Brims Tidal Array Ltd
Physical Processes Modelling

15th June 2015

1 INTRODUCTION

This Appendix describes the numerical modelling of hydrodynamics that has been undertaken to support the physical processes chapter of the Environmental Statement (ES) for the proposed Brims Tidal Array Ltd. (BTAL) project.

The hydrodynamic modelling has helped to both characterise the baseline physical processes environment and assess the potential impacts of the proposed Project on those baseline conditions.

The modelling has been undertaken using the MIKE21 software developed by the Danish Hydraulic Institute (DHI). MIKE21 is a two-dimensional hydrodynamic model that provides depth-averaged current velocity. Two-dimensional hydrodynamic modelling has been used widely across the marine renewable industry for the purposes of informing Environmental Impact Assessments (EIAs), including the use of MIKE21 on the nearby Meygen Tidal Energy Project Phase 1 ES. The two-dimensional hydrodynamic modelling approach has also been used within the following major projects within the tidal energy sector:

- SMARTtide, (Simulated Marine Array Resource Testing), commissioned and funded by the Energy Technologies Institute (ETI) to investigate the interactions between tidal energy systems around the UK, including how they combine to form an overall effect of tidal range and flow velocity; and

- Pentland Firth and Orkney Waters (PFOW) Marine Modelling Enabling Action (MMEA), commissioned and funded by The Crown Estate to deliver a live marine modelling facility on behalf of, and for the use by, PFOW project developers to support the ongoing work in wave and tidal energy development within the PFOW strategic area.

In addition to the Meygen Tidal Energy Project in the Pentland Firth, two-dimensional hydrodynamic modelling has also been used on numerous other tidal energy developments, including Copeland Islands (Northern Ireland), The Skerries (Wales), the Shannon Estuary (Republic of Ireland) and the Bristol Channel (England/Wales).

MIKE21 model set-up files (mesh, bathymetry and boundary conditions) covering the BTAL project and its surrounding areas were obtained by BTAL from The Crown Estate's PFOW MMEA project.

It should be noted that the purpose of the modelling was to determine the magnitude and extent of potential far-field impacts on hydrodynamics arising from the proposed BTAL project as part of the EIA. The modelling was not intended to replicate near-field processes, including turbulence, wake effects and eddies associated with individual devices, which will be considered as part of the resource assessments and design optimisation of the layout.

2 MODEL DESCRIPTION

The extent of the MIKE21 model available from the PFOW MMEA project is shown in Figure 1 together with the AfL boundary. Also shown are the model mesh and seabed bathymetry, together with the indicative layout for the array of turbines that was used in the modelling of potential Project impacts (note that the red turbine locations represent Phase 1 of the Project and black turbine locations represent Phase 2).

