



Rampion Offshore Wind Farm



ES Section 6 – Physical Environment

Appendix 6.4

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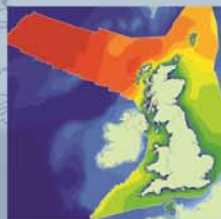
E.ON Climate and Renewables UK Ltd

Rampion Wind Farm: Coastal Processes Assessment

Report R.1945

November 2012

Creating sustainable solutions for the marine environment



E.ON Climate and Renewables UK Ltd

Rampion Wind Farm: Coastal Processes Assessment

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Summary

ABP Marine Environmental Research Ltd (ABPmer) has been appointed by E.ON Climate and Renewables UK Rampion Offshore Wind Limited (E.ON) to undertake the Coastal Processes component of the Environmental Impact Assessment (EIA) for the Rampion Wind Farm and export cable corridor. This proposed development is part of Round 3 and is sited at Zone 6 to the south of Brighton, offshore from the Sussex Coast.

This report follows the baseline assessment report (ABPmer, 2011) and provides an assessment of the potential impacts of the proposed Rampion development upon existing coastal processes. In order to assess the potential effects relative to the baseline (existing) coastal environment, a combination of qualitative assessment of site data, empirical evaluation and detailed numerical modelling has been used to establish the potential magnitude and significance of the predicted changes. This has been supported by the evidence base derived from existing offshore wind developments. These effects have been assessed for the realistic 'worst-case' characteristics of the proposed development as presented within the Project Description.

Considerations of the proposed impacts upon the tide and wave regimes have been made and the subsequent effects upon a series of receptors determined. These receptors include the offshore sediment transport pathways, offshore seabed morphology and the nearby coastline. It is shown that the majority of potential impacts can be considered to be of *minor* significance.

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ABPmer would like to extend their thanks to Professor Mike Collins for his continued support, providing a comprehensive understanding of the hydrodynamic, sedimentary and morphological regime within the study area.

Abbreviations

µm	micrometre(s)
ABPmer	ABP Marine Environmental Research Ltd
AWAC	Acoustic Wave And Current
BERR	Department for Business, Enterprise and Regulatory Reform
BGS	British Geological Survey
CD	Chart Datum
CEFAS	Centre for Environment, Fisheries & Aquaculture Science
COWRIE	Collaborative Offshore Wind Research Into the Environment
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
Dir	Direction
DONG	DONG Energy Ltd
DTI	Department for Trade and Industry
EC&R	E.ON Climate and Renewables UK Rampion Offshore Wind Limited
EECHM	Eastern English Channel Habitat Map
EIA	Environmental Impact Assessment
ES	Environmental Statement
GBS	Gravity Base Structure
GLV	Greenwich Light Vessel
GW	Gigawatt(s)
Hmax	Maximum wave height
HDD	Horizontal Directional Drilling
Hs	Significant Wave Height
HW	High Water
IPC	Infrastructure Planning Commission
JNCC	Joint Nature Conservation Committee
kg	kilogram
km	kilometre(s)
LSO	Long Sea Outfall
LW	Low Water
m	metre(s)
mm	millimetre(s)
m/s	metres per second
mg/l	milligrams per litre
MMO	Maritime Management Organisation
MW	Megawatt(s)
N/m ²	Newtons per square metre
OWF	Offshore Wind Farm
PDS ² RWC	Project Design Statement to Realistic Worst Case
PE	Peak Ebb
PF	Peak Flood
PSA	Particle Size Analysis
Ramsar	The Convention on Wetlands (Ramsar, Iran, 1971)
REA	Regional Environmental Assessment
rMCZ	regional Marine Conservation Zone

ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
SAS	Surfers Against Sewage
SCOPAC	Standing Conference on Problems Associated with the Coastline
SCREC	South Coast Regional Environmental Characterisation
SDCG	South Downs Coastal Group
SEA	Strategic Environmental Assessment
SMP	Shoreline Management Plan
SPA	Special Protection Area
SSC	Suspended Sediment Concentration
SSE	South-southeast
SSW	South-southwest
SW	Southwest
SSSI	Sites of Special Scientific Interest
T _m	Mean wave period
T _p	Peak wave period
TSHD	Trailing Suction Hopper Dredger
T _z	Zero crossing wave period
UKCIP	UK Climate Change Impact Programme
WSW	West-southwest
2D	two dimensional
3D	three dimensional

Rampion Wind Farm: Coastal Processes Assessment

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1. Introduction

1.1 Project Description

ABP Marine Environmental Research Ltd (ABPmer) has been appointed by E.ON Climate and Renewables UK Rampion Offshore Wind Limited (EC&R) to undertake the Coastal Processes component of the Environmental Impact Assessment (EIA) for the Rampion Wind Farm. This proposed development is sited within Zone 6 of The Crown Estate's Round 3 Lease Option Areas.

An integral part in the determination of the potential impact of the proposed wind farm upon the existing environment is the assessment of its interaction with the coastal process regime. The purpose of the coastal process study is to demonstrate a sufficiently robust understanding of the potential interaction of the wind farm development on wave, tidal and sediment regimes and to assess any direct, indirect and cumulative impacts. This report follows the baseline assessment (ABPmer, 2011) and provides an assessment of the potential impacts of the Rampion development upon existing coastal processes. It should be noted that this study is not intended to directly inform the engineering or design of the project structures.

This report has been updated since the draft issued in March 2012 and to reflect more recent changes to the design characteristics of the proposed development. These changes are with respect to the total number of structures and the type of foundations to be used throughout the array and result from further engineering and geological considerations undertaken since March 2012. Eight revised layouts were produced by E.ON for consideration and following initial calculations to determine the realistic worst-case scenario in terms of blockage to waves and current, one layout (Layout E as shown in Figure 2a.5 of the Environmental Statement (ES)) has been taken forward within the coastal process assessment to present the realistic worst case option..

1.2 Rampion Wind Farm Development

The application site is located, approximately, 13 km offshore from Brighton, in the eastern part of the English Channel (Figure 1), and between two headlands; Selsey Bill and Beachy Head (classified as Sub-Cell 4d within Shoreline Management Plans (SMP) (SDCG, 1997; 2004). The wind farm application site covers an area of approximately 271 km². Within the application site, a Site Development Area of 139 km² has been identified within which there exists the opportunity to install between 175 (based upon 3 MW) and 100 (based upon 7 MW) turbines. The full description of the wind farm's characteristics, including details of all planned infrastructure, is given in Section 2a of the ES (Offshore Project Description).

Although a Round 3 development, the scale of the Rampion Wind Farm is considerably smaller than most other proposed Round 3 developments and indeed, according to scale, it could be considered to be on par with other Round 2 schemes. Further, Rampion is located at a distance offshore (13 km) more similar to Round 2 developments than other Round 3 zones. Round 2 developments are no further than 12 km offshore whilst Round 3 developments range between 14 and 125 km offshore (calculated from the centroids of lease areas).

