place for over a year.

3.6.3.4 The third option, which is based on the main seawall design, remains an alternative under active consideration and further details are provided in Chapter 4.

3.6.4 Hard options

3.6.4.1 Two ‘hard’ options were originally considered: a circular sheet-piled cofferdam; and a twin sheet-piled cofferdam.

3.6.4.2 The circular sheet-piled cofferdam would be fabricated onshore by installing sheet piles around a prefabricated steel frame. A jack-up barge, loaded with a crawler crane, would then be floated into position along with a crane vessel to lift and accurately position the cells. Once the sheet-pile cell is in place, resting on the sea bed, the crawler crane would vibrate the sheet-pile into the seabed to ensure that it stays in the correct place. This process would be repeated until the cofferdam is formed. The cells would be filled with sediment and a working platform/access road created on the top. This option was rejected due to the difficulty in removing the piles for re-use or resale, thereby significantly increasing the cost of the option.

3.6.4.3 The twin sheet-piled cofferdam remains an alternative under active consideration and further details are found in Chapter 4, Project Description.

3.7 Grid connection

3.7.0.1 During the development of the Project, the grid connection was also a key consideration and this has evolved significantly over the last two years. Some factors which have influenced the grid connection include:

a. The generation capacity of the Project and the proximity of a suitable substation connection point;

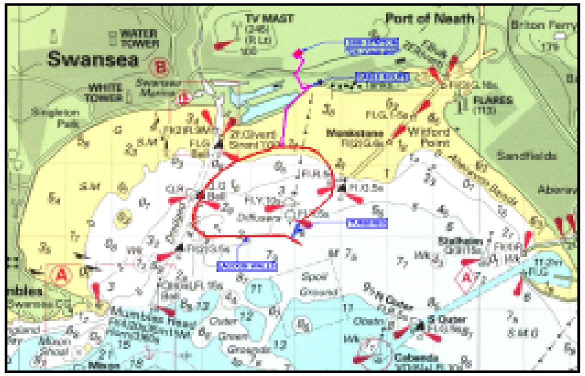
b. The presence of a landfall to minimise marine works; and

c. Options to minimise impacts on the surrounding environment through use of existing brownfield/linear development routes versus previously undeveloped land.

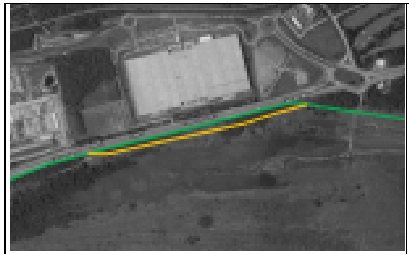
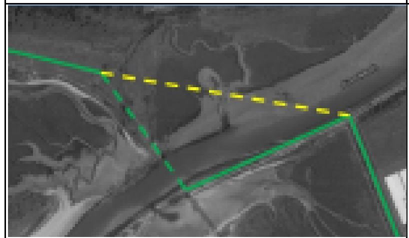
3.7.0.2 With regard to the latter point, both greenfield and brownfield routes have their own advantages and disadvantages. For instance, use of brownfield or linear routes such as roads or footpaths would have the potential to minimise impacts on ecology. However, previously developed land would have the potential for contamination or the presence of existing services which would inhibit or restrict its use.

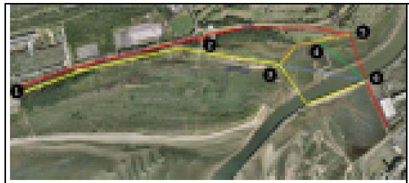
3.7.0.3 The following table summarises some of the key stages of the grid connection development:

Table 3.2 Key stages of the grid connection development

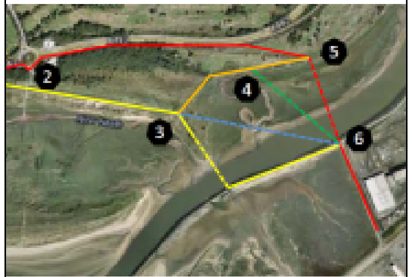
LAGOON DESIGN	DESIGN DATE & RATIONALE	EIA FEEDBACK & DECISION
Early project definition		
	With the original lagoon designs of less than 100MW a local grid connection point to the north of Swansea Port was identified at Tir John. In terms of the "offshore" lagoon design, the most direct cable route from the lagoon to the coast was chosen to minimise the extent of marine cable. The cable route then followed existing port road infrastructure or crossed brownfield land to head north to Tir John. This most direct route north would require the need to cross railway lines and Fabian Way (A483).	The most direct route north from the port was rejected due to issues associated with the crossing of the main railway line and Fabian Way. With the development of the land connected lagoons (options B – C, Table 3.1) the need for expensive marine cable was negated and the cable was to be laid within the lagoon seawall. The Tir John substation connection point continued to be considered for the "smaller" lagoons (<100MW). Alternative less direct routes to Tir John were investigated to find alternative means of crossing the railway line and Fabian Way.
	With the increase in generation capacity of lagoon (>100MW) connection to Tir John was no longer appropriate and a connection to National Grid's Baglan Bay Substation was required. Initially, two land based routes were looked at one utilising the eastern landfall to the Port, and either the M4 road bridge crossing of the river Neath (Red) or directional drilling beneath the river (green). In addition a more direct marine option was also considered (yellow).	The marine cable route option was rejected due to a number of factors including: the high costs associated with underwater cables and issues with maintaining appropriate burial depth for crossing the Neath whilst still allowing for maintenance dredging of the channel. The red route was submitted with the scoping document in October 2012. In terms of the land based routes, with the change in the eastern landfall from the port to further east, these options were no longer viable and further investigation was undertaken.

