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An Approach to Optmising the Harvesting of Tidal Energy

AN APPROACH TO OPTMISING THE HARVESTING OF TIDAL ENERGY

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This paper presents details of how different configurations of tidal turbine devices behave in a large, tidally active estuary. The deployment of fields of tidal turbines have to be carefully designed with respect to many issues: optimise energy take-off; reduce interactions between devices; device orientation; hydro-environmental impacts; hydrodynamic regimes and water level regimes.

The Shannon River and its estuary is one of the largest systems in the British Isles. The tidal range at the mouth of the estuary is over 5m during normal spring tides, inducing currents up to 2.5m/s in water depths of 35m. The estuary has been rightly identified as a potential location for tidal energy extraction; however, little detailed analysis has been carried out to determine accurate potential. A 2-dimensional hydrodynamic model has been amended to include the effects of energy take-off on momentum equations. This model is used to investigate the deployment of tidal turbine fields in the Shannon Estuary, Ireland. The research considers 3 different configurations, with different turbine densities in the estuary; the domain of the tidal farm is presented in Figure 1.

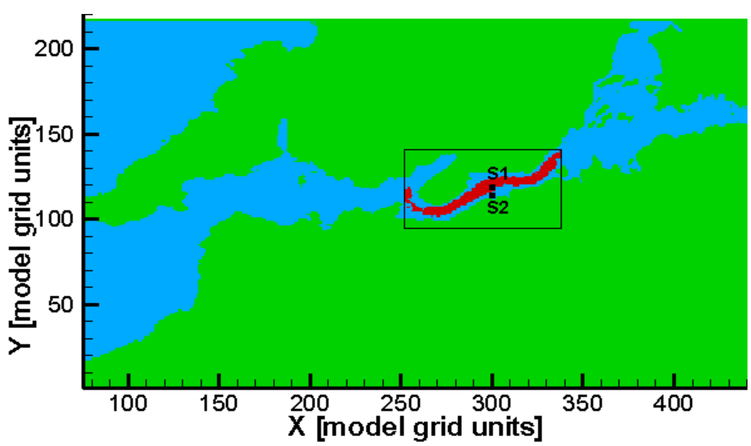

Figure 1 Shannon Estuary showing extent of tidal turbine field

This research presents details of changes in hydrodynamic regimes due to different densities. In particular, the research considers how tidal ellipses are altered due to the presence of

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devices. Results show that there can be significant changes to the semi-minor and semi-major axes, leading to changes in maximum speeds and directions of flow. The latter is highly significant, since tidal energy converters cannot rotate into the flow stream, it is important that their orientation is correctly determined a priori. Results also quantify likely changes to flow regimes within and outside the tidal farm; the effects outside the farm are shown to extend considerably. Depending on the density, significant changes are made to the tidal regime, mainly upstream of the farm. Likely hydro-environmental impacts are summaries through the determination of flushing/residence times of the estuary with and without the turbines. It is shown that significant changes may take place. This research provides a framework for determining the carrying capacity of turbines in a estuary and optimising energy harvesting in a wide context.

The following are the main conclusions drawn from this research:

- The density of turbines significantly affects the degree of reduction in water velocity within the turbine field at points such as S1. When the spacing is of the order of five rotor diameters the impact is negligible. At a spacing of two rotor diameters the velocities are modulated by about 15%. Rotor tip spacing of half a rotor diameter induces large changes in velocities of approximately 50%.
- Considering a point outside the turbine field, such as S2, velocities increase due to water tending to flow around rather than through the turbine field.
- At a point located about 60 rotor diameters to the seaward side of the turbine field, the velocity curves changes noticeable in an asymmetric manner. On the flood tide there is virtually no change in current magnitudes, however, on the ebb tide a significant reduction (order 25%) is computed. The shape of this curve is intuitively as expected and the model has helped quantify the expected changes.
- Regarding flushing characteristics, the change in the hydrodynamic regime has a consequential effect on flushing characteristics. It has been shown that the flushing of dye, through decay curves, is different in the presence of a turbine field. As a general parameter of change, the residence time of the region has increased by about 8%. This could have consequences for pollutant transport, sedimentation and other ecosystem processes.
- Changes to tidal ellipses can be considerable depending on the density of energy extractor devices as shown in Figure 2.

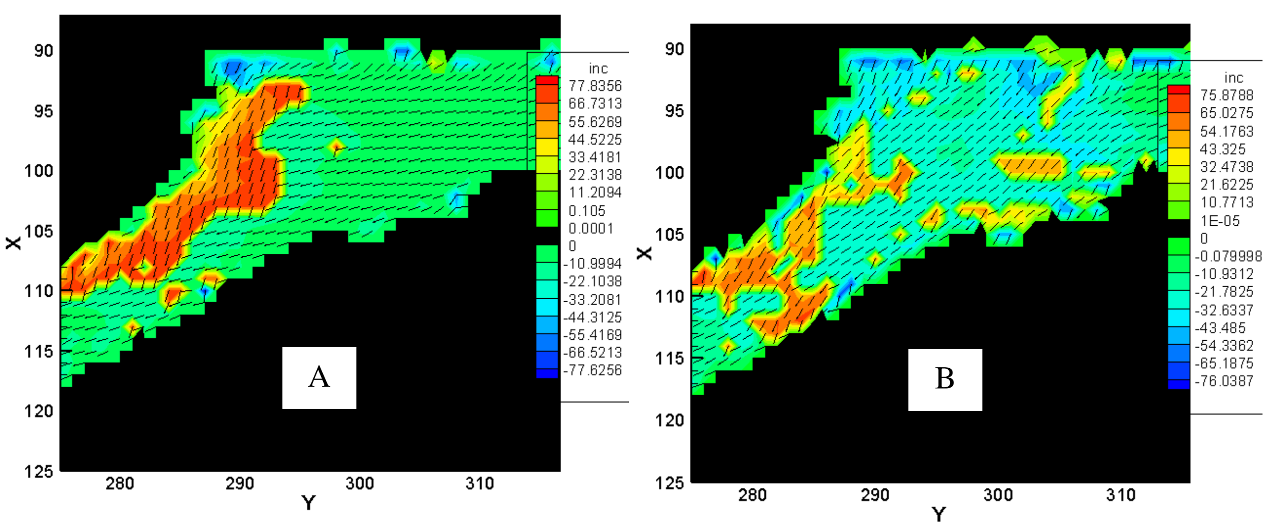

Figure 2 Tidal ellipses within tidal farm: (A) no turbines and (B) turbines at 2 rotor diameter spacing