2. Assessment Methodology

2.1 Overview

The purpose of the coastal process impact study is to provide a realistic 'worst-case' assessment of the potential effects arising from the wind farm development as well as to assess the potential for interaction with other activities and projects in the area. The assessment has been undertaken in three stages. These are:

- (i) Determination of the baseline (or pre-development scenario) physical environment (as reported in ABPmer (2011);
- (ii) Determination of the realistic worst-case development scenario from the information received from E.ON; and
- (iii) Assessment of effects arising from the realistic worst-case.

The assessment of effects on the marine physical environment has been considered in terms of a *Source-Pathway-Receptor* conceptual model whereby the:

- *Source* is the 'initiator event';
- *Pathway* is the link between the source and the receptor impacted by the effect (e.g. sediment transport processes); and
- *Receptors* are the receiving entities as defined in Section 2.3.

A receptor can only be exposed to change if a pathway exists through which an effect can be transmitted between the source activity and the receptor.

A typical application of the source–pathway–receptor model to an OWF development includes the:

- Foundation structure and support column being considered as the source of a potential effect on the waves or tides;
- Interaction of the waves and tides acting as the pathway for transporting sediment; and
- Receptor being a feature identified as being potentially sensitive to any change in the physical environment.

Details on the coastal process issues that require consideration within the EIA process for the proposed development are discussed in Sections 2.2 and 2.3 and summarised in Table 1 and Table 2.

Key guidance documents used to inform the EIA assessment process are also summarised in this section, along with the findings of the consultation and scoping of EIA issues phase. The distribution of physical process receptors is also considered in this section. Their distribution is necessarily wider than the immediate area of the zone (the near-field). This therefore also includes for those areas where a pathway might exist connecting the zone and the receptor (in the far-field).

2.2 Consultation and Scoping of EIA Issues

The EIA Scoping report for the Rampion Wind Farm was submitted in September 2010 to statutory and non-statutory consultees and relevant parties (E.ON, 2010b). A number of issues and particular concerns to address in the EIA were raised in the scoping responses (IPC, 2010). Those that are considered to be of direct relevance to the assessment of coastal processes are presented in Table 1.

Table 1. Coastal process issues and concerns expressed during the EIA consultation and scoping process

Coastal Process Issue	IPC	MMO	Brighton and Hove City Council	Havant Borough Council	Southern Water	Surfers Against Sewage
Sediment dynamics		Scour and impact to sediment transport pathways and its effect on the coastline				
Hydrodynamics	Cumulative hydrodynamic impact			Impacts upon marine currents and implications for coastal processes and existing and planned sea defences	Altering hydrodynamics at the long sea outfalls and the dispersion of effluent	
Sediment availability and transport pathways			Impact on marine aggregate extraction operations			
Wave climate						Interruption of offshore wave transmission and reduction in offshore swell energy

(Taken from: IPC, 2010 and SAS, 2009. Note that comments received from Natural England and the Environment Agency did not specifically address coastal process issues)

2.2.1 Environmental Statement Consultation

Following consultation on the draft ES (June 2012) a number of comments were subsequently received from consultees regarding the potential impacts of the proposed development upon coastal processes. The main issues highlighted during this consultation process and requiring further consideration are:

- Potential changes to longshore sediment transport;
- Potential changes to waves at the coast, impacting the surfing resource;
- Potential impacts to existing coastal defence schemes (as detailed in the Shoreline Management Plans); and
- Cable exposure.

Since the consultation process, and as a result of further engineering and geophysical studies, E.ON made a series of revisions to the Project Description. In particular, the maximum number of turbines was decreased from 195 to 175 and the spatial extent of the array was also reduced. Further, these studies allowed the determination of a more realistic maximum number of GBS that could be included in the array and potential locations of these foundations. This process substantially reduced the numbers of this foundation type compared to the previous worst case scenario as assessed in the earlier draft coastal process chapter.

2.3 Identification of Coastal Process Receptors

Waves and, tides are typically considered as pathways that can be altered by the presence of structures placed within the application area. As previously stated, alterations to the hydrodynamic regime may also result in changes to sediment transport pathways with the potential for a consequential effect on, for example, coastal morphology and seabed features. Coastal processes receptors occur within the application site and the wider far-field region.

The receptors that form the basis for exploring the potential impact of the proposed development are summarised in Table 2 and illustrated in Figure 2.

Also included in Table 2 is seabed infrastructure, which includes cables and pipelines. This receptor belongs to the human, rather than the physical environment, although it is included here as they are potentially sensitive to changes in the physical environment.

2.4 Spatial and Temporal Scales of Assessment

Spatial Scales of Assessment

A consideration of the tidal, wave and sedimentological regimes is required over the following spatial scales:

- Near-field (i.e. the area within the immediate vicinity of the wind turbine grid and along the export cable corridor; the 'application area'); and
- Far-field (i.e. the wider area that might also be affected indirectly by the development, e.g. due to disruption of waves, tides or sediment pathways passing through the site).

Table 2. Identified coastal process receptors

Receptor	Coastal Process Theme	Designation	Description
Seabed infrastructure including pipelines and cables	Hydrodynamics Sediment dynamics	None	This includes investigating current properties and the large-scale cumulative impact and the influence on scour and sediment transport pathways.
Aggregate sites	Sediment dynamics and transport pathways	None	Investigating the potential for plume interaction from aggregate activities during foundation installation works.
Coastline of Sub-Cell 4d	Sediment dynamics and transport pathways	None	The coastline of this Sub-Cell has a number of urban areas along the entire frontage; these are of high socio-economic value hence the “Hold the Line” policy that is prevalent along most of the frontage.
Pagham Harbour	Hydrodynamics Sediment dynamics	SPA (*) and Ramsar site	Changes to the coastal processes acting within the designated sites which could impact the habitats they support. The further assessment of effects on other EIA topics will be informed by these results, but will be reported in other chapters.
Beachy Head West	Hydrodynamics Sediment dynamics	rMCZ (**)	
Kingmere			
Offshore Overfalls			
East Meridian			
Pagham Harbour	Hydrodynamics Sediment dynamics	SSSI	
Bognor Reef			
Selsey, East Beach			
Felpham			
Adur Estuary			
Brighton to Newhaven Cliffs			
Climping Beach			
Seaford to Beachy Head			
Surfing Locations	Waves Hydrodynamics	None	
(*) Where SPA – Special Protection Area (**) Where rMCZ – recommended Marine Conservation Zone (***) Where SSSI – Site of Special Scientific Interest			

These extents are defined in Figure 1. The near-field boundary includes the array of wind turbines and foundation structures, its immediate surroundings and the export cable corridor, and is the area in which direct effects to the physical environment are expected to occur within the lifecycle of the development. As previously discussed, the far-field boundary broadly delineates the wider area that might also be affected indirectly by the wind farm.