LATER PROJECT DEFINITION		
CABLE ROUTE	**CONSTRAINTS SUMMARY**	
All cable route options	Subsequent to feedback on the scoping document and advancement in the lagoon design, the cable route iteration process has been further progressed. Since January 2013, this has included the examination of several route options along different sections of the overall route to Baglan Bay Substation. Key constraints applying to the various sections are discussed below.	
CABLE ROUTE	**DESIGN DATE & ROUTE**	**CONSTRAINTS/COMMENTS**
January 2013 to July 2013		
	**January 2013 – July 2013** Cable route from the turbine house to the Baglan Bay substation, following the western breakwater, and from the breakwater landing point through the Port of Swansea land. After Baldwin's crescent, the route enters the verge next to Fabian Way (A483). Before the roundabout (eastern side of the SSSI), the route diverges into the SSSI to follow the existing path to a valve pit associated with existing pipes/ducts prior to crossing the River Neath. The route would use the existing ducts to cross the river or a directional drill would be undertaken before following the existing path on land to the Baglan Bay substation. Approximate route length: 10km	This route was presented in the PEIR. It was based on initial OS maps and further statutory undertaker search is required to progress analysis of the route. Initially, this route seemed to be fairly clear of obstructions and issues. If progressed, topographic survey would be required to assess the levels of vegetation alongside Fabian Way and other parts of the route, to see if this would affect the planned cable route. At this stage no information was available regarding the proposed Swansea University Bay Campus (SUBC - previously known as the Science and Innovation Campus). Option to be taken forward. Further information to be obtained for various key sections and refinement to be undertaken following information review.

	**July – August 2013** Cable route as previous, but with an optional route diverging into the SSSI to follow the existing path. Western arm route, with optional route through SSSI (see picture, left - orange indicates the optional route).	After a statutory undertaker search was completed the original cable route was altered slightly to ensure that crossings of existing services were minimised where possible. The optional SSSI route was introduced as it was unclear whether the Fabian Way verge narrowed parallel to the SSSI zone. NPTCBC also advised that Fabian Way verge is a conservation verge and is managed as a hay meadow. As such plans to minimise impact should be considered where possible (Chapter 12, Terrestrial Ecology). The option to use paths in the SSSI would minimise the impact on the verge, whilst also avoiding entering the SUBC land. The SSSI route passed through patches of vegetation within the SSSI, which may be environmentally sensitive, therefore posing potential issues for this cable route. Notwithstanding this with careful consideration this route could still be feasible. Both options (Fabian Way verge and SSSI) remain alternatives under active consideration.
	**September – October 2013** An alternative directional drilling location was proposed for the River Neath crossing should the existing ducts be unsuitable for the cable route. Previously it was proposed to cross adjacent to the ducts (see picture, green indicates old route and yellow indicates the new directional drilling route).	The path of the new directional drilling was selected to run from the valve pit diagonally across the River Neath to minimise the impacts on the SSSI. Note, this option is more expensive than reusing the existing ducts. However, a lack of information regarding the existing ducts and their suitability for reuse means that alternative options to cross the Neath needs to be retained. Option of using new HDD is considered if the existing ducts are proven unsuitable.



Close up of end of route



Overview of routes August – September 2013

Cable route as previous (July/August), but with extended route options through the SSSI. The Fabian Way route was extended to continue past the roundabout (point 2) and enter the SSSI east of the golf course. Route options prior to the valve pit (3) made use of new directional drilling to cross the River Neath.

Western arm route, multiple SSSI options (see picture, left. Options: red route – following Fabian way up to the golf course with new horizontal directional drilling (HDD) at point 5, yellow route – following the path through the SSSI zone and reusing existing duct crossing (point 3), blue route – new HDD from the yellow route (point 3), orange route – following the path through the SSSI and joining red HDD, green route – new HDD from orange route).