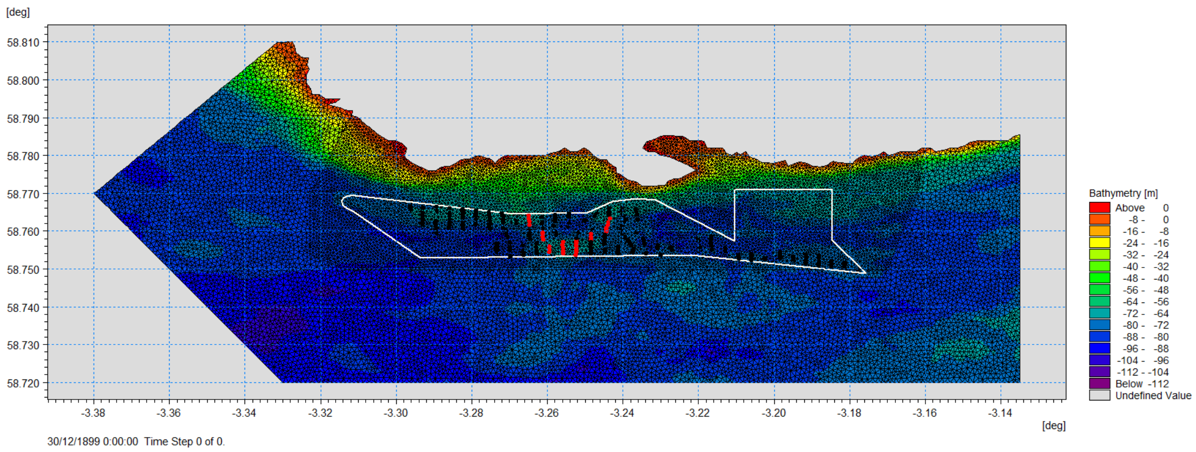


Figure 1 – MIKE21 model extent

3 BASELINE VERIFICATION

The model set-up files that were extracted for use from the PFOW MMEA project covered the period 1st June 2012 to 5th July 2012. This period was deliberately selected to cover the period of deployment of ADCPs during metocean surveys. Using the set-up files provided from the PFOW MMEA project, a baseline run was undertaken.

It was not possible to modify the extent or set-up of the PFOW MMEA project's model, but results from the baseline run were verified against both:

1. previous (separate) MIKE21 modelling outputs provided by SSE Renewables covering the BTAL Project study area (Figure 2); and

2. measured ADCP data from within the Area for Lease (AfL) (Figure 3).

Results prove the PFOW MMEA project's model set-up files to replicate previously modelled and measured conditions satisfactorily and therefore demonstrate it to be suitable for use within the ES.