Temporal Scales of Assessment

There are three main phases of development that have been considered in conjunction with the baseline over the next 25 years. These are construction, operation and maintenance, and decommissioning:

2.5 Best Practice and Guidance

The baseline (ABPmer, 2011) and impact assessment (this report) have been compiled following best practice and current guidance for coastal process studies in relation to OWF developments as presented in the following documents:

- 'Guidance on Environmental Impact Assessment in Relation to Dredging Applications' (Office of the Deputy Prime Minister, 2001);
- 'Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects' (Cefas for MMO, 2011);
- 'Using the Rochdale Envelope. Advice Note 9: Rochdale Envelope' (IPC, 2011);
- 'Nature Conservation Guidance on Offshore Wind Farm Development' (Defra, 2005);
- 'Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment' (COWRIE, 2009);
- General advice on assessing potential impacts of and mitigation for human activities on MCZ features, using existing regulation and legislation' (JNCC & Natural England, 2011);
- National Policy Statements for Energy (DECC, 2011a) and Renewable Energy (DECC, 2011b).

The purpose of the available generic guidance is to provide an overall consistency in approach and methodology to the identification and assessment of potential impacts. Using the recommended approaches, specific issues in relation to the Rampion OWF application site have been determined during the EIA scoping and consultation process as detailed in Sections 2.2 and 2.2.1.

2.6 Data Sources

As part of the planning, assessment and development of the proposed Rampion Wind Farm, both new and historical data collation exercises were completed. These yielded a range of comprehensive datasets, including geophysical, benthic and metocean (meteorological and hydrodynamic) parameters (Table 3; Figure 3 and detailed in ABPmer (2011)). In addition to providing input into the conceptualisation of the baseline coastal processes regime (ABPmer, 2011), the collected information has also been used to calibrate the numerical model developed to assist the impact assessment of the realistic worst case scenarios.

Additional information has been obtained from other sources, to complement that obtained from the geophysical, geotechnical, benthic and metocean surveys. These additional data includes:

- British Geological Survey (BGS) 1:250,000 surface sediment maps, used to provide a regional indication of the seabed material. This has been broadly verified within the application site using the grab samples provided by the benthic survey;
- UKCIP '09 (Lowe *et al.*, 2009) predictions of future changes to the hydrodynamic regime due to climate change;
- Wave observations from the Rustington wave buoy, Worthing Pier meteorological station and Arun Platform tidal gauge downloaded from the Channel Coastal Observatory (CCO);
- Wave observations from the Greenwich Light Vessel (GLV) obtained from Met Office; and
- Modelled wave data for a 10-year period out of the Seastates model (ABPmer, 2011c).

Table 3. Project specific data and information sources used in the baseline assessment

Survey/ Study	Undertaken By	Date of Survey	Description
Geophysical Surveys	Osiris Projects (Osiris Projects, 2010a-c)	04/05/2010-19/08/2010	High-resolution swath multibeam and single beam bathymetric survey, side-scan sonar imagery, magnetometer and sub-bottom profiling.
Geotechnical Survey	Fugro Geoconsulting Ltd (Fugro Geoconsulting Ltd, 2011)	27/03/2011-09/04/2011, 24/06/2011–26/06/2011	Geotechnical data to allow an assessment of the soil conditions across the wind farm site and cable route.
Benthic Survey	EMU Ltd. (EMU Ltd, 2011a)	03/2011-04/2011	Baseline information on the benthic communities within and adjacent to the proposed wind farm application site has been collected. 52 grab samples are available from the application site. These samples have been used for particle size analysis (PSA), which provides an indication of the seabed characteristics throughout the application site.
Metocean Surveys	EMU Ltd. (EMU Ltd, 2011b)	L1:01/11/2011-07/01/2011 L2: 01/11/2011-18/02/2011 L3: 01/11/2011- 10/05/2011 (AWAC) 25/01/2011-10/05/2011 (wind)	Provides data on waves, tides, water levels, suspended sediment concentrations (SSC) and wind at three locations over winter periods to collect high energy events. Waves: height, period and direction Currents: depth-averaged and profiles of speed, direction Wind: speed and direction SSC: Temperature and turbidity (depth-averaged and profile).

Further to the additional data sets acquired, a number of key reports have been used which are of direct relevance to this project. These include, but are not limited to:

- Strategic Environmental Assessment Area 8 Superficial Seabed Processes and Hydrocarbon Prospectivity (Tappin *et al.*, 2007);
- JNCC Coastal Directory Series: Coasts and Seas of the United Kingdom. Regional Report 8 Sussex: Rye Bay to Chichester Harbour (Barne *et al.*, 1998);
- Coastal flood boundary conditions for UK mainland and islands. Project SC060064/TR2: Design sea levels (McMillan *et al.*, 2011a);
- Coastal flood boundary conditions for UK mainland and islands. Project SC060064/TR3: Design swell waves (McMillan *et al.*, 2011b);
- The Eastern English Channel Marine Habitat Map. Science Series Technical Report 139 (James *et al.*, 2007);
- The South Coast Regional Environmental Characterisation (James *et al.*, 2010);
- The Marine Aggregate Levy Sustainability Fund (MALSF) synthesis study in the central and eastern English Channel (James *et al.*, 2011);
- Eastern English Channel Regional Environmental Assessment (Royal Haskoning, 2002);
- Extreme tidal water level estimations for different sites in the English Channel (ABPmer, 2004);
- Coastal processes scoping assessment for the EON02 zone, south coast (ABPmer, 2008a);
- Beachy Head to Selsey Bill Shoreline Management Plan and First Review (SDCG, 1997 and 2004); and
- Sand banks, sand transport and offshore wind farms (Kenyon and Cooper, 2005).

2.7 Project Description and Construction Methodology

2.7.1 Turbine layout

The Project Description (Section 2a of the ES) states that, based upon recent geological and engineering studies, there now exists the opportunity to install between 175 (based upon 3 MW) and 100 (based upon 7 MW) turbines.

2.7.2 Foundation Type

A range of foundation options are considered for installation within the Rampion Wind Farm:

- Monopile;
- Jacket and Keystone (Twisted) Jacket;
- Tripod;
- Gravity Base; and
- Suction Caisson.

2.7.3 Foundation installation techniques

The turbines are expected to be installed using an installation crane of suitable size located on a floating vessel, which would be either a shear-leg barge or a purpose made barge. It has been assumed that the legs on such a barge would have a footprint of the order of 75 m², with any associated anchors being of the order of 2 to 3 m. It is an option that the gravity base foundations are floated to site, and once on site, the individual structures are ballasted (if required) and sunk into position.

