

BACKGROUND TO THE PROPOSALS

Community Energy Plus are working with Mojo Maritime Ltd to assess the feasibility of installing tidal power generation technologies in Carnsew and Copperhouse Pools, Hayle.

The sluicing gates and culverts in Carnsew Pool, and the flood gates in Copperhouse Pool, present an opportunity to adapt these features to store water for use in the generation of renewable energy.

The feasibility study will look at a retrofit and community-ownership approach, that will be in keeping with historic use and support future needs in the estuary, whilst also exploring the viability of tidal energy with consideration to the biodiversity supported by the significant RSPB bird habitats within the pools.

As well as developing options for Carnsew and Copperhouse Pools, the feasibility study will provide an opportunity to develop appropriate scale technologies and assess the financial viability to replicate similar scale projects in other coastal sites in Cornwall.

FUNDING HAS BEEN SECURED FOR THIS FEASIBILITY PROJECT FROM THE RURAL COMMUNITY ENERGY FUND (RCEF) WHICH IS DELIVERED BY WRAP AND JOINTLY FUNDED BY THE DEPARTMENT FOR ENVIRONMENT, FOOD AND RURAL AFFAIRS (DEFRA) AND THE DEPARTMENT FOR BUSINESS, ENERGY & INDUSTRIAL STRATEGY (DBEIS).

IT SUPPORTS RURAL COMMUNITIES IN ENGLAND TO DEVELOP RENEWABLE ENERGY PROJECTS WHICH PROVIDE ECONOMIC AND SOCIAL BENEFITS TO THE COMMUNITY - WWW.WRAP.ORG.UK/RENEWABLES



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TIDAL ENERGY GENERATION

Tides are driven by gravitational and oceanographic factors and tidal energy is a massively under-utilised resource.

There are two key advantages to tidal energy:

- It is completely predictable
- It has a high power density, in terms of extractable energy per unit area.

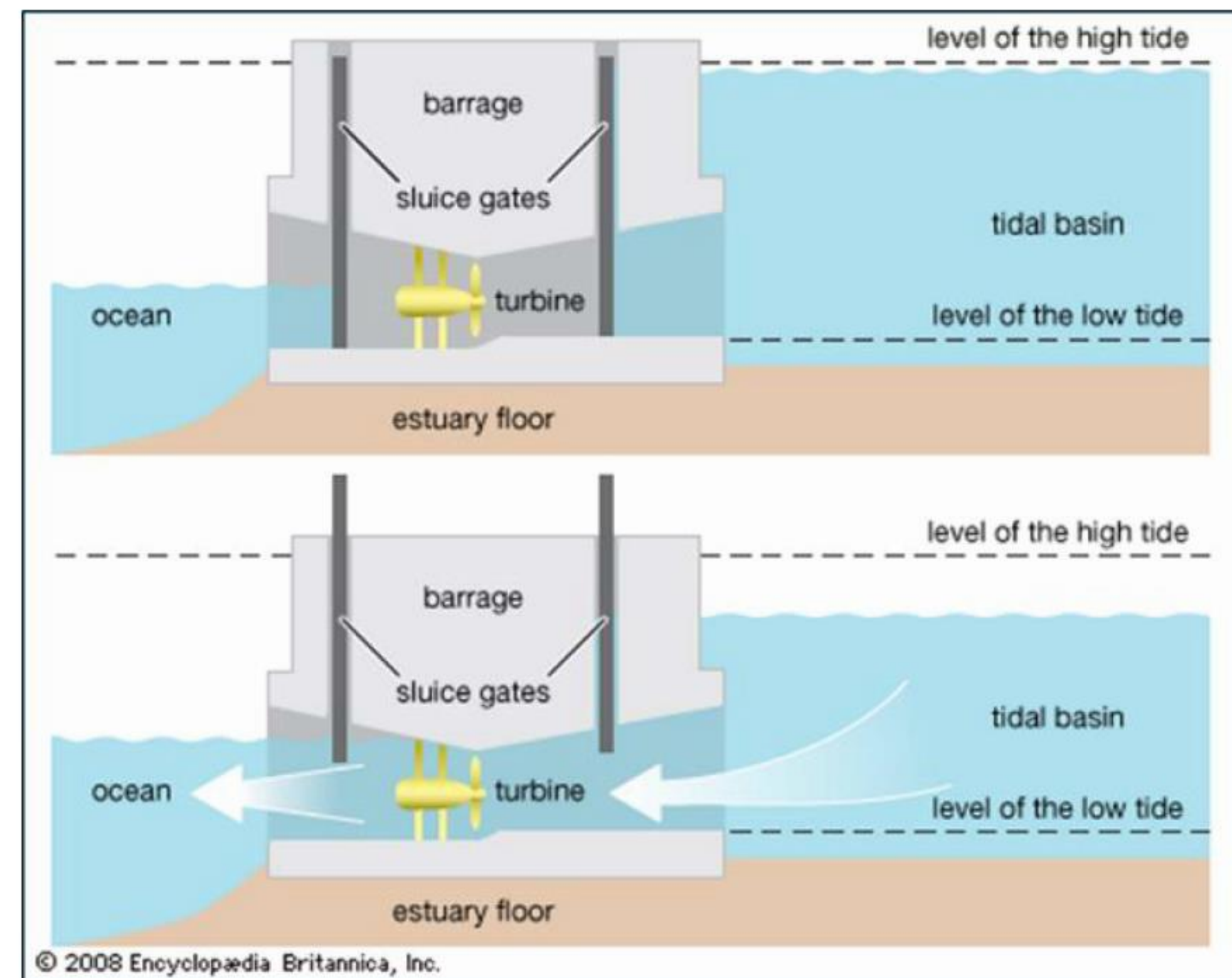
Two ways exist for extracting tidal energy.