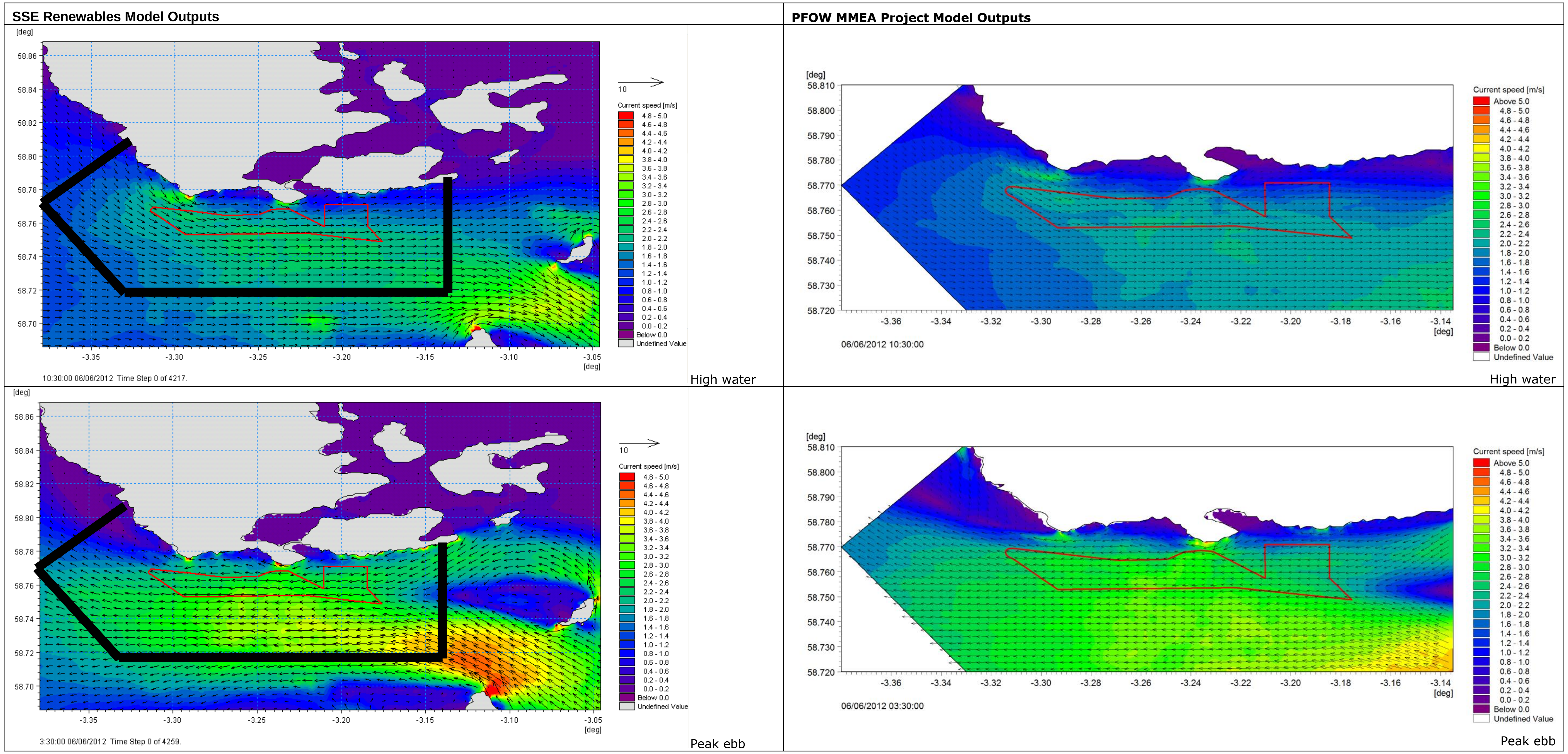


Figure 2 - Comparison of PFOW MMEA Project Model Outputs against previous SSE Renewables Modelling Outputs