The multiple route options through the SSSI were proposed in order to consider the route with the least environmental impact on the SSSI.

The advantages and disadvantages of each route are as follows:

Red route – Advantage: Shortest HDD (350m) avoids SSSI and therefore there are potentially less environmental restrictions. Disadvantage: The southern verge of Fabian Way is a conservation verge and it also has existing utilities present.

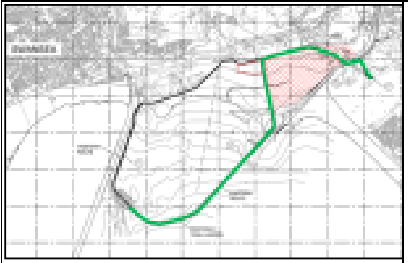
Yellow route – Advantage: Well established track within the SSSI, minimal shrub clearance to get plant equipment through, no HDD required if access to existing ducts under the river Neath were available. Disadvantage: Permission for works within SSSI required and unknown condition and suitability of existing ducts under Neath.

Blue route (variation on end of yellow route) – Advantage: Direct route and reduced length of cables, well established track within the SSSI, minimum disturbance to the SSSI with easy plant and equipment access using the existing track. Disadvantage: Longest HDD (680m).

Orange and green routes (variation on end of yellow route) – Advantage: The route between point 3 and 5 is an existing raised track, shortest HDD (350m). Disadvantage: Existing track contains concrete and large boulders and would be difficult to excavate, difficult access through SSSI, longest cable route.

Yellow route considered with blue route and sections of red route kept as alternatives.

	**September - October 2013** Western arm cable route, with various options through the university campus (see picture, left. The original Fabian Way route and earlier eastern arm route are also shown). Following further detailed information regarding the plan for the SUBC, several options were proposed, including running parallel (where possible) to Fabian Way, and a route following the campus perimeter.	The verge in Fabian Way is likely to be significantly narrowed to allow better road access to the campus, thus limiting the space for the cable route and rendering this option unsuitable. The proposed route parallel to Fabian Way is likely to encounter pinch points and may clash with planned landscaping works. The route following the campus perimeter is likely to increase the number of crossed services and will also increase the overall length of the route. Phase 2 of the university campus expansion is expected on this site, and therefore a route following the campus perimeter may cause issues for future construction. Pink option through the University site is considered (see below).
	**October 2013** Cable route with options as previous, but with the route relocated within the university campus rather than running in the verge alongside Fabian Way. Western arm route, with the cable route relocated within the university campus (see picture, left).	Following information regarding the SUBC, an option to relocate the route within campus parallel with Fabian Way was examined. This was in response to a suggestion that ducts could be installed as the campus is constructed in order for the cable to be pulled through in the future. Disadvantage of this option would be that it may be difficult to enter the Fabian Way verge at this point due to vegetation and a nearby bridge. Option considered – further information required.

	**October 2013** Cable route from the turbine house to the Baglan Bay substation, following the eastern breakwater, and from the breakwater landing point through the SUBC. The proposed path via Fabian Way is then followed, entering the SSSI zone prior to the roundabout. The route then uses either the existing ducts or new directional drilling to cross the river before following the existing path on land to the Baglan Bay Substation. Eastern arm, via the university campus. Approximate route length: 10.6km	Although crossing fewer existing services and less existing land, the additional length of the cable route is likely to cost approximately £1.2million extra, therefore making it not financially viable. Furthermore, the eastern arm has not been designed for vehicular access, and so access to the cable may be problematic. A route diverging at the point at which the eastern arm turns north towards the SUBC was also considered. This route would run underwater to the River Neath crossing before following the existing road to the Baglan Bay substation. Although being a shorter overall route, the costs of the underwater cable together with maintenance costs are likely to make this route not economically viable. Options rejected.

3.8 Water quality optimisation applications

3.8.0.1 Water quality within the Bay and within the Lagoon comprised in the Project will be affected by the presence of the Swansea long sea outfall. This currently discharges within the lagoon area. Under normal dry weather conditions the outfall from the Swansea waste water treatment works (WWTW) discharges high quality, fully treated and UV disinfected effluent. During significant rainfall events the outfall will also discharge dilute storm water which carries a more notable bacterial load. Without mitigation, during these rainfall events there is a potential for the water from within the lagoon area to:

A. affect the water quality at the designated bathing waters of Swansea Bay and Aberafan; and

B. reduce the water quality within the lagoon thereby affecting the potential for all year round water contact sport usage.

3.8.0.2 As discussed in Table 3.1 in the early stages of the Project the location of the turbine housing was assessed and optimised to minimise impacts on designated bathing waters at Aberafan. This was achieved through the selection of a south to westerly facing turbine housing. The detailed assessment in Chapter 7, Marine Water Quality confirms that the untreated discharge of storm water would not affect the compliance of these designated bathing waters.