Tidal stream technologies are similar to underwater turbines. The tidal stream is the flow of water as the tide ebbs and flows, which results in a tidal current. The tidal stream technology extracts energy from the kinetic movement of water.

Tidal range uses the vertical difference in height between the high tide and following low tide. In order to maximise the potential vertical difference and extract most energy, water may be captured at high tide and then released through turbines once the tide has receded.

The power available from tidal range technologies is determined by the area of water enclosed and the tidal range, which is the difference in height between low and high tide.

Diagram illustrating storage of water at high tide and extraction of energy through water release



HAYLE

Historically to the present day, Hayle port is hazardous with constantly shifting channels which vary in depth and size as a result of siltation. With the initial development of the commercial port, maintaining the waterways for safe navigation became essential.

In 1769 the Cornish Copper Company constructed flood gates at both ends of Copperhouse pool, which were filled with water at high tide, this was then impounded and released at low water, causing a tidal surge sufficient to scour out the channels into the sea. On the western side of the Estuary, Harvery & Co. began construction of Carnsew Pool in 1833, complete with sluice gates to clear the channel for large ships to travel up to the foundry and quays.

Sluicing ceased in the 1950s, but with increasing siltation in the channel, it is becoming increasingly unnavigable. Options are now being considered to reinstate sluicing within the channel to support the development of Hayle Harbour once more.



Why is tidal generation a good opportunity for Hayle?

- The area and location of the Carnsew and Copperhouse pools are relatively sheltered.
- The project is low risk from a civil engineering perspective.
- The enclosed water masses are large enough for reasonable power generation potential.
- There is existing infrastructure that may support a tidal-range installation.
- An established grid connection is in close proximity to the site.
- There are other potential political and local economic advantages.

TECHNOLOGY SELECTION

No technologies currently exist that have been optimised to extract energy from mini and micro-scale tidal range projects, options have therefore been developed from the potential adaptation of tidal stream and tidal range technologies.

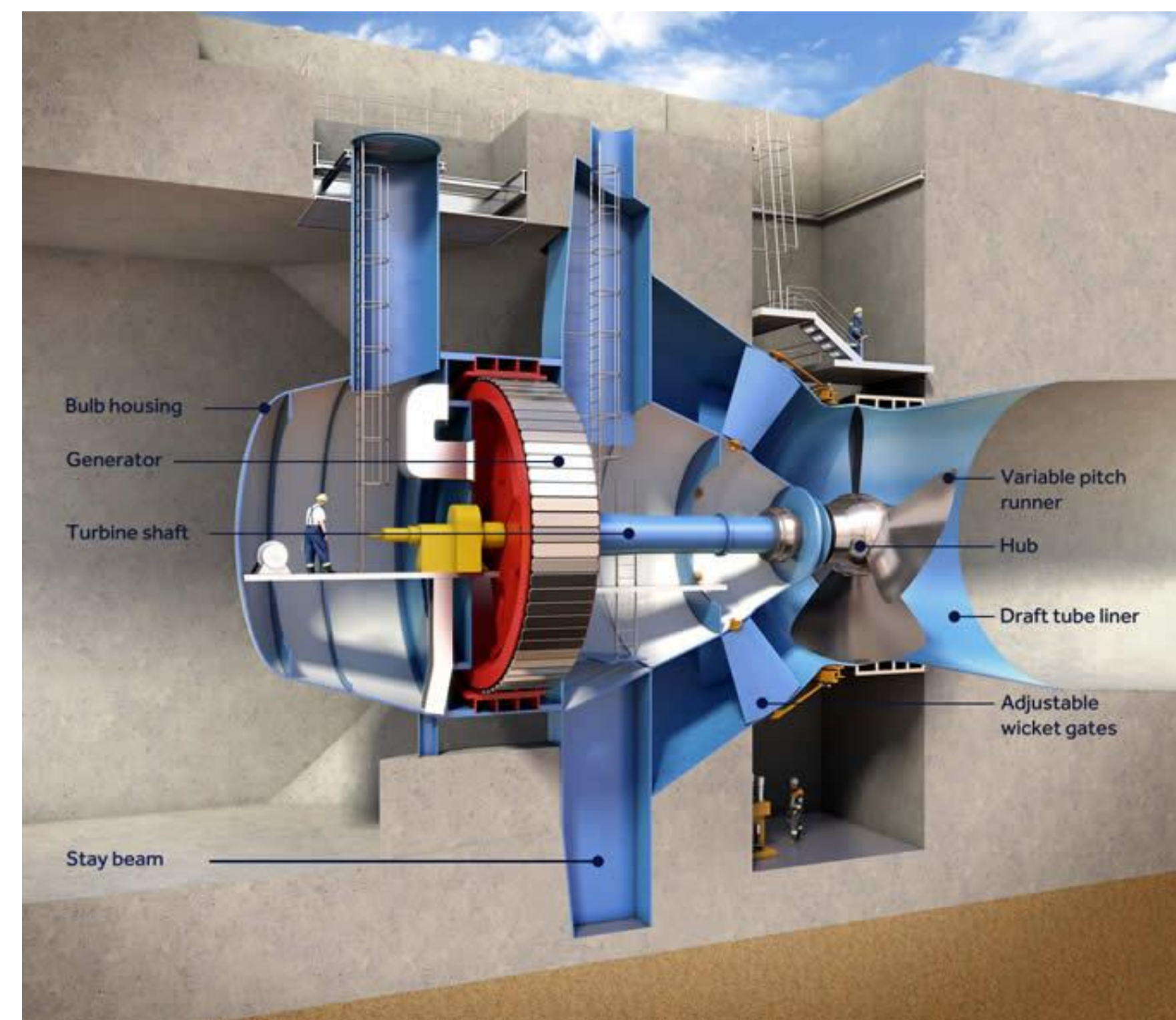
A minimum tidal stream speed is required to make tidal stream technologies economically viable. Although there is potential to meet such stream speeds, the smallest scale of existing technology would not be useable in the water depths in both Carnsew and Copperhouse pools.

