An Operational Hydrodynamic Model of a Key Tidal Energy Site: Inner Sound of Stroma (Pentland Firth)

*M.C. Easton *, D.K. Woolf *, S. Pans ***

Work stream: 4. Arrays, Wakes, and Near Field Effects

Introduction

During 2010 seabed leases for up to 1 GW of installed tidal-stream energy have been awarded within Pentland Firth-Orkney waters (see Fig. 1). There is now a growing research emphasis on environmental responses to large scale development. A site-specific scoping study has previously identified the key ecological considerations for the Pentland Firth [1]. Presented here, as well as in [2], is an initial assessment of physical changes due to power extraction based on the application of an operational hydrodynamic model of the Inner Sound of Stroma, Pentland Firth.

Figure 1. The Pentland Firth separates mainland Scotland and the Orkney Isles

Natural Flow Environment

A model of the Inner Sound was constructed using the MIKE 21 (flexible mesh) hydrodynamic model by DHI to establish a 'baseline' description of the existing flow environment. The error in the predicted current speed between the model and ADCP site-survey data is shown in Fig. 2. The mean absolute percentage error along the transects is generally <15%.

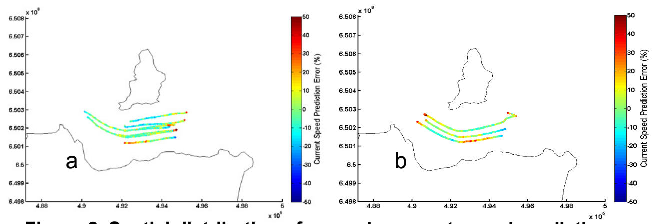

Figure 2. Spatial distribution of errors in current speed prediction for a) spring tides b) neap tides

Two emerging characteristics from both the ADCP surveys and the hydrodynamic model are (see Fig. 3):

- Translation in the position of the current 'core'; and
- Asymmetry between the direction of flood and ebb tidal-streams over large areas.

These features are prevalent over the entire spring-neap cycle and may have significant influence on operational efficiency, turbine placement and energy yield.

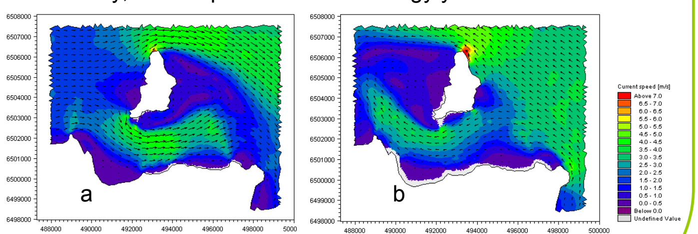

Figure 3. Current speed vector plots showing flow patterns within the Inner Sound for (a) flood tide and (b) ebb tide.

Tidal Energy Extraction

The calibrated flow model was modified with the simulation of a partial tidal-turbine fence across the centre of the Inner Sound. Analytical and numerical models have been used to investigate tidal energy extraction, a good review is included in [3]. The energy dissipation by the turbines was represented by an additional bed-resistance term in the governing equations. This is a suitable approach for assessing changes in the far-field environment [4]. Fig. 4 shows the changes in current speed for the case of a spring flood tide.

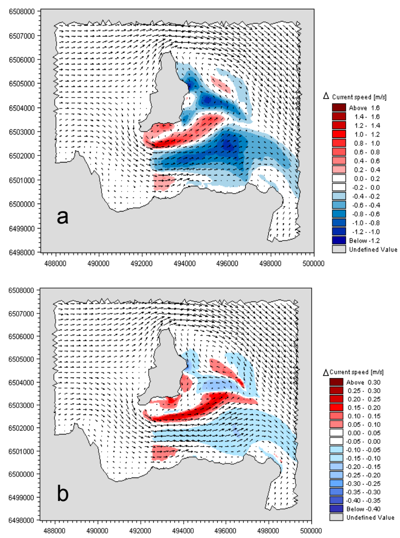

Figure 4. Changes in current speed compared with the natural flow environment for a simulated turbine fence dissipating (a) 2000 MW and (b) 400 MW.

Average natural dissipation over the extraction zone during a spring tide is around 100MW. Fig. 4a represents the extreme case of 2000 MW of tidal dissipation above the natural rate. There is a decrease of *circa.* 50% in current speed behind the turbines and an increase of 50% to the north of the extraction zone. This induces an eddy south of the island of Stroma.

In reality 400 MW of additional dissipation is more likely (Fig. 4b). Although the overall pattern of flow change here is very similar to the high dissipation case, changes in velocity are limited to only 5 – 15%.

References

[1] M.A. Shields, L.J. Dillon, D.K. Woolf, & A.T. Ford (2009): Strategic priorities for assessing ecological impacts of marine renewable energy devices in the Pentland Firth (Scotland, UK). Marine Policy 33, 635-642

[2] M.C. Easton, D.K. Woolf & S. Pans: An operational hydrodynamic model of a key tidal-energy site: Inner Sound of Stroma, Pentland Firth (Scotland, UK), 3rd international conference on Ocean Energy – *ICOE 2010*

[3] S. Draper, G.T. Houlsby, M.L.G. Oldfield, & A.G.L Borthwick (2009): Modelling tidal energy extraction in a depth-averaged coastal domain. Proc. EWTEC, Uppsala, Sweden

[4] B.L. Polagye & B.C Malte (2010). Far-field dynamics of tidal energy extraction in channel networks. Renewable Energy 36, Issue. 1.

Acknowledgment

Matthew Easton acknowledges PhD funding as part of the SuperGen Marine research consortium including, UHI Millenium Institute, Highlands and Islands Enterprise, Scottish Funding Council, and the European Regional Devevelopment Fund. Additonal thanks to the Renewable Energy and the Environment Group at the ERI, in particular Dr Lonneke Goddjin-Murphy for use of ADCP survey datasets.

* Environmental Research Institute
North Highland College
UHI Millennium Institute
Thurso
Caithness, KW14 7JD

** DHI Group, Agern Allé 5, Hørsholm, Denmark

EPSRC Engineering and Physical Sciences Research Council