3.8.0.3 With respect to water quality within the lagoon, during rainfall events when a storm water spill may occur, the water quality would be reduced in the absence of further mitigation and this would preclude the use for water contact sports at or after such events. As such, for all year round water contact sport usage, options to address the storm discharges from the WWTW are important.

3.8.0.4 Three options were originally considered to reduce the effects of storm discharges from the Swansea WWTW. The options are summarised in Table 3.3, and a high level indication of the engineering feasibility and estimated cost (which serves as a proxy for use of resources and difficulty of delivery), carbon footprint and construction timescale for each option is also provided.

3.8.0.5 Options 1 (Storm Water Storage) and 2 (Storm Water Disinfection) address the discharge of storm water from the WWTW, by reducing either frequency of operation or discharge concentration. This would improve water quality both within the lagoon and within Swansea Bay. Option 3 (Outfall Extension) would completely remove the treated effluent and storm discharges from the lagoon, into the Bay.

Table 3.3 Comparison of optimisation options

Option	Advantages / Disadvantages	Feasibility	Cost[1]	Timescale[2]	Carbon Footprint
Option 1 **Storm Water Storage** a) Storage of storm discharge flows from the WWTWs near to the Project/WWTW. Effluent is stored until it can be returned to the WWTW for treatment.	**Advantages** Reduces storm discharges to a very small number, i.e. only under extreme rainfall conditions. Storm flows returned to WWTW for full treatment, reducing net impact of storm flows. **Disadvantages** Storage requirement is extremely large, potentially in excess of 150,000 m^3. The land required is unlikely to be available within Project Area for a single storage solution. Large (prohibitive) construction costs. Returning stored effluent to the WWTW would be difficult as the capacity of the WWTW is limited to its design flows. Significant pumping to / from storage required. If storm storage cannot be emptied between storms additional spills would occur. Time taken to return stored effluent to the WWTW would present risk of odours. Volume of storage may not keep pace with changes in the catchment or rainfall patterns. Large embedded carbon footprint. Ongoing pumping and maintenance costs and power needs.	LOW	HIGHEST ≥£200M	SHORT	HIGHEST
OR					
b) Provision of storage and storm water removal in the catchment upstream of the WWTW (which would need to be implemented in agreement and cooperation with DCWW).	**Advantages** Reduces storm flows to WWTW by removing storm water at source in the catchment. Reduces storm discharges to a very small number, i.e. only under extreme rainfall conditions. More efficient alternative to storage at the WWTW requiring less storage volume, pumping etc. Improvements throughout the catchment, additional benefits to Swansea Bay water quality. **Disadvantages** Solutions cannot be identified at this stage, full network assessment required. Solutions may require many years to design and implement. Solution may not provide sufficient spill reduction at the WWTW. Implementation and timescale would be beyond the control of TLSB. Additional storage may still be required at the WWTW, although less than under method a). Disadvantages identified under a) would be likely to remain, although reduced in magnitude.	HIGH	HIGH ≤£200M	LONG	MID

1 Cost estimates are preliminary based on previous schemes. Improved cost estimates for options are being determined in consultation with DCWW

2 Timescale: Short– completion within lagoon construction period. Long – greater than lagoon construction period.

Table 3.3 Cont.

		Feasibility	Cost[1]	Timescale[2]	Carbon Footprint
Option 2 **Storm Water Disinfection** UV treatment of raw storm water to reduce FIOs and pathogens.	**Advantages** Similar technology UV disinfection of the Swansea WWTW final effluent. Proven technology which has been successfully applied at a number of locations in South Wales. Small footprint, could be accommodated within available land at WWTW. Reduction in indicator organisms of between 100 and 600 times can be achieved. Available all of the time to treat all storms. All flows can be treated by a sufficiently large plant. Can accommodate future change in the catchment e.g. - growth or changes in rainfall patterns (operate more). - reductions in storm water flows from future DCWW improvements (operate less). Energy consumption relatively low, only required when storms flows occur. Can be updated and improved with advancements in technology over the lifetime of the Project. **Disadvantages** High UV dose needed, requiring specially designed UV plant (separate to existing one). Design must be able to ensure sufficient bacteria removal for wide range of flow / turbidity conditions. Power required to power UV lamps. System/lamps must be maintained to ensure operation/dose available when needed. Special consenting requirements. UV system failure would allow untreated discharge – back-up procedures required (e.g. prevention of access to lagoon for contact water sports if storm event and UV treatment not functioning).	HIGH	LEAST £8-12M	SHORT	MID

1 Cost estimates are preliminary based on previous schemes. Improved cost estimates for options are being determined in consultation with DCWW

2 Timescale: Short– completion within lagoon construction period. Long – greater than lagoon construction period.

Table 3.3 Cont.