Tidal range technologies have been successfully developed, with most modern power projects using Kaplan Bulb turbines. This turbine has a six mode operating capability which enables the turbine to:

- Generate power on flood and ebb tides; and
- Pump and sluice water in both directions.

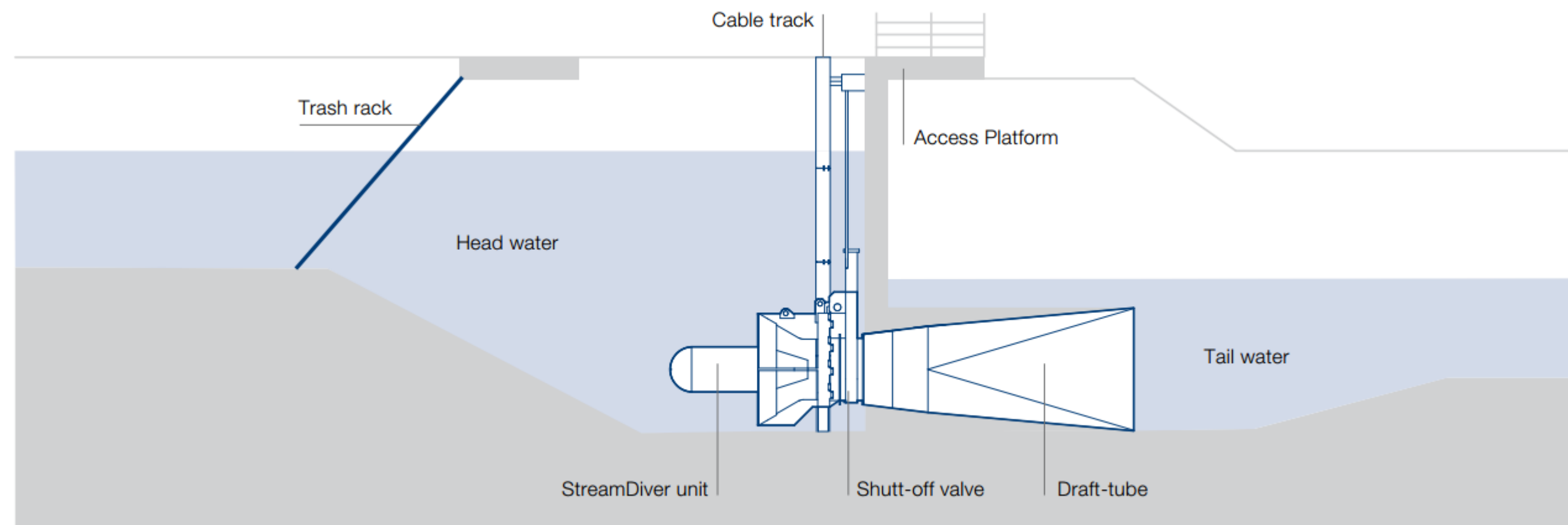
These mode functions allow the control systems to maximise energy capture, for example pumping water into the pools to increase head at high tide and therefore potential power available. A diagram of the Kaplan Bulb turbine proposed for Swansea Bay tidal scheme can be seen to the right.

Although there are no very low head river turbines that could be used for this scale of tidal range scheme, there are river turbines similar in design to the Kaplan Bulb turbine and of the right scale. The Voith StreamDiver has been used as a proxy, with appropriate dimensions, weights, installation and O&M methods to complete an engineering feasibility analysis.