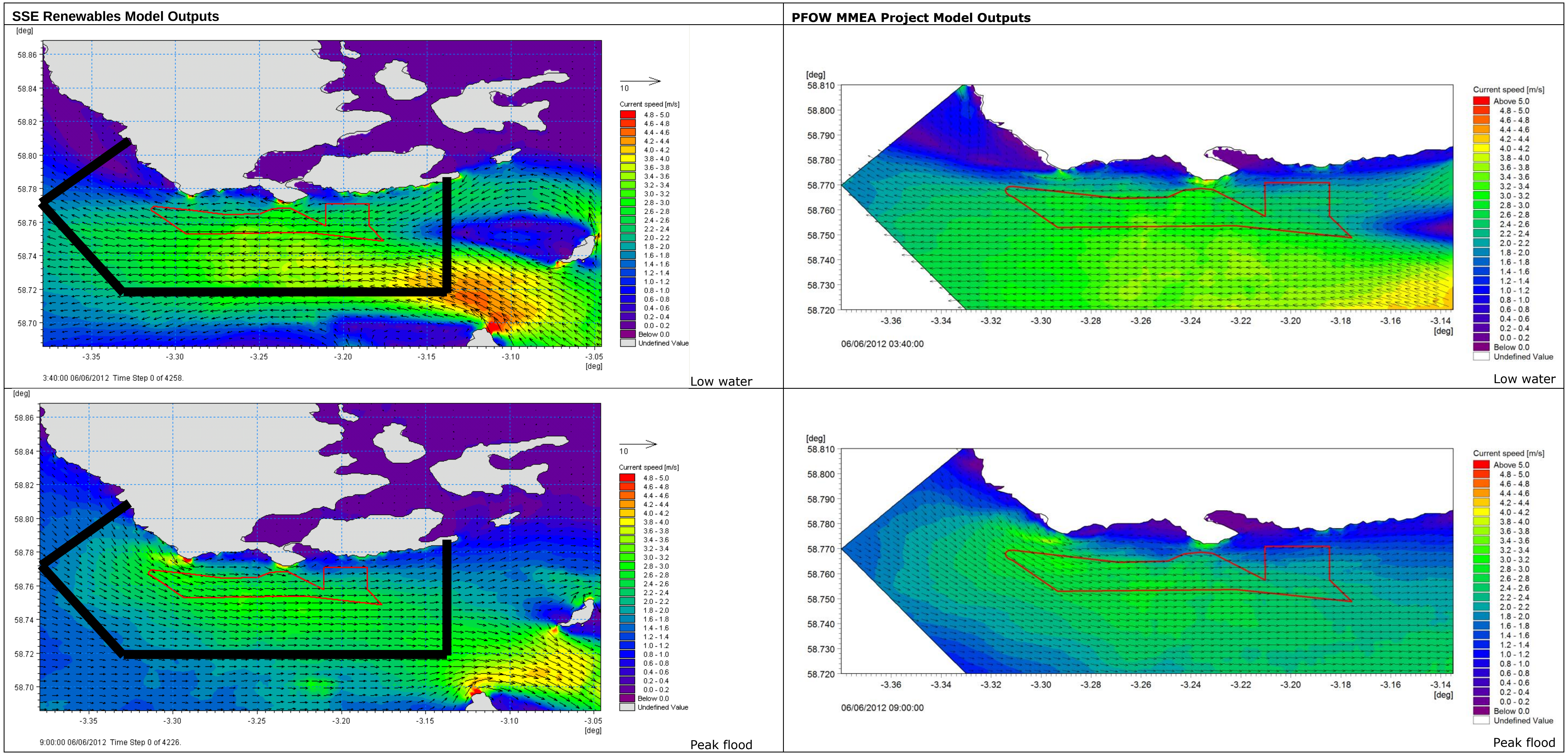


Figure 2 (cont.) - Comparison of PFOW MMEA Project Model Outputs Against Previous SSE Renewables Modelling Outputs