2.7.4 Scour protection

The requirement for any scour protection will be determined following the design of the structure in association with the wave, currents and geological properties at site. Outputs from the baseline assessment indicate the potential for wave and current induced sediment mobility for coarse sand sized sediments. Therefore, there is a potential for seabed erosion (scour) and the deposition of transported materials in some parts of the site. On this basis, gravity base foundations will require scour protection. The basic method of protection is to use rock armour and possibly large sized aggregate at the periphery of the base plate. As a worst case, the estimated total volume of scour protection material per gravity base foundation would be 10,600 m³ (Section 2a of the ES).

2.7.5 Associated Infrastructure

The information presented on the properties of the associated infrastructure is based on the Project Description (presented in Section 2a of the ES).

Sub-stations

It is expected that two substations will be installed to serve the development, but at the time of writing, the properties of these are unknown. The exact location, design and visual appearance will be defined once the electrical design is completed, post consent. However, it is currently understood that the sub-stations will be mounted on jacket foundations and also be within the proposed turbine layout grid. Construction and fabrication of the offshore sub-station is likely to take place onshore and be transported to site by a barge. Once on site, the sub-station would be installed on to the foundation structure using a similar method as described for the wind turbines.

Transmission cable corridor

It is expected that up to four export cables would be required to transmit the power to shore. These will be installed with at least a 50 m separation distance between cables to facilitate installation and maintenance. The export cables will be buried to target depths of 1 to 3 m.

The required width for the cable route and installation corridors will vary along the length of the cable route and will be dependent on water depth and width restrictions. The most suitable route between the wind farm site and landfall will be determined based on knowledge of the site consultation with stakeholders.

The proposed cable landfall window is at East Worthing (Figure 1). Submarine cables will be installed underneath the beach and the A259 road using horizontal directional drilling (HDD) from the landward side. Four separate subsea power cables will then be pulled shorewards under the beach and road by drilling and winching equipment stationed north of the A259. It is proposed that the marine cables would remain beneath the beach and seabed all the way out to the wind farm, and no surface disruption to the road and beach defences would take place, although access to the beach and foreshore would be required by track type machinery to aid in the drilling works and cable pulling activities.

The exact alignment of the four subsea power cables will not be known until much further into the development process and as such E.ON are seeking an option over a broad area within which the four power cables will converge to the onshore joint bays and cable trenches. Further studies are required to assess the interaction of the cable with the coastline to ensure that the cable will not be affected by coastal erosion during the life of the project. Protection of the cables may be required at the cable landfall location if coastal erosion proves to be problematic. In this instance the cables will have to be protected by being re-buried or covered with aggregate or rock mattresses.

Inter-array cables

Inter-array cables will be used to connect each of the turbines in a radial or ring network arrangement to the offshore sub-station. Each radial string would connect between six and eleven turbines depending on the size of turbines used or the use of a ringed network. Therefore, the total length of the inter-array network will differ depending on turbine selection, site layout and network methodology. The array cabling will be designed in such a way as to minimise the amount of cable installed, while allowing enough space around each foundation for additional cables to be installed and for other construction vessels to operate safely.

It has been noted that each of the two substations will have between eight and twelve strings, depending on the turbine selection and the cables used. The routing of which will consider any identified wrecks and may also avoid geological features highlighted in the site geophysical investigations. It is also estimated that the inter-array cables will be buried to target depths of 1 m, with a total of up to 230 km of inter-array cabling required for a 700 MW project.

Cable installation methodology

Options for the cable installation include, ploughing, jetting and trenching for the export and inter-array cables and at landfall.

Ploughing involves cutting through the seabed with a blade, behind which the cable is laid. In a simultaneous 'lay and trench' mode, cable depressors push the cable into position at the base of the cut trench; as the plough proceeds the trench is then back-filled to provide immediate burial. Ploughs are generally pulled directly by a surface vessel or, they can be mounted onto a self propelled caterpillar tracked vehicle which runs along the seabed. Ploughing is a one-off process and cannot be repeated to re-bury an exposed cable.

Jetting involves directing water jets towards the seabed to fluidise and displace the seabed sediment, which typically forms a rectangular trench, into which the cable generally settles under its own weight. During the formation of the trench the displaced sediment is forced into suspension and settles out at a rate determined by the sediment particle size, density and flow conditions. The jetting process is not intended to displace sediment to an extent that it is totally removed out of the trench. Instead it requires that the fluidised sediment is available to fall back into the trench for immediate burial through settling. It is only the finer fractions of sediments that are likely to be held in suspension long enough to become prone to dispersal away from the trench as a plume. A key benefit of a jetting tool is that it is able to operate close to structures and it is also possible to use jetting tools for remedial burial, if required. The water jets are usually deployed on jetting arms beneath an ROV system that can be free-swimming or based on passive skids or active tracks. There are also towed jetting skids available for the installation of cables.

Trenching involves the excavation of a trench whilst temporarily placing the excavated sediment adjacent to the trench. The cable would then be laid and the displaced sediment used to back-fill the trench, covering the cable. This is most commonly used where the cable has to be installed through an area of rock or seabed composed of a more resistant material. Trenching is a difficult, long and expensive method to use compared to other methods and would only be used in exceptional circumstances.

The installation methodology applied, would be dependent on water depth and seabed geology, with the possibility for the combination of these methods in relation to the ground conditions and cable function. A burial depth of 1 to 3 m is aimed for all cables. Ground conditions along the route may mean that the cable burial depth cannot be achieved. In these instances, the installation methodology will be reviewed and the cable may be deemed suitably buried or may be buried deeper using other techniques.

2.8 Rochdale Envelope Considerations

2.8.1 Overview

It is recognised that the development of offshore wind farms is complex and initially many different layout and foundation options may be under consideration. Much of the final design of both the turbine array (layout, foundation type, and inter-array cabling and turbine model) and the associated infrastructure is refined throughout the development process and the EIA will need to accommodate this.

The assessment of the potential environmental impacts of the development has been undertaken using the realistic 'worst case' scenario in line with the Rochdale Envelope approach (IPC, 2011). As such, any impacts arising from the final scheme design (during construction, operation or decommissioning) are assumed to be within the predicted 'envelope' of impacts identified within the EIA. Where such design or methodology options remain at the time of application, these are clearly identified in the ES together with the reasons for such required flexibility.