ENGINEERING FEASIBILITY – VOITH STREAMDIVER

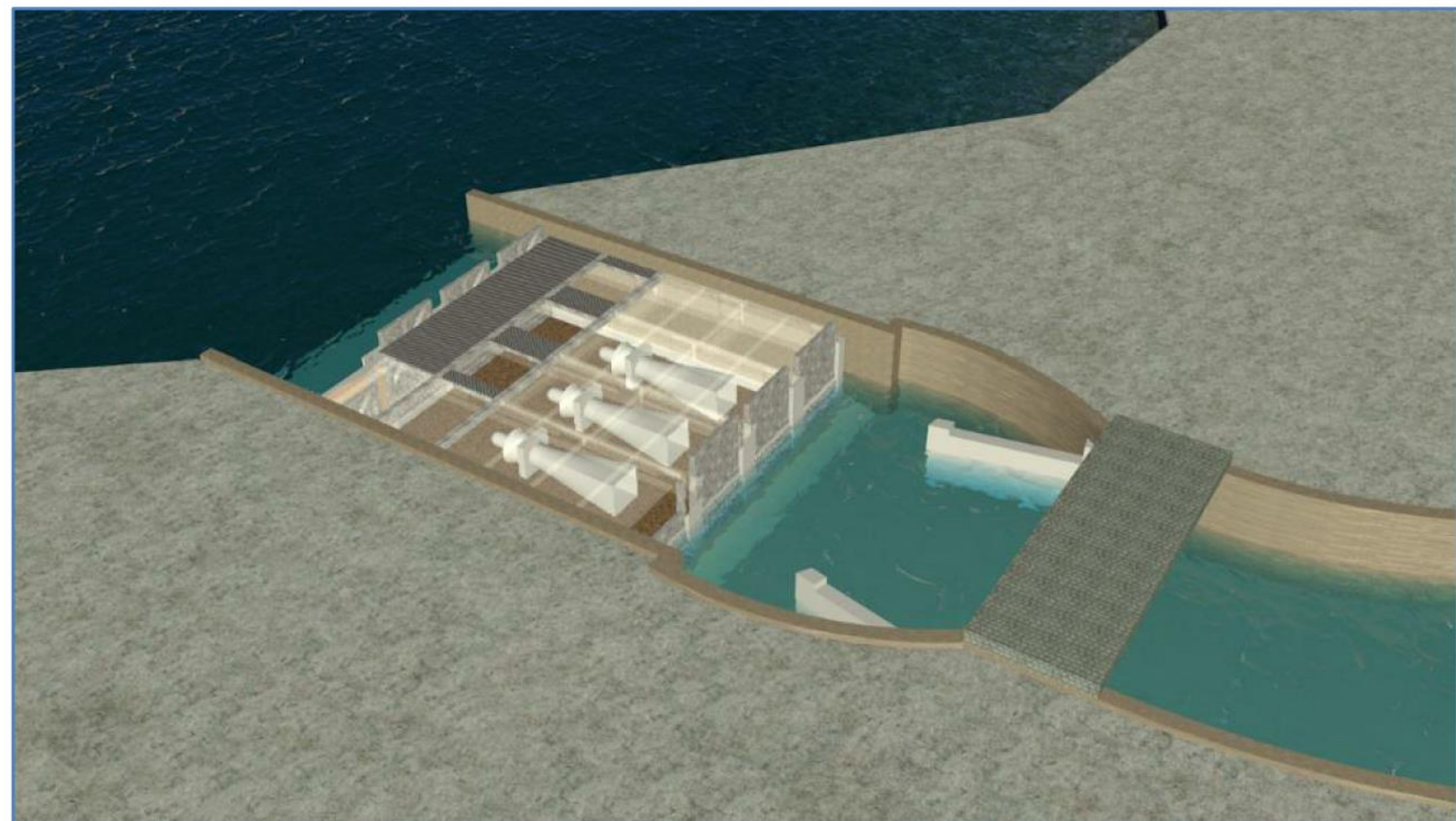
The power unit is installed in the water, within a bulb turbine housing. The bulb is filled with water to provide lubrication and avoid water contamination. This approach has been used successfully to adapt other Voith turbines to be used within sea water. A schematic can be seen in the diagram on the right.



For the project, the turbines have been designed for modular installation and can be easily installed or removed using a mobile crane. The modular approach has been used for feasibility to ensure broader utility of the findings for other mini or micro-scale projects, depending on site requirements.

Sluicing and potential small craft locking has been facilitated through the incorporation of a penstock unit. In the case of Hayle, should an adaptation of the Kaplan Bulb turbine be used, the two way flow function could allow sluicing through the turbines without an additional penstock needed.

Installation strategies would be unique depending on the site, however an indicative time scale of 7-10 days would be allowed for the installation of three turbine units and 1 penstock. The installation would include site preparation, installation, flooding up, grid connection and landscaping.



SITE OPTIONS

All three sites have been identified as feasible in civil engineering terms. Of the sites, Carnsew Sluice Gates would be the simplest due to the relative ease of installation in the new lock gate approach.

Copperhouse Flood Gates represent the next best opportunity, with the Carnsew Culvert Gates being the most complex due to the need to coffer-dam more water resulting in greater site preparation.

Although Copperhouse has a higher surface area when full, the pool volume decreases very rapidly to a small channel as the sea level falls. There is very little change in depth across the area of Carnsew pool and as such, Carnsew offers a better total energy prospect than Copperhouse.

Annual potential energy from:

- Carnsew – 1,911 MWH
- Copperhouse – 1,497 MWH



A combination of energy generation and sluicing has been considered to maximise energy capture from the flood and ebb tide phases.

CARNSEW POOL: CULVERTS AND SLUICE GATES

The culverts in Carnsew Pool offer the most complex site for retrofitting tidal turbines. With significant water turbulence in the culverts and mussel growth, there is evidence of wear and tear. Unlike other sites, the culverts would require substantial civil engineering preparation once coffer-dams are in place.



The sluice gates offer the simplest location. The gates and surrounding civil engineering were installed as part of restoration of the sluicing capacity in 2014 and are therefore in good condition.



CARNSEW POOL: TECHNICAL AND ECONOMIC FEASIBILITY

Economic feasibility has been determined using a scaling factor to calculate the cost of the turbines. ‘Drying’ has also been considered where turbines will not be inundated at all points in the tidal cycle. This will reduce efficiencies of the turbines, with estimations indicating a greater effect on the energy potential from the flood tide. Levelised Costs of Energy (LCOEs) can be considered as an indicator of the competitiveness of price for energy generated.

Of the turbine power ratings considered, installing one 30kW turbine offered the cheapest LCOE, at £84 MWH⁻¹. This is extremely competitive for marine renewable energy.

Maintaining a higher head during the ebb-tide maximises the energy yield for longest generation window, but reduces Carnsew's interior tidal range. However, due to the low discharge rate of the small 30kW turbine and approximated inefficiencies giving preference to power generation on the ebb tide, there is a loss of nearly 80% of intertidal areas.

To mitigate this loss, four 30kW turbines are proposed, which would largely eliminate the loss of intertidal area. The best proposed approach for sluicing and energy capture looked at the possibility of combining energy generation from turbines placed at Carnsew Culverts, with sluicing to occur through Carnsew Sluice Gates. This would result in an increased LCOE, but also an overall increase in energy capture to an estimated 474 MWH/year, enough to power 146 homes.