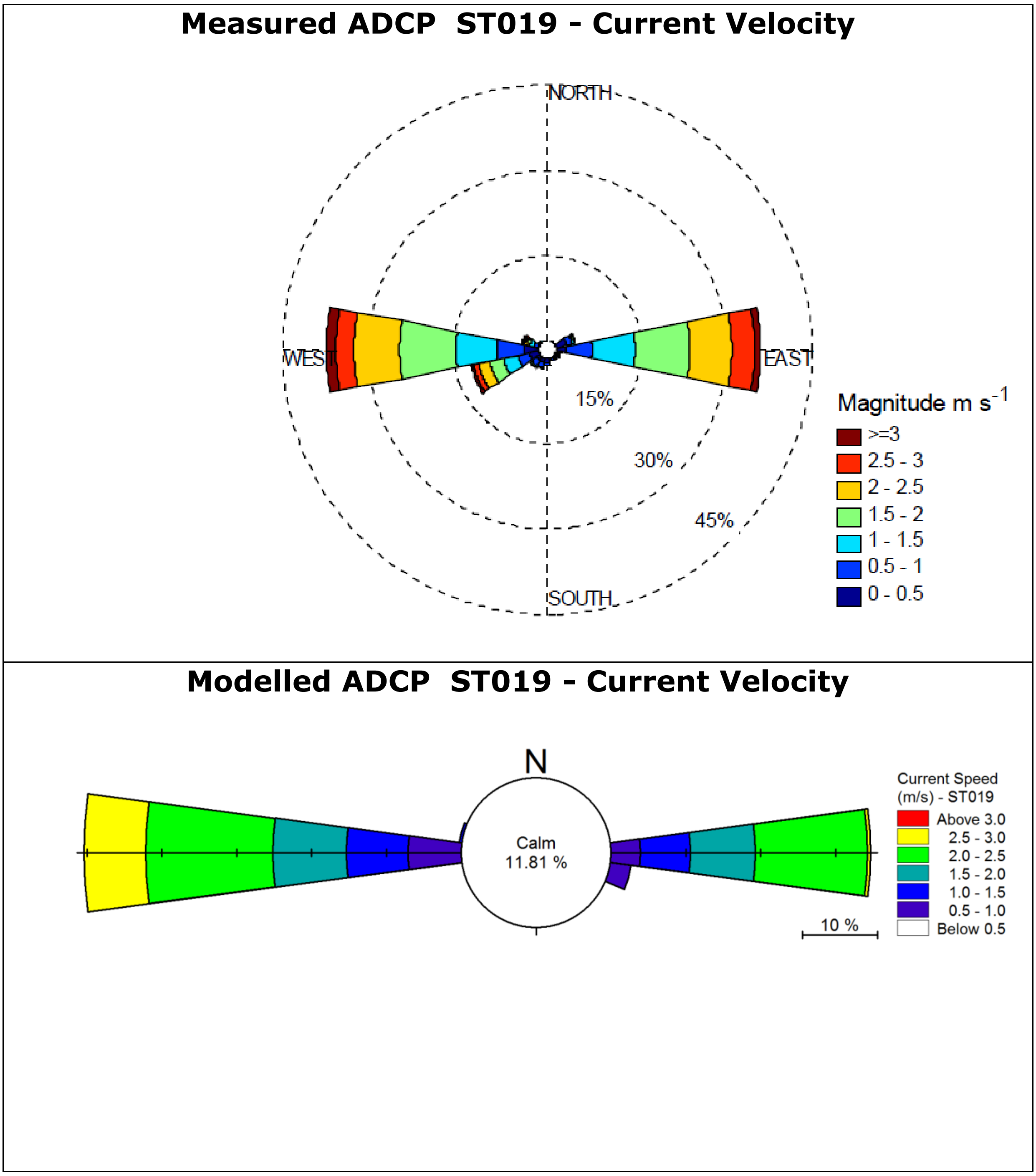


Figure 3a - Comparison of PFOW MMEA Project Model Outputs Against Previous Metocean Survey Outputs at Site ST019 (note the different colour banding on the legend bars)