ABPmer has developed and operate a best practice analytical tool, PDS²RWC (Project Design Statement to Realistic Worst Case), that enables an assessment of all Project Design Statement options at an initial high-level. It assimilates design envelopes, with ranges of minimum and maximum sizes of varying foundation types, with a range of layouts of turbines and cables, both inter-array and export. The outcome of this initial analysis can then be reviewed in order to produce a set of one or more scenarios of layout and foundation type that represent the 'realistic worst case' or the 'Rochdale Envelope' for the development. These scenarios can then be assessed against the baseline environment, using detailed modelling tools (or the evidence based approach) to examine the impacts on the known receptors.

The PDS²RWC analysis uses a series of simple metric calculations to consider a range of initial design parameters. The output determines which foundation type and which turbine layout provides the biggest potential impact with respect to blockage to waves and tides and the creation of sediment plumes. The two main considerations here are therefore the evaluation of which option of an operational project (layout and scale of structure):

- Has the potential to generate the greatest amount of disturbed sediment during the construction phase - i.e. sediment plume (disturbed sediment may be from levelling, drilling, scouring or cable laying, including considerations of source location, sediment volumes, sediment type and particle size); and
- Presents the greatest "blockage" to existing pathways and risks the greatest effect on the known range of receptors (during the operational phase these pathways may be wave, tidal or sediment).

The PDS²RWC tool was previously used to determine the Rochdale Envelope characteristics for coastal processes based upon information received from E.ON. Since this time, the design parameters of the proposed wind farm have changed and multiple foundation options are now being considered.

The following sub-sections provide the full suite of details for the realistic worst case scenario, as identified above, and as applied to the present study.

2.8.2 Worst Case: sediment disturbance

Seabed preparation for gravity base structures

Prior to the installation of gravity base foundations, the seabed may have to be prepared by levelling the local area. This could involve excavating and installing imported material on the seabed. The amount of material to be excavated and deposited would be determined during the preliminary design stage, based upon information from detailed geophysical and geotechnical investigations at each foundation location. Options for disposal of seabed material would be on site or disposal at a licensed disposal site. It is preferable that arisings be disposed of on site where possible. A worst case assumption is that the sediment is deposited next to the foundations rather than being transported away from the site and deposited within licensed grounds.

Seabed arisings as a result of foundation installation can be estimated based on the area of potential disturbance. Based upon the information received from E.ON at the time of assessment, the realistic worst case total volume of sediment disturbed per gravity base foundation was 1,103 m³. Recent engineering considerations (Section 2a of the ES) have revised this volume to 1,820 m³ (for a 5 to 7 MW structure). The arisings would then typically return to the seabed naturally

Monopile, pin pile and suction caisson jacket foundations do not require seabed preparation prior to installation.

Drilling for monopile structures

The most efficient and preferred method for installation of monopile foundations or jacket pin piles is to simply drive (hammer) each pile to the required depth, which would result in minimal, or no, sediment resuspension.

Due to the geotechnical properties of the soil (Fugro Geoconsulting Ltd, 2011) within the Site Development Area, there remains the possibility that driving installation techniques will prove difficult and, as such, drilling operations will be required (Section 2a of the ES). Should these operations be required, sediment arisings are to be anticipated. The realistic worst case option for the disposal of this material is that it is allowed to return to the seabed naturally. Based upon the information received from E.ON at the time of assessment, the realistic worst case sediment volume arising for individual monopile foundations was 1,470m³. Recent engineering considerations (Section 2a of the ES) have revised this volume to 1,824 m³ (for a 5 to 7 MW structure based on a revised pile diameter of from 6 m to 6.5 m), with the assumption that material is released at the seabed.

Cable installation

Jetting typically results in sediment suspension, introducing a potential for mobilisation over a wider area than for other cable laying techniques which may be employed during construction. As such, the effects of cable jetting are assessed as the worst case scenario for cable installation, determined by the length of cabling required. This is achieved using results from previous monitoring campaigns and numerical modelling analyses. The geological and geomorphological seabed characteristics will determine the sediment type disturbed during the cable burial operations.

2.8.3 Worst case: blockage

Based upon the present understanding of the wind farm characteristics (as provided in eight layouts provided by E.ON), it is possible to conclude that:

- For wave and tidal blockage, it is the combination of a larger number of smaller units, placed closer together that provides the greatest potential blockage. Of the two layouts which provide this option, it is the layout which contains the greatest number of gravity base structures (GBS) that may be considered the option with the greatest potential impact (Example Layout E, as given in Figure 2a.5 of the ES);

- When considering sediment sources from scour and GBS ground preparation, the larger number of GBS units (4 MW turbine layout) presents the greatest potential sediment source; and
- When considering sediment sources from piling activities, it is the monopile structures that present the greatest potential sediment source.

Accordingly, it is considered that **the layout containing 80 4 MW GBS structures and 95 monopile structures (175 structures in total) presents the realistic worst case scenario.** These are anticipated to have a spacing of 750 m by 1000 m and will be set out on a hexagonal grid. The realistic worst case scenario with respect to the positioning of the 175 foundation structures within the Site Development Area relates the different foundations to water depth and geophysical properties. The resulting worst case turbine layout is illustrated in Figure 4.

2.8.4 Summary

The worst case scenarios from the range of characteristics adopted within this physical process assessment, as detailed in preceding sections, are summarised in Table 4. Assessments provided in the following sections may consider more than just the worst case scenario.

2.9 The Offshore Wind Evidence Base

2.9.1 Overview

Prior to undertaking the assessment phase, consideration was given as to whether the coastal process impact assessment could be satisfactorily completed using baseline surveys and monitoring evidence from previously constructed offshore wind farms, or whether location-specific numerical modelling analyses were required to supplement the existing evidence base.

In order to ascertain whether numerical modelling analyses are required to inform the assessment process, there is a need to understand both (i) the coastal process regime at the Rampion Wind Farm; (ii) and the likely design characteristics of the development. The evidence base can then be examined for other developments sharing close environmental and design similarities with this scheme, with the necessity for modelling then advised by the adequacy of the available evidence.

2.9.2 Evidence Relevant to the Rampion Wind Farm

As previously stated (Section 1.1.1), the Rampion Wind Farm is of a scale more in line with Round 2 developments as opposed to Round 3. Therefore, with respect to this aspect of the project alone, it is considered that the information present within the evidence base can potentially be used to support the impact assessment.