Table to show LCOE for 4 x 30kW turbines

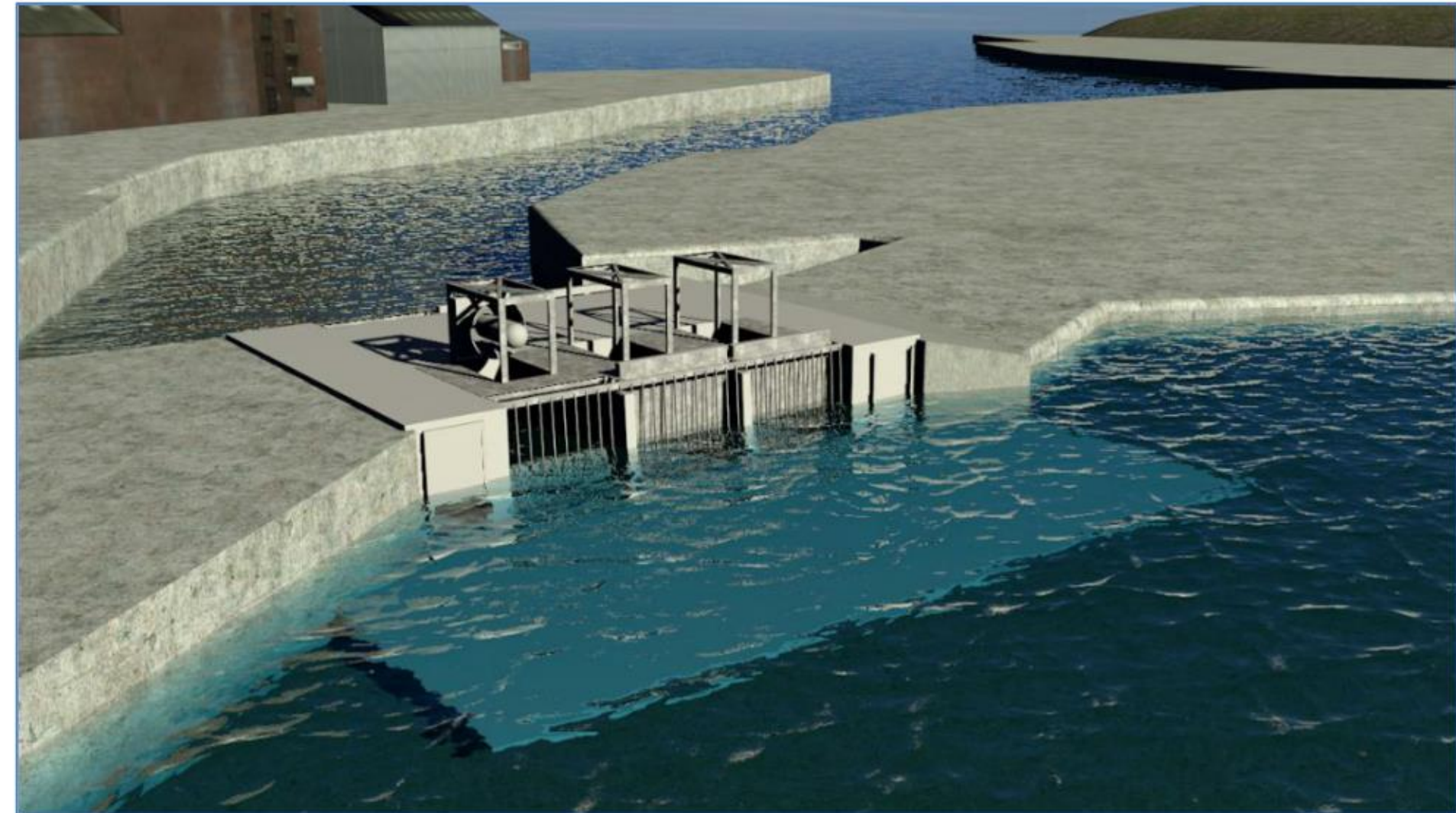
Turbine	OPEX Assumed	Rated Power (kW)	LCOE (£/MWh)	Turbine Nos	Sluice Width (m)	Energy (MWh)	CAPEX (£000's)	Intertidal Area Retained (%)	Pessimistic LCOE (£/MWh)
3	100%	30	£ 98.16	4	9.5	474	448	99.76%	£ 119.98
3	75%	30	£ 85.89	4	9.5	474	392	99.76%	£ 104.98
3	50%	30	£ 73.62	4	9.5	474	336	99.76%	£ 89.98

With a pessimistic outlook, an LCOE of £119.98 is estimated, still significantly lower than large scale tidal range schemes. But with an assumption that civil engineering costs would likely fall as a percentage of the number of turbines, LCOEs in the range of £86 to£74 MWH⁻¹ could be achieved.

* Based on OFGEM annual consumption value of 3.3MWH per UK domestic home:
<https://www.ofgem.gov.uk/ofgem-publications/64026/domestic-energy-consump-fig-fs-pdf>

COPPERHOUSE FLOOD GATES: TECHNICAL AND ECONOMIC FEASIBILITY

The flood gates are of intermediate complexity from a civil engineering standpoint, with a requirement to coffer-dam a greater wave area to undertake preparatory work. The current gates are of modern design and are used for flood mitigation, but do not have the bearing strength to be operated in periods other than slack water.



A single 30kW turbine offers the best LCOE for energy generation in Copperhouse Pool, with the cheapest LCOE of £82 MWH⁻¹. This does not take into account the requirement to close the gates approximately 5-10 days per year on occasions for flood protection. As such, it is necessary to take into account loss of yield for these days.