		Feasibility	Cost[1]	Timescale[2]	Carbon Footprint
Option 3 – Outfall Extension Extension of the existing outfall to place the discharge point outside of the lagoon.	**Advantages** Places outfall beyond lagoon impoundment and in deeper water with potentially higher dispersion. Low energy consumption. Low maintenance once installed. Unlikely to be affected by future growth or changes in rainfall patterns. **Disadvantages** Discharge impacts may be moved to offshore waters or increased along adjacent coastline. Outfall must pass under the lagoon wall without risk to the outfall pipe, and without compromising the integrity of the lagoon wall. Connecting the extension to the existing outfall would require temporary diversion of discharge from the WWTW during the connection period. Ground conditions and water depth may make outfall extension difficult. The additional length of outfall may have hydraulic effects at the WWTWs, and could potentially require pumping of the discharge to overcome, with increased operational risks and costs.	MID	HIGH £25-30M	SHORT	LEAST

1 Cost estimates are preliminary based on previous schemes. Improved cost estimates for options are being determined in consultation with DCWW

2 Timescale: Short– completion within lagoon construction period. Long – greater than lagoon construction period.

3.8.0.6 Owing to a number of issues, including the high cost, practicalities of implementation and limited benefits, which do not apply to the two remaining solutions, storm storage has not been taken forward as part of the Project. UV disinfection of storm water and outfall extension have been considered further in this EIA and details of the modelling runs and results can be found in Chapter 7, Marine Water Quality.

3.9 Decommissioning options

3.9.0.1 In Chapter 4 Project description, the options for the treatment of the Project at the end of its predicted 120-year lifespan that are assessed are discussed. However, the more radical approach of the complete or partial removal of the Project from Swansea Bay has also been considered and is described below, as well as an explanation of the choice not to progress this option with a description of the environmental reasons behind that selection.

3.9.0.2 The Project has been designed to be operational for up to 120 years and a Development Consent Order is being applied for on this basis (see Chapter 1). Appropriate works will be undertaken over this timescale in order that the condition of the structures will be maintained such that electricity generation will be continued. At the end of this period, it is considered that with refurbishment and regular maintenance, the Project could be functional for electricity generation for a further 50 years. Once the capital costs associated with construction of the Project have been paid off, the Project will be a cost-effective source of electricity, and as such, retaining the Project would be of benefit to meeting future renewable energy targets. For a similar project, La Rance, a tidal barrage in Brittany, France which generates 240MW of electricity, the capital cost for construction in 1960-66 was 620 million Francs, which is approximately 94.5 million Euros at 2011 prices. Capital costs have been recovered and electricity production costs in 2011 were 18 Euro cents per kWh, compared with nuclear generation at 25 Euro cent per kWh[2].

3.9.0.3 If at some future time, alternative energy sources have been developed that are more cost effective, proposals for decommissioning the Project are likely to be considered. At that time, it is likely that the Project would have been *in-situ* for a period of at least 120 years, and would have become an established recreational, leisure, art and educational facility (see Chapter 4 and 22 for further information). In addition, a stable marine environment would have been created as a result of the artificial reef habitat formed by the rocky seawall and the impoundment of the waterbody.

3.9.0.4 Wholesale decommissioning, involving removal of the entire structure would result in loss of the facilities described above, as well as significant environmental effects to then established marine and terrestrial ecological habitats, which could otherwise be avoided. The works would be likely to involve or require:

i. Demolition of the concrete turbine and sluice gate housing structure – probably using explosives to demolish the concrete works in sections. The concrete would be removed by vehicle, crushed and re-used. Reinforcing steel would be salvaged and recycled. The sheet-piles would be cut-off and left *in situ* embedded below the seabed.

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[2] http://www.theecologist.org/News/news_analysis/678082/how_france_eclipsed_the_uk_with_brittany_tidal_success_story.html

ii. Scour protection – the concrete scour protection mattress would be left in-situ as it would not result in obstruction of movement of sediment, water or navigation.

iii. Demolition of onshore and offshore buildings. The Offshore Building would be demolished, but the options for retention of the Western Landfall building would be considered.

iv. Demolition of seawalls – two options could be considered for removal of the seawalls: Option A – removal of entire structure; and Option B – retention of sections of eastern and western seawalls. These options are described further in Table 3.4.