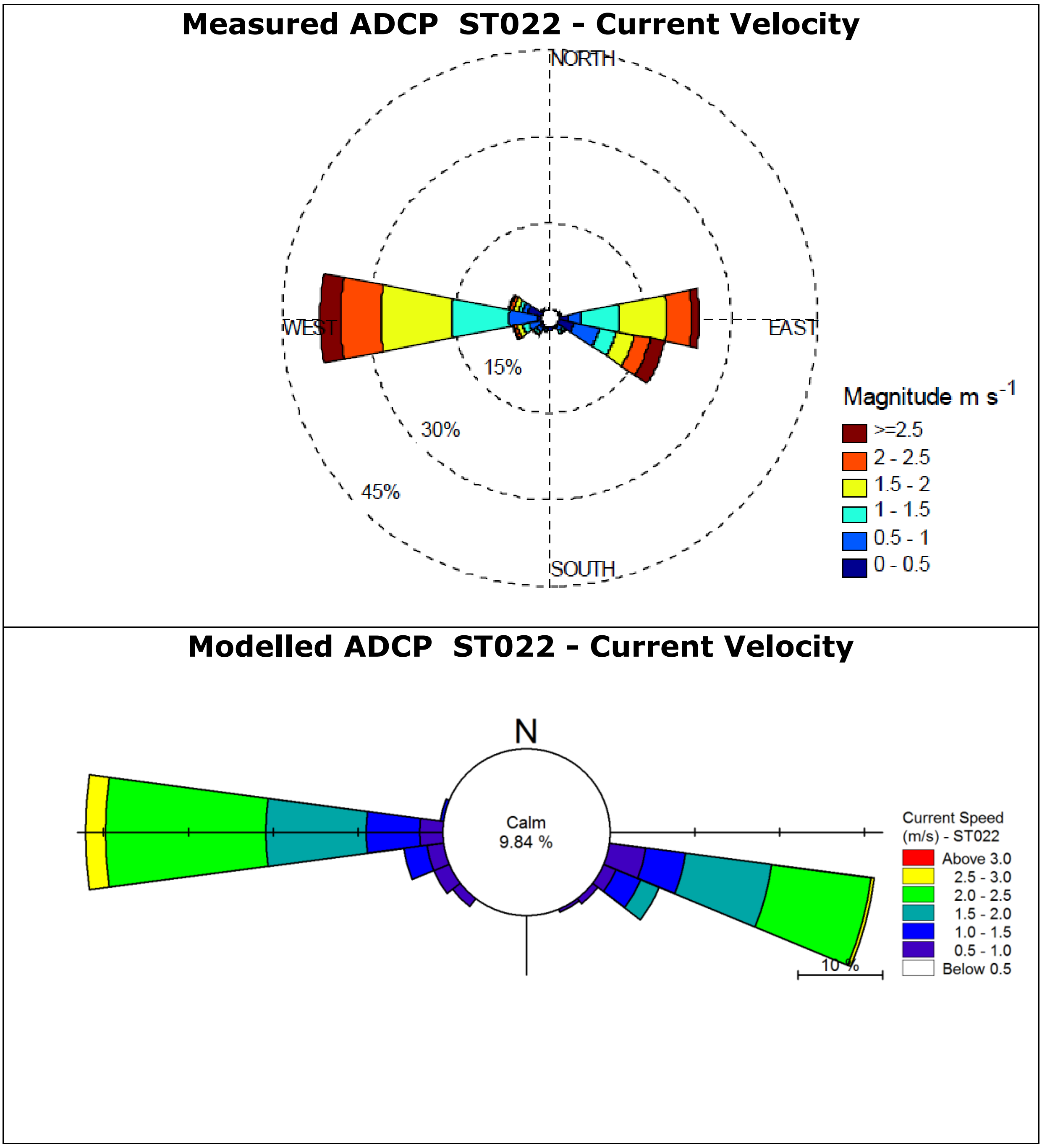
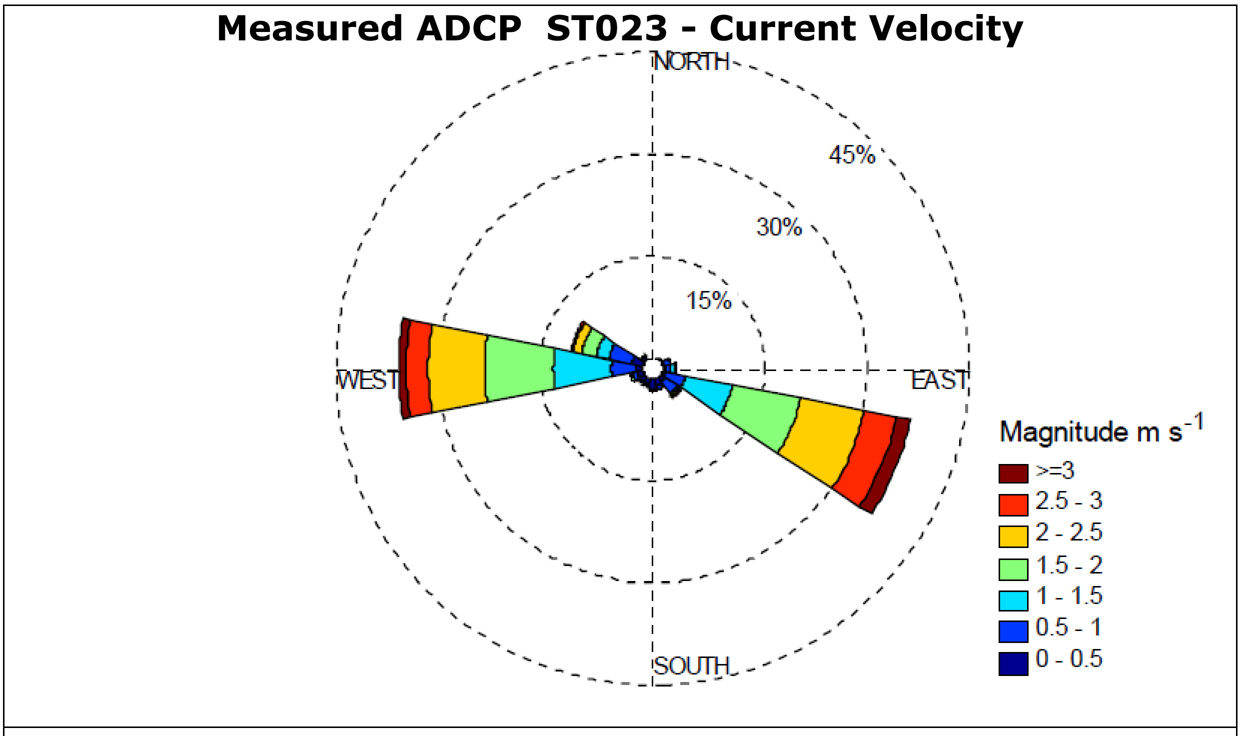