Table 4. Scenarios assessed for physical processes

Phase	Potential Impact	Realistic Worst Case Scenario
Construction	Increase in suspended sediment concentrations as a result of foundation installation activities	Monopile foundations, sediment released as chalk drill arisings released on site.
	Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	
	Increase in suspended sediment concentration, bed level change and seabed textural change following re-deposition of suspended sediments as a result of inter-array cable burial & export cable burial activities	Trenching by energetic means (e.g. jetting). Cable burial to 3 m depth. 100% of material resuspended. Sediment medium sands.
	Indentations left on the seabed by jack-up vessels and large anchors	Jack-up legs, 75 m ² footprint. Anchors 2 to 3 m length scale.
	Disturbance of coastal morphology at the export cable landfall site	Directional drilling and nearshore trenching.
Operational	Scour effects due to the presence of the turbine foundations	All foundation types and layouts and no scour protection measures
	Scour effects due to the exposure of inter-array and export cables and cable protection measures	Inter-array and export cables and cable protection measures
	Changes to wave and current regimes affecting patterns of near-field (offshore) sediment transport due to the presence of the turbine foundations	175 structures, 80 x GBS foundations and 95 x monopile, 4 MW
	Changes to wave and current regimes - affecting patterns of far-field (coastal) sediment transport due to the presence of the turbine foundations	
	Disturbance of coastal morphology at the export cable landfall site	Cable previously buried by directional drilling and nearshore trenching.
Decommissioning	Increase in suspended sediment concentrations and accumulation of sediment and change of sediment type at the seabed as a result of wind farm decommissioning activities	Monopile foundations.
	Indentations left on the seabed by jack-up vessels and large anchors	Inter-array and export cables and cable protection measures
	Changes to wave and current regimes affecting patterns of near-field (offshore) sediment transport due to the removal of the turbine foundations	175 structures, 80 x GBS foundations and 95 x monopile, 4 MW
	Changes to wave and current regimes affecting patterns of far-field (coastal) sediment transport due to the removal of the turbine foundations	

Based on current developmental information, an assessment of the realistic worst case scenario for coastal processes would require the inclusion of the 4 MW GBS layout (Section 2.4).

All Round 2 developments have been consented on the basis of GBS structures. However, the majority of real-time observational information contained within the present evidence base is related to monopile arrays (ABPmer *et al.*, 2010). The Beatrice Demonstrator Project used

jacket structures, whilst Nysted (Denmark) and Thornton Bank (Belgium) used GBS foundations.

Nysted OWF has 72 2.3 MW turbines in water depths between 6 and 10 m. The hydrodynamic regime is classified as benign (DONG Energy *et al.*, 2006). The sediments are characterised by medium sands, which forms a thin veneer over clay formations. The data available is for suspended sediment concentration monitoring during cable installation procedures. It is considered therefore, that only data relating to cable installation activities will be of relevance here.

Thornton Bank OWF is comprised of 60 5 MW turbines in water depths between 12 and 25 m. The hydrodynamic regime is classified as energetic (mean spring tidal range of 4 m; current speeds greater than 0.8 m/s and storm events reaching wave heights of greater than 6 m (ABPmer *et al.*, 2010). The sediments are characterised by medium to coarse sands with active bedforms (sand waves and ripples) present. In this regard therefore, there are parallels to the environmental conditions at Rampion OWF. However, there is currently only limited post-construction data available on scour and morphology at Thornton Bank (ABPmer *et al.*, 2010).

On the basis of the above discussion, it is apparent that Round 2 developments have been consented on the basis of GBS foundations and as such there are numerous ES documents that provide detail on the potential impact of these structures upon coastal processes. However, only two developments have been constructed with GBS foundations. Further, of these two developments, only one has similar environmental conditions (in terms of the hydrodynamic and sedimentary environment) to those experienced within the Rampion site. Thus only one set of construction / post-construction measurements will be applicable.

As a consequence of the above discussions, it is considered that the evidence base is unlikely to provide sufficient detail to *fully* underpin the effects of GBS foundations on coastal processes to a level that represents the least risk for consenting. To this end, the applicable information held within the evidence base has been supported by numerical modelling activities for this present study.

2.10 Analytical Approaches

The detailed investigation of changes to the hydrodynamic and sedimentary regime has been supported by the application of a numerical model, comprising a spectral wave model linked to a 2D tidal model. The calibration of this model was supported by the same data sources applied in the baseline assessment and presented in Section 2.6; further details regarding the model and calibration are presented in Appendix A.

The representation of the full scale development is provided to the model as a 'realistic worst case' option, based on the outcome of the initial theoretical considerations and a number of high-level assumptions as summarised in Section 2.8. For the purpose of this assessment, the model includes a representation of array Layout E (Figure 2a.5 in the ES) with the two selected foundation options (80 x GBS; 95 x monopile, 4 MW turbine capacity and as shown in Figure

4). The results from the modelling scenarios should be regarded as conservative as the final design may moderate the description of the development.

The effects of the scheme development are determined by operating the model for a set of baseline scenarios, and an equivalent set of scenarios that include a conservative based representation of the full scale development. Changes are expressed as the difference between these two scenarios, spatially across the near and far-field effect, in order to determine any effects at the receptor locations.

2.11 Determination of significance

The significance of potential impacts to the coastal process receptors (Table 3) have been assessed using the parameters given in Table 5 to 7, as provided by RSK Ltd (2011). These criteria allow the potential issues that are clearly insignificant to be determined. The significance of an issue is assessed further based on the magnitude of the anticipated change (relative to baseline values), the location of the change (i.e. proximity to key features or interests), the measurability of the change and expert-led judgement.

Table 5. Definition of terms relating to the sensitivity and value of generic coastal process receptors

Receptor Importance/Sensitivity	Examples
High	Areas of contaminated seabed. Special Areas of Conservation (SAC) classified due to their physical characteristics (e.g. shallow sandbanks <20m deep). Special Protection Areas (SPA) where conservation objectives include maintaining habitats that include sub-tidal sandbanks and intertidal mudflats and saltmarsh. Seabed features/sediments at high risk of damage during construction
Medium	Seabed features/sediments with moderate risk of damage during construction. Potential Annex I habitats (i.e. shallow sandbanks)
Low	Seabed features/sediments with low risk of damage during construction. Features which have a high recoverability rate

(Source: RSK Ltd, 2011)

The impact assessment should also define the magnitude of the effect, from high to no change. Magnitude refers to the 'size' or 'amount' of an impact (Table 6).

Table 6. Definition of terms relating to the magnitude of an effect

Magnitude	Definitions
Large	Change is likely to cause a direct adverse permanent or long-term (more than 10 years) impact on the integrity/value of the receptor. Permanent damage to a sandbank/protected seabed feature. Impacts which are long term and affect physical processes e.g. sediment transport beyond the vicinity of the project.
Medium	Change is likely to impact adversely the integrity/value of the receptor but recovery is predicted in the medium term (5-10 years) and there is predicted to be no permanent impact on its integrity. Permanent changes to the local seabed topography in vicinity of the project (but not causing changes to regional sediment processes). Locally increasing sediment re-suspension and deposition to levels significantly higher than natural levels.
Small	Change is likely to adversely impact the integrity/value of the receptor but recovery is expected in the short term (0-4 years). Increasing sediment suspension and deposition to levels which are comparable to natural levels.
Negligible	No impact detectable.
Beneficial	Change is likely to beneficially impact the integrity/value of the receptor

(Source: RSK Ltd, 2011)

The 'significance' reflects the relationship between the sensitivity (or value) of the affected environmental receptor and the magnitude of an impact. Following the identification of receptor value/sensitivity and magnitude of the effect, the significance of the impact can be determined using the matrix in Table 7.