Table 3.4 Decommissioning of seawall options

Option Description	Expected demolition activities
Option A: Removal of entire western and eastern seawalls and associated facilities.	The seawalls would be removed working from offshore to onshore. The concrete cap would be broken up (blasting or use of hammer/chisel). It is estimated that approximately 200,000m^3 (500,000 tonnes) of concrete would be demolished. Some of this material would be crushed and re-used but due to the large amount generated, it is expected that a significant proportion would need to be transported by road to landfill. The rock armour would be removed by crane and truck. Approximately 2.5 million tonnes of rock armour will be removed based. To stock pile this amount of rock would require a temporary storage area of approximately 100 hectares of land. Alternative uses of this rock would need to be investigated at the time of decommissioning as local land availability for rock stockpiling is unlikely to be available with the potential synergy of development within the Port and surrounding area over the intervening years. Removal of Geotubes® – anticipated methodology: the Geotubes® would be exposed and then cut open along their length possibly by divers. Contained sediment would be eroded over subsequent tidal cycles or if deemed necessary, based on predictive coastal modelling the sediment undertaken at the time of decommissioning, could be dredged and disposed of to a licensed dredging disposal site. The geofabric would then be removed where exposed using grabs. Potential difficulties could arise with retrieval of the material if any sediment is retained which may result in tearing. Any material left behind is likely to be washed ashore and this would need to be collected and disposed of over time. Sediment within seawalls – this would either be allowed to scour away naturally over tidal cycles or dredged and disposed of as for the Geotubes® sediment. However, due to the large volumes of material, the later is more likely to be required in certain areas affected by increased sediment deposition. Disposal of this dredged material would be to a licensed dredging disposal site. Disposal of waste material generated as a result of the demolition of the Project is likely to be significant and appropriate disposal routes would have to be identified nearer the time. Removal of the entire structure would significantly affect established intertidal and subtidal marine environments and its recreational and leisure use. Temporary impacts would also be experience from decommissioning noise, disruption to navigation, water quality and coastal processes. In terms of terrestrial habitats, the extension of sand dunes is likely to have occurred along the

	eastern wall. The removal of the eastern wall would mean that any sand in this area would be move westward across the Lagoon beach. It is likely that mitigation through removal and disposal of this sand would be necessary. Part of the western lagoon seawall would need to be retained to continue the function of the current eastern Port breakwater.
Option B: Retention of 1000m of western seawall and retention of 500m of eastern seawall	Removal methods as described above. Demolition works would result in less impact to inter-tidal areas although a similar impact to the subtidal areas would be experienced. There would be less material for disposal generated again reducing overall impacts in terms of noise, water quality, coastal processes and navigation. There would still be potential effects on leisure and recreational facilities although at a slightly reduced level. The western seawall will provide protection to the entrance of Swansea Port. In addition, the Western Landfall Building is housed on this section of the seawall. The sheltered beach and water environment to the east of the seawall will be available for continued use for recreation and leisure. Potential effects on terrestrial ecological habitats would also be less as the retention of part of the eastern lagoon seawall would maintain any sand dune system which has established here. Notwithstanding this removal of the remaining seawall may result in erosion of the beach and potentially dune system in this area and as such appropriate computer modelling tools available at the time would be used to assess the potential effects. If retained, this section of seawall may continue to be used by occupants of the Swansea University Bay Campus as a recreational facility.

3.9.0.5 As can be seen from Table 3.4, proposals to decommission the Project involving removal of the entire structure or parts of the structure are likely to result in significant effects, particularly in terms of recreational and leisure use of the facility, disposal of waste material and effects on established intertidal and subtidal marine habitats.

3.9.0.6 It is therefore considered that decommissioning options should be focused around retaining the socio-economic potential of the facility whilst minimising potential environmental effects. To this end, it is proposed that at the end of its operational life, the turbine and sluice gates and associated mechanical and electrical equipment within the concrete turbine housing structure will be removed. This will allow unhindered flow of water to occur into and out of the lagoon over the tidal cycle equalising water levels. Removal of the concrete turbine housing could be undertaken, but this would result in a loss of connectivity between the eastern and western seawalls reducing the benefit for recreational use. The cable connection between the Project and Baglan power station could be dug up and the cables removed and recycled. At the time of decommissioning, agreements would be sought as to the responsibility for maintenance of the structure for public use.

3.10 Project infrastructure

3.10.1 Introduction

3.10.1.1 Details of other infrastructure forming part of the Project and/or representing enhancements/mitigation are also presented in Chapter 4, Project Description. In order to develop some of these designs, assessments and feasibility studies have been undertaken in the fields of art, education, mariculture, and sporting and recreational opportunities, all centred on the Lagoon which is integral to the Project. Consideration of the potential options and opportunities are summarised below. These elements are important in fitting the Project into its environment, and in terms of off-setting the consequences of impounding an area of Swansea Bay.

3.10.2 Sports and recreation

3.10.2.1 TLSB carried out a feasibility assessment for potential sporting opportunities founded on the Lagoon, at both local and community level, and to national and international events. To gain a better understanding of this potential, the assessment first considered the need and demand for the various sporting opportunities around Swansea Bay.