Figure 3b - Comparison of PFOW MMEA Project Model Outputs Against Previous Metocean Survey Outputs at Site ST022 (note the different colour banding on the legend bars)



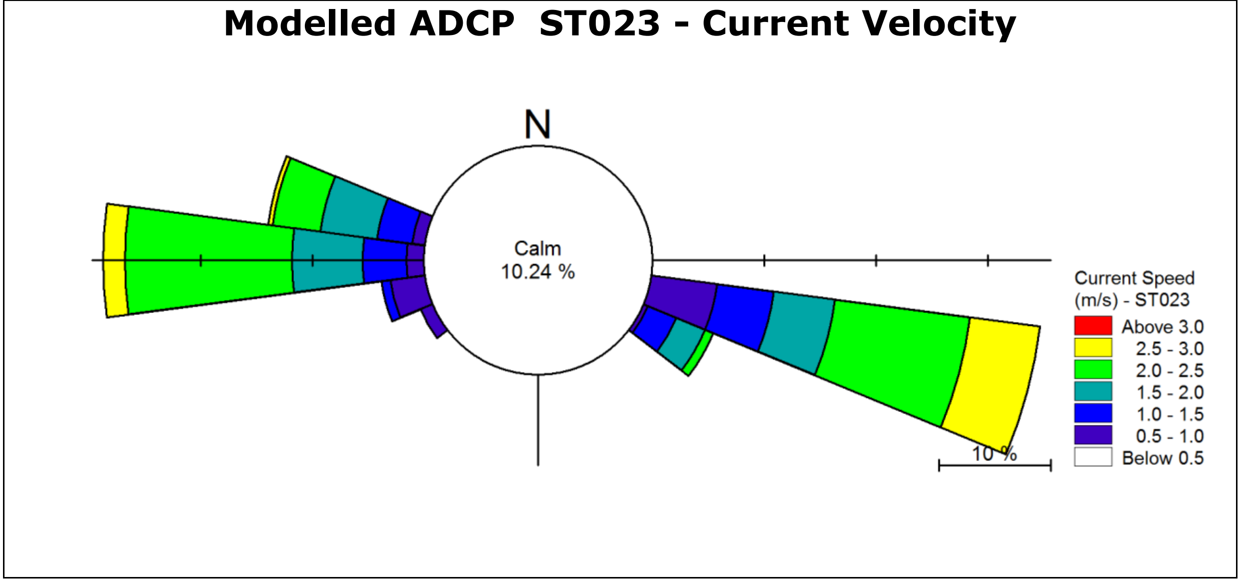


Figure 3c - Comparison of PFOW MMEA Project Model Outputs Against Previous Metocean Survey Outputs at Site ST023 (note the different colour banding on the legend bars)

4 IMPACT MODELLING

Background

In order to simulate the potential impacts on the baseline hydrodynamics arising from the proposed Project during its operational phase, it was necessary to represent the following elements in the MIKE21 model:

- Turbines
- Turbine support structures (TSS)
- Subsea cable connecting hubs
- Surface-piercing cable connecting hubs

The turbines were represented in the MIKE21 model using the 'turbine' function. This enables a sub-grid representation of the effect or the turbine on the hydrodynamics to be represented by means of a 'drag coefficient'. The drag force is determined as a function of the turbine diameter and the drag coefficient which depends on the rated capacity.