Table 7. Significance of an effect resulting from each combination of receptor sensitivity and the magnitude of the effect upon it

Magnitude	Sensitivity/Importance		
	High	Medium	Low
Large	Major	Major/ Moderate	Moderate
Medium	Major/Moderate	Moderate	Minor
Small	Moderate	Minor	Minor
Negligible	Minor	Negligible	Negligible

(Source: RSK Ltd, 2011)

The overall significance of the potential impacts identified during construction, operation and decommissioning of the wind farm are summarised in Sections 3 and 4. The significance of the impacts in relation to individual coastal process receptors are given in Section 6

3. Coastal Process Assessment: Construction and Decommissioning Phases

3.1 Potential Impact: Increase in Suspended Sediment Concentrations as a Result of Foundation Installation Activities

3.1.1 Overview

Increases in suspended sediment concentrations (SSC) may result from the disturbance of sediment by foundation installation activities. These activities include:

- Drilling for monopile installation; and
- Bed preparation prior to gravity base installation.

This disturbed material may then be transported away by entrainment due to tides and waves. With regards to the potential for sediment plumes, the main concern raised during the consultation process was for the release of fine grained chalk material into the water column and the subsequent deposition of chalk particles across areas of seabed hitherto not characterised by the presence of chalk. As such, this section has focused on this particular concern.

According to the source-pathway-receptor model:

- The operation of the drilling of the monopile into chalk is considered as the *source* of the potential change to the suspended sediment concentrations;
- Both tides and waves act as the *pathway* for transporting the suspended sediment; and
- The *receptor* is the feature identified as being potentially sensitive to any increase in suspended sediments and consequential deposition.

3.1.2 Baseline Conditions

Baseline (0.5 m above the seabed) levels of SSC measured within the OWF application site range between 5 to 10 mg/l, although values exceeding 10 mg/l also frequently occur (EMU, 2011). Regional assessments of SSC levels within the study area indicate surface values of between 5 to 10 mg/l during winter months and generally <3 mg/l during the summer period (Eggleton *et al.*, 2011). It is noted that surface values are typically less than those experienced towards, and at, the seabed.

Higher turbidity measurement values are observed in shallower water depths such as those encountered along the export cable corridor. Elevated levels have also been shown to occur during storm events where wave heights in excess of 3 m are shown to increase SSC levels up to 35 mg/l in water depths of 25 m (ABPmer, 2011). It can logically be assumed that in the shallower water depths such events would result in an elevation beyond 35 mg/l.

3.1.3 Impact Assessment

Monitoring evidence

Following recommendations made from the review of Round 1 monitoring activities, monopile OWF's are normally not required to monitor SSC levels as part of a FEPA licence. The exception, to date, remains at the Lynn and Inner Dowsing OWF. The particular concern here was the possibility of sub-surface chalk arisings leading to high levels of SSC of an atypical sediment type (ABPmer *et al.*, 2010). The result of sediment trap monitoring (located as close as 100 m from the operation) was that the chalk was not observed to collect in significant quantities; direct measurements of SSC were not possible during the works. Subsequently, it was found that the majority of chalk arisings were in the form of larger clasts that settled immediately to the bed and did not persist in suspension. This spoil pile was inspected four months after drilling and was found to have lowered to around 1m, from an initial height of over 3m, for a site average (per turbine) of displaced chalk c. 330 m³ at Lynn and c. 270m³ at Inner Dowsing, (ABPmer, 2010).

This example is relevant to the present study as there remains the possibility that drilling operations may be required to install some of the foundation structures and chalk horizons maybe encountered. However, it is worth noting here that the chalk encountered at Lynn and Inner Dowsing was mechanically strong whilst the chalk underlying the Rampion site is of moderate to weak strength (Fugro, 2011). The geological characteristics of the chalk will influence the size of the arisings and therefore the monitoring evidence from Lynn and Inner Dowsing may not represent a close analogue for the Rampion study.

Within the Rampion application area, the depth of the Holocene surficial sediments and thickness of the underlying sub-soils is highly variable. However, the 'worst case' scenario for chalk arisings will be represented by those foundations sited in areas where chalk is either at or very near to the surface and is encountered to a depth of over 50 m. On this basis, the greatest amount of chalk arisings is likely to occur in the northeast of the development, where chalk outcrops at the bed.

Numerical modelling assessment

To investigate the issue of chalk arisings during foundation installation, the Delft Particle Tracking Model has been used to predict the spatial extent and likely temporal duration of any plume arising and the fate of the suspended sediments. A range of turbine foundations are currently under consideration and have been detailed within the Project Description (Section 2a of the ES). The worst case scenario with regards to sediment arisings will be associated with the foundation type that has the potential to displace the greatest amount of chalk material during installation. On this basis, monopiles are considered to represent the worst-case option (Section 2.8.2). (It is noted that whilst GBS have the potential to displace a similar volume of material, it has been assumed that minimal bed preparation involving chalk removal would be necessary for these structures).

At this juncture it should be noted that the preferred installation method for steel monopiles is pile driving and this installation option will release a negligible amount of sediment. However,

an alternative installation method includes drilling to assist piling operations (“drive, drill and drive”) and this approach may be applied where ground conditions make driving impossible or difficult. Drilling represents the ‘worst-case’ installation scenario and therefore has been considered in the modelling analyses presented below. Although it is anticipated that this installation method will be used in conjunction with piling, it is theoretically possible that some monopiles will have to be installed entirely by drilling. At the time of the coastal process assessment, this scenario resulted in the maximum displacement of material of 1,470 m³. Recent engineering modifications have resulted in a revised volume of 1,824 m³ that could be released per 5 to 7 MW structure due to an increase in maximum pile diameter from 6 m to 6.5 m. Drilling will be undertaken using a ‘reverse circulation’ drill technique with the cuttings discharged directly onto the sea bed immediately adjacent to the foundation (Fugro-Seacore, 2012).

It must be noted that there are a number of uncertainties in determining how the chalk will breakdown during drilling. However, in the absence of any supporting engineering information, the highly conservative assumption of 100% dis-aggregation into component particle sizes has been made. This has been simulated by looking at the release of silt sized material (20 µm) and coarse sand sized material (750 µm). In reality, it is highly probable that most of the drill arisings will arrive at the surface as larger clasts which will settle out immediately adjacent to the foundation.