3.10.2.2 A study was carried out looking at the “requirements for various sports” if located within the Lagoon. In addition to this, feedback was sought from local residents, liaising with local universities, colleges and schools, and working with existing local watersports clubs and the individual national federations of potential core sports.

3.10.2.3 Subsequent to this, an analysis was undertaken of core sports capable of using the Lagoon, taking into account the level that the sport could be undertaken at, local opportunities for events, and the facilities required to support that sport.

3.10.2.4 From this work, key sports were chosen as follows:

a) Sailing opportunities: The opportunities for sailing are considerable in the Lagoon, from grassroots participation through to high performance events. A study was made into the potential for the site to host Extreme Sailing events. These World Series events would be the largest and most high-profile sports events hosted on the Lagoon and would attract the world's best sailors. The required racing area is small (minimum of 800m by 200m) and the Project could offer excellent accommodation and views for spectators.

b) Open water swimming: This sport has increased significantly in popularity in recent years. Swim Wales is currently developing a bid to become the first "UK Indoor and Open Swimming Competition and Training facility". Events of this nature in the past have been subject to fluctuations in weather conditions, tides and wind force. It is thought that the Lagoon, with its seawalls providing shelter, would make the cancellation of events less likely. A number of emergency access points around the Lagoon walls would need to be incorporated, and disability accesses could also be created. Further information on water quality within the Lagoon is discussed in Chapter 7, Marine Water Quality.

c) Triathlon: Triathlon is one of the fastest-growing sports in the UK. In 2011, there were 140,000 triathlon race starts with an estimate of 70,000 people taking part nationally. The Lagoon's safe, sheltered waters could be excellent for all levels of this sport. During the study, it was evident that Wales is in need of further leading international venues and that the Project facility has the potential to be a suitable venue.

d) Rowing: The Lagoon could have the potential to host both international and national coastal rowing events encompassing all levels of participation. In addition, the site could become a leading UK training facility throughout the year. There is an opportunity to provide an excellent area for spectators to view such events in a unique and complementary setting.

3.10.2.5 The Swansea Bay area is also known to be popular for recreational fishing. For this reason, the opportunity to provide platforms and access on the seawall for recreational fishing was also considered important.

3.10.3 Mariculture opportunities

3.10.3.1 A key aim for the Project would be to provide input to the marine environment initially at a conservation level, but potentially in the future for individual or commercial interests. Central to this is facilitating the regeneration of the native oyster within the Bay. In addition to this, the Lagoon seawall will form a new, artificial, rocky reef which is predicted to be of ecological benefit (Chapter 8, Intertidal and subtidal benthic ecology). Careful consideration of materials and detailed design of the seawall would provide a range of habitats which would be colonised by local marine species.

3.10.3.2 In order to develop a better understanding of the concepts around this area, SEACAMs[3] undertook research into the feasibility of different opportunities available for mariculture. Table 3.5 shows the options considered and the current thoughts for inclusion within the Project.

[3] SEACAMS, a project part-funded by the European Regional Development Fund through the Welsh Government is a partnership between Bangor, Swansea and Aberystwyth Universities. SEACAMS aim is to integrate research and business opportunities in the marine sector in Wales.