Looking at projected power output from the 30kW scenario, the turbine would reach the maximum output for nearly every tide and this would suggest that the theoretical 30kW turbine would be under-rated.

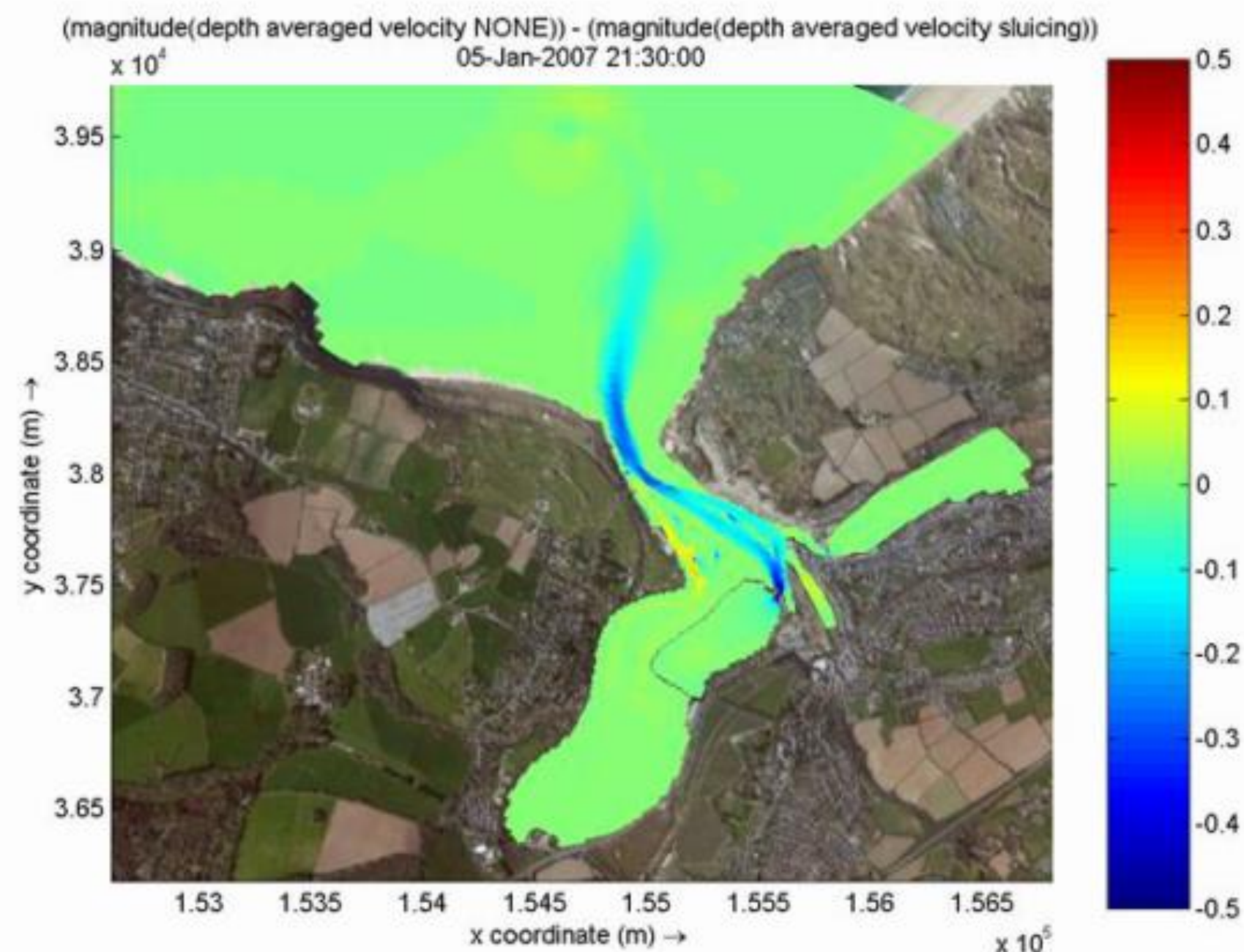
To optimise energy generation, water levels would need to be maintained as high as possible for best ebb-tide generation, however much of the intertidal area would be retained and thus there would may be less overall environmental impact than modelled for the same scenario in Carnsew pool.