The TSS and both the subsea and surface piercing cable connecting hubs were represented in the MIKE21 model by means of the 'pier' function. This enables a physical blockage of a certain width and height to be inserted into the model. If there are variations in shape of a structure with depth in the water column, a series of layers of different widths and heights can be used if required.

Worst Case Assumptions

Impact modelling was undertaken for Phase 1 of the Project alone (up to 30 turbines), and Phases 1 and 2 combined (up to 200 turbines). An indicative layout was provided by BTAL for the location of turbines in each Phase of the Project. Whilst only indicative, this layout does adhere to the spacing rules established in the Project Description and therefore is reasonably representative.

The principal parameter which influences the potential impact on the baseline hydrodynamics from a turbine is the size of its rotor. The greatest effect arises with the greatest rotor diameter (and hence greatest swept area) within the design envelope; this being 23m. As a conservative approach, all 30 turbines in the Phase 1 array and all 200 turbines in the combined Phase 1 and 2 arrays were represented by 23m diameter turbines. In practice, this may not be the case and either a smaller number of these turbines or up to this number of smaller turbines may instead be selected for use. In such cases, the effects would be within the range covered by the impacts modelling of the worst case.

The principal parameter which influences the potential impact on the baseline hydrodynamics from a TSS is its cross-sectional area, which creates a physical blockage effect in the water column. It was therefore considered that of the different TSS being considered, gravity base structures (GBS) would have the greatest potential blockage effect. Although some alternative TSS being considered occupy a greater height in the water column, they present only a slender obstacle to flow. GBS on the other hand present a considerably greater obstacle, although only near the seabed.

Similarly to above, the principal parameter which influences the potential impact on the baseline hydrodynamics from a subsea connecting hub is its cross-sectional area, which creates a physical blockage effect in the water column.

The worst case arrangements considered in the impacts modelling are presented in Table X.1.

Table 1: Worst case assumptions for modelling

Project parameter relevant to the assessment	Maximum Project parameter for impact assessment
General arrangement: **Turbine numbers**	Phase 1: 30 turbines Phases 1 and 2: 200 turbines
General arrangement: **Turbine spacing**	Minimum cross-flow spacing: 80m Minimum down-flow spacing: 150m
General arrangement: **Turbine layout**	Turbines will be arranged in rows perpendicular to the direction of the prevailing tidal flow, with 2 – 15 turbines per row and between 10 and 40 rows in total. An indicative layout has been defined in the Project Description based upon these maximum Project parameters and this has been used as the basis for the impact assessment. It is acknowledged that the final arrangements will depend on the turbine type, rating and numbers, resource availability and seabed conditions.
Specific element: **Turbine**	Rotor diameter: 23 m Total swept area: 415 m^2
Specific element: **Turbine support structure (TSS)**	Type: GBS supporting a central supporting column Seabed contact: flat bottom Dimensions: 30 x 40 x 2.5 m
Specific element: **Cable connecting hubs**	Phase 1: 4 subsea hubs Phases 1 and 2: 16 subsea hubs Hub dimensions: 15 m length x 7 m diameter Support structure: subsea base

Outputs

The modelling produced outputs covering the period 1st June 2012 to 5th July 2012 for the following scenarios:

- Baseline conditions
- Phase 1 of the BTAL Project (up to 30 turbines and TSS, 4 subsea hubs)
- Phases 1 and 2 of the BTAL project (up to 200 turbines and TSS, 16 subsea hubs)

Results from the modelling are presented and interpreted within the ES chapter.