Table 3.5 Assessment of potential mariculture opportunities

Option	Initial assessment	Potential
Oysters	The SEACAMS assessment concluded: a) There are currently rudimentary oyster beds present in Swansea Bay. b) Settlement of oyster larvae occurring naturally in the water column could be encouraged by providing suitable settlement material (cultch). c) Natural and artificial materials could be tested as possible cultch, in particular large amounts of molluscan shell material. d) The success of settlement will depend on availability of oyster larvae, and is suggested that further research to establish the current presence and abundance of larvae should be undertaken. e) Spatting ponds inside the Lagoon stocked with local oysters could be a realistic prospect for generating large numbers of larvae and spat for the wider bay. However, it would not be recommended to introduce stocks from non- local hatcheries as this would introduce a biosecurity risk.	The encouragement of the native oyster through spatting ponds would be great opportunity for Swansea Bay as a whole, and would complement other projects within the Bay. With this in mind, discussions have been undertaken with SEACAMS to take this opportunity forward. Research is currently ongoing with respect to existing oyster larvae levels and current condition of oyster within the Bay. Details of the requirements of spatting ponds and their location within the Lagoon have been integrated into the masterplan. A 10-year project plan is being developed.
Lobsters	Lobsters are present around the coast of Wales and they tend to prefer rocky habitats. Within the Swansea Bay area, good rocky habitat is present around the Mumbles headland. In addition, lobsters can be found associated with diffusers on long sea outfalls. There are a few outfalls in the Bay where lobsters may be present. The Project would provide further habitat for lobsters, through the new reef, but to increase this opportunity a hatchery could be considered.	The Centre for Sustainable Aquaculture Research (CSAR) has extensive experience and knowledge of running a hatchery and rearing a range of species including lobsters. A hatchery has been integrated into the Project such that this element of the Project can be taken further. In addition to this, opportunities to rear native marine fish species would also be considered in the future.
Porphyra (laverbread/Nori)	The collection of Porphyra around the UK is small and localised. However, on a wider scale, it is most well known as a South East Asian foodstuff, particularly Nori which is often used to combine fish and rice in a distinctive and attractive casing. Demand from Japan remains high, and to meet this requirement Porphyra farming and processing systems have replaced foraging of natural stocks.	This relatively modest demand for Porphyra in the UK appears to be easily supplied by the large and predominantly rocky Welsh coastline. In the wider context, the process of Porphyra farming is quite complex, with the needs met through the SE Asian market. From the commercial point of view, it is not proposed to take this opportunity further.
Kelp and biofuel	Kelp is a large seaweed which grows on a stype attached to a rocky/hard surface around the low water spring tidal mark. A variety of research has suggested that Kelp and other seaweeds could be grown and used for biofuel production in the future. This would	The development of alternative sources for fossil fuels is important, as a whole. However, in terms of the Project it is considered that development of the seawall for kelp harvesting would conflict with its biodiversity

Option	Initial assessment	Potential
	be a good source for biofuels as it grows quickly and does not compete with food production like land-based biofuel crops do. However, there have been difficulties in cultivation and harvesting kelp and it has not yet been cost effective. The suitability of the kelp's chemical composition also varies on a seasonal basis so the seaweed is best harvested in the summer. However, even with this seasonal consideration it could be a viable biofuel in the future, even more so with rising oil price. Other options could also be considered, for instance first extracting higher-value products from the seaweed such as food additives or protein for fish food before converting the remainder to bio-fuel.	enhancement objective. As such, this opportunity will not currently be taken forward for the Project.
Community allotments	The concept of a community farm or allotments is well known and well practised around the UK. To bring a new slant to this idea, marine community allotments are being considered.	At this stage of the Project, it has been decided to focus on a few key elements to enhance the ecology of the Bay as a whole, and which can be secured through existing links with SEACAMS/CSAR. As such, at present, community allotments will not be progressed, but they may be considered sometime in its future.

Education and Art

3.10.3.3 Cape Farewell was appointed as TLSB's education and cultural partner in early 2012. TLSB believes education is a very significant part of this Project and its legacy, and it is committed to lead wholehearted collaboration in reducing carbon, delivering low-carbon green electricity and serving our communities.

3.10.3.4 To facilitate this, TLSB created an education programme and resource for the schools and colleges of Swansea and Neath Port Talbot. The programme is aimed at helping young people develop their skills and knowledge, so that they can make their own choices for the future environment.

3.10.3.5 An education officer has been appointed to assist schools in the implementation of workshops, and an ongoing programme has been established to widen the scope of the resource and ensure all levels of education are encompassed.

3.10.3.6 TLSB also aims to strengthen the understanding and exploration of community values and the environment to increase stakeholder involvement in the development. To aid in this TLSB has established an art programme to create a forum for artists, scientists and communicators to be brought together to stimulate the production of art founded in scientific research.

3.10.3.7 Future creative educational features and topics being considered for inclusion within the visitors centre and around the Lagoon wall include:

a) **Looking at the Honeycomb Worm (*Sabellaria alveolata*):** This is a UK Biodiversity Action Plan species found in areas within Swansea Bay and along the Welsh coast. It is a frequently gregarious segmented worm that builds tubes from sand or shell fragments. It is found inter-tidally (although occasionally sub-tidally) in exposed areas, and the tubes created by this species are often densely aggregated forming a honeycomb pattern. These honeycomb structures could be located around the Lagoon wall as an art and education feature.

b) **An historic art trail depicting the story and future hopes for an oyster industry:** Swansea Bay was famed for native oyster species from the 1600s through to Victorian times. The oyster industry went into decline in the late 1870s due to over-fishing and then disease wiped out stocks in the early 1900s. The last Oyster skiff was retired in the 1930s. Ideas are being investigated to reinstate oysters in the Bay.

c) **Information on fish species:** rays/skates (elasmobranches) have a firm tradition in Wales, though it has declined in recent years. Further information on their biology and shape, as well as on other fish species caught in the Bay could be provided along the lagoon seawalls.

d) **Schools art:** areas could be allocated along the Lagoon wall for murals made from pottery tiles from different schools depicting what Swansea Bay means to them.

3.11 References

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