IMPACTS: COASTAL MODELLING

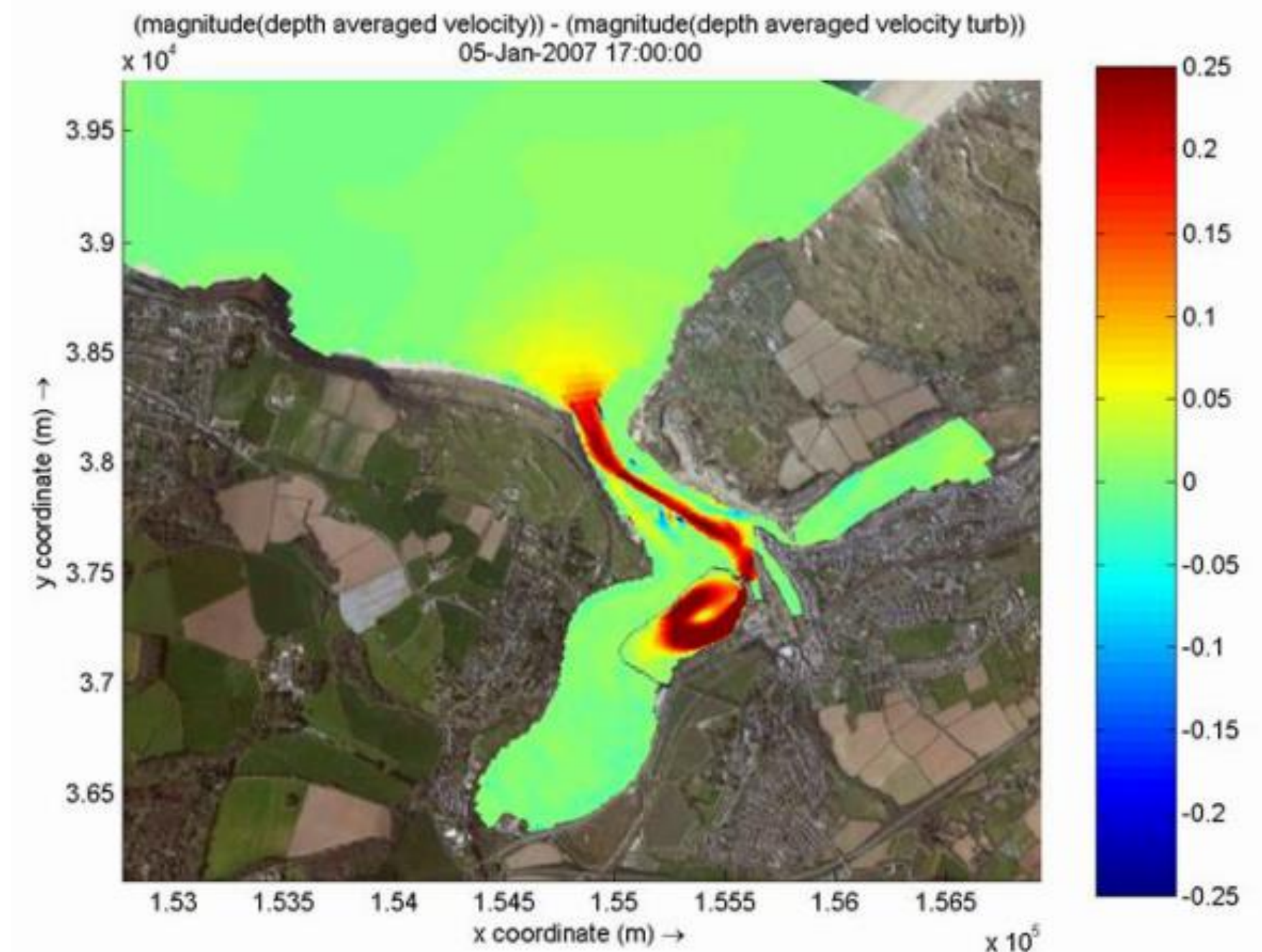
Preliminary coastal modelling has been used to provide a basis for impact analysis, for example how the construction of new barriers might effect sediment movement. Overall the installation of a Carnsew turbine would slightly reduce flow speeds in and out, with a greater reductions on the flood-tide.

The current sediment movement around the beach and estuary shows a dominance of the flood tide, which transports material into the mouth of the estuary and channel. This material is deposited and as a result siltation occurs. Should tidal range generation take place, this may well reduce the flood-tide flow speeds, thus helping to maintain the navigable channel and reduce siltation. Modelling illustrates a reduction in flood-tide speeds of around 0.2ms^{-1} to 0.25ms^{-1} .

Carnsew Sluicing Scenario



Carnsew Turbine Scenario



Tidal range generation may also compensate for a loss of ebb-tide sluicing operations, where the increase in ebb-tide current speeds from sluicing would be less than the impact of tidal power range generation on dominant flood-tide flow speeds. Sluicing shows an increase in ebb-tide current speeds between 0.10ms^{-1} to 0.2ms^{-1}

IMPACTS: ENVIRONMENTAL

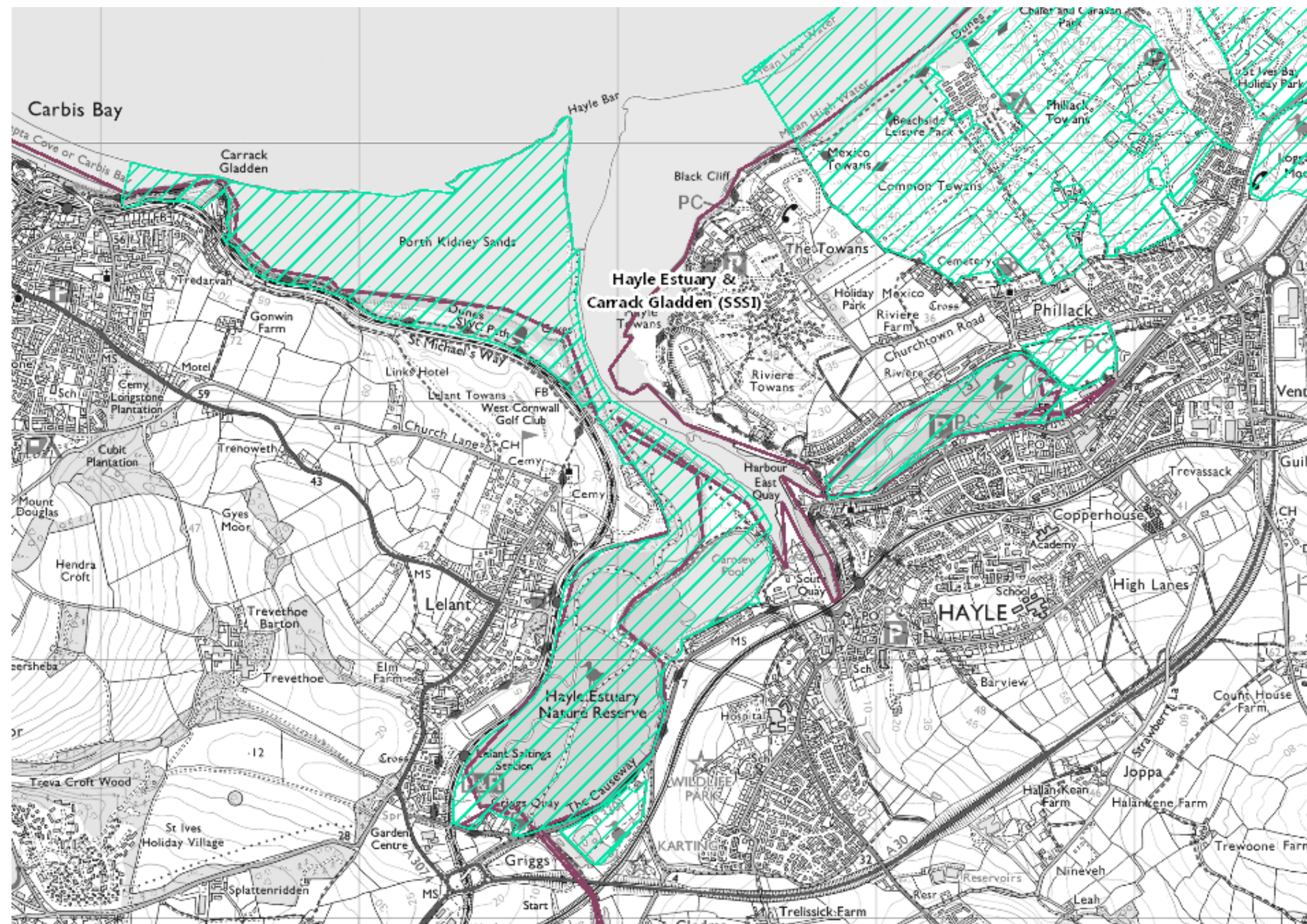
Kaplan turbines are slow turning, which in combination with envisaged penstocks, would allow for safe migration of estuarine fish and molluscs. Some disruption would occur during the construction phase in coffer-dammed areas.