Table 8. Summary of plume modelling input parameters for monopile installation

Variable	Input Parameter
Sediment Spill volume *	1,470 m ³
Pile penetration into seabed *	52 m
Pile external diameter *	6 m
Minimum time to install one monopile *	8 hours
Minimum time between monopile installations *	72 hours
Release point for arisings *	Bed
Total duration of model run (days)	15 days
Total number of plume releases	5
Sediment type	Chalk
Approximate relative moisture content**	20 %
Dry Sediment Density**	1,760 kg/m ³
Rate of (dry) sediment release	90 (kg/s)
* Derived from E.ON (2012) ** Derived from Fugro (2011) Of note is that some variables have been modified following engineering considerations made since this coastal process assessment. 1,824 m³ of sediment may now be released for a pile diameter of 6.5 m. It is also now considered that the minimum time between monopile installations is 48 hours.	

Installation of a single monopile could take from 8 to 24 hours (if the geology proves to be particularly difficult). The highest SSCs will result from the fastest rate of installation and as such, it has been assumed that each foundation installation takes 8 hours. It is now understood that, since the time of the coastal process assessment, the 3 day (72 hour) gap between sequential foundation installations has been reduced to a 2 day (48 hour) gap. It is also expected that there will not be multiple concurrent foundation installations at the site. (Even if two installation vessels were deployed, to reduce noise impact only one monopile would be

driven at a time. Since drilling would be a contingency measure, a drill would only be made available on one vessel).

The results of the numerical plume dispersion simulations for the release of 1,470m³ of coarse sand sized (750 µm) and silt sized (20 µm) material are presented as depth averaged suspended sediment concentration elevations (above background concentrations) throughout a neap-spring tidal cycle (15 days) (Figure 5 and Figure 6, respectively). A model run of this duration should reveal maximum plume concentrations and excursions since the former are expected to occur during neap tides whilst the latter are anticipated to coincide with spring tidal conditions. In total, five sediment releases occur during this 15-day period. On the basis of Figure 5 and Figure 6, it is evident that:

- Peak SSCs are encountered when installation is occurring during slack water (i.e. around the time at which the tide turns) and are associated with the release of 750 µm sized material. This is seen towards completion of the first foundation installation which is associated with peak depth averaged SSCs of up to 200 mg/l across an area of ~ 0.5 km. However, concentrations of this magnitude are unlikely to persist for more than a few hours;
- The longest excursion from an individual installation is associated with the release of 20 µm sized material during spring tide conditions. These conditions are experienced during installation of the third foundation (i.e. day 7). During this foundation installation, a plume extends across a distance of approximately 8 km from the release point although concentrations are typically <10 mg/l;
- After 72 hours (immediately before the installation of the second foundation), the plume originating from installation of the first foundation has dispersed away from the release location as a result of advection and diffusion. Indeed, both the silt and coarse sand sized plumes have concentrations typically <20 mg/l and are found to the east of the release location;
- After ~ 13 days (and following installation of the fifth foundation), material from the first four foundation installations has been advected to the east-northeast in accordance with residual tidal flows across the far-field. Elevated SSCs are observed ~15 km from the installation locations although depth-averaged concentrations at this distance are typically <5 mg/l; and
- After 15 days (such that no installation works have been undertaken for a total of 88 hours), the material from all foundations has been advected away from the source in response to the residual tidal flows across the far-field. Elevated SSC's are observed over a similar area to that shown after 13 days with depth-averaged concentrations typically being no greater than 5 mg/l.

The numerical modelling undertaken here introduces a high level of conservatism as it assumes that:

- Each monopile will be installed using drilling techniques in its entirety. It is noted that piling remains the preferred installation option;
- 100% of the sediment released during drilling operations is mechanically disaggregated into fine particles. Therefore the chalk will not have the opportunity to form larger cuttings which would most likely fall out of suspension adjacent to the

foundation. As discussed previously in Section 3.1.3, monitoring evidence indicates that this is the most likely process when drilling into chalk;

- Each installation will take only 8 hours (Section 2a of the ES notes that this activity could take up to 24 hours). Thus, the largest sediment volumes are released over the shortest time periods; and
- No downtime occurs due to, for example, unfavourable weather. A total of 190 days would be required to install all 95 monopile foundations via drilling.

Engineering considerations undertaken following the numerical simulation of the 6 m diameter monopiles have resulted in, approximately, a 20% increase in the sediment volume (i.e. from 1,470 to 1,824m³) that could be released per monopile should drilling methods be used for installation. A similar increase in the resultant SSC values would be expected, such that orders of magnitude remain as modelled and presented above. In addition, the minimum length of time between installations has reduced from 72 hours to 48 hours. Of note is that a shorter time period between successive sediment releases will only affect the finer sediments. A consideration of sediment mobility within the study area indicates that coarser sediments will fall out of suspension relatively quickly, with this material only being mobile under peak spring periods (ABPmer, 2011).

The highly conservative assessment discussed here would indicate that, away from the foundation locations, SSC are unlikely to be significantly elevated beyond that modelled. Dispersion of the suspended sediments away from both the sediment source (foundation) and array occurs after, approximately, 48 hours following the commencement of works. It is the spatial extent of any elevated concentrations (above background levels) that has a greater potential to increase.

To place these findings in perspective, Section 3.1.1 shows that surface SSC concentrations are typically:

- Between 5 and 9 mg/l during winter months; and
- Between 1 and 3 mg/l during summer months (Eggleton *et al.*, 2011).

Further, storm events are shown to elevate near-bed SSC levels to 35 mg/l within the application site (ABPmer, 2011). Therefore, the SSC increases resulting from foundation installation through drilling are unlikely to be greater than that which occurs as a result of natural variability and will exist for the short-term only.

The effects of foundation related construction activities with respect to SSC are considered to be of small magnitude, have only a limited spatial effect and are temporary on time-scales similar to duration of installation. The potential effect is therefore considered of **minor significance**.

3.2 Potential Impact: Accumulation of Sediment and Change of Sediment Type at the Seabed as a Result of Foundation Installation Activities

3.2.1 Overview

The source of this impact is the chalk introduced into the water column which settles to the seabed resulting in a spatially varying thickness of sediment accumulation. The thickness of the accumulated sediment depends upon the total volume initially released and the rate and extent of dispersion from the source. This is in turn dependant upon the grain size, water depth and any tidal flows. Where the grain size of the re-deposited sediment is greatly different from that normally present at the seabed surface, the superficial textural properties may be changed. The relative change will be in proportion to the thickness of the deposit and the extent of grain size difference.

3.2.2 Baseline Conditions

The baseline characteristics of the sediment transport and morphological regimes are summarised within this section. For further detail, the reader is referred to ABPmer (2011). This information is derived from existing literature, in addition to the calibrated numerical model