Loss of intertidal area has the largest potential impact. Considered as part of the technical feasibility and scheme design, options have been presented that limit the loss of the intertidal zone, however more detailed analysis would be undertaken to understand and model impacts, for example over a lunar month.

Map of SSSI Designation

Further areas for investigation may include:

- The impact of suspension of sediment and altered sediment movement on pollution and the concentration of heavy metals in the water.
- How the retention of water in the pools on the ebb-tide may effect the temperature of the water and any impact this may have on flora and fauna.
- To what extent there will be an impact on the intertidal zone, with consideration to feeding times and patterns of wading birds.



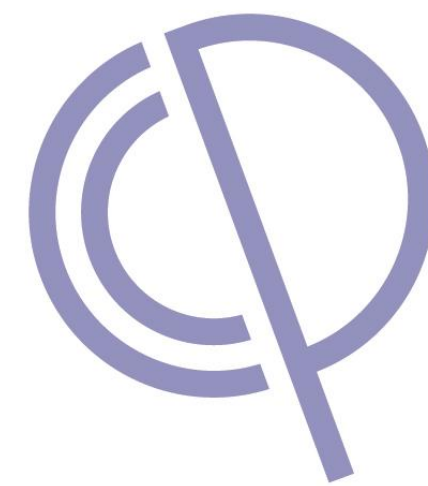
COMMUNITY BENEFITS & COMMUNITY OWNERSHIP

The project could bring a number of other benefits to the local economy:

- Expenditure in the local economy for the phases of development, installation, operation and maintenance; with the potential for job creation.
- To provide a second marine renewable energy source alongside WaveHub and thus leverage the Hayle Marine Energy Park.
- An opportunity to create a diverse, sustainable and secure energy supply, with potential for profits to be returned to the local economy.

There are a number of opportunities to raise finance for the project, for example: community share issues, where local people have the chance to invest money, raise capital for the project and get a return on their investment.

Share offers will increase the opportunities for the community to have a viable, sustainable, long term future. They can provide capital for the projects, as well as allowing the community group installing the project to access to capital at lower interest rates than through commercial borrowing.



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CONCLUSIONS AND RECOMMENDATIONS

Overall, assuming the right technologies can be developed at the right prices, then the scheme(s) are technically and economically viable.

The project could offer the first redevelopment of a tide mill with the possibility of securing a significant technology and export opportunity.

Development of a modular installation process would be cost effective and portable to other small tidal range schemes.

There would be little, if any visual disruption or impact on the leisure characteristics of the pools. The scheme may also provide sufficient power for around 146 households. With a project lifespan that could extend well beyond an assumed 40 years, positive environmental benefits of renewable energy would be assessed against any potential environmental impact on flora and fauna.

Recommendations and next steps:

- **Hayle Project** should continue with an investment appraisal for the installation of a mini or micro-tidal range project.
- **WRAP Stage 2** can potentially provide a loan to support planning applications and develop a robust business case to attract further investment.
- **Master Thesis** will use the results of the study to inform a thesis drawing together the development and planning requirements for such tidal projects.
- **Technological R&D** to investigate opportunities for private and public sector investment to continue technical development, including; a sophisticated coastal modelling resource, micro and mini-tidal range turbine technologies and modular civil engineering installation methods. Of particular interest, InnovateUK and DFID have recently started investing in renewable energy technology development for use in developing countries.
- **South West Tide Mills Review** to establish the power opportunity and civil engineering context of other historic tide mill sites in Cornwall and Devon, and the regional energy opportunities therein.

HAVE YOUR SAY

This is your opportunity to shape projects for your local area, contribute ideas and provide feedback on the feasibility assessment so far.

**Please complete and return a
feedback form today, or go online
at:
www.cep.org.uk/consultations
by the 27th of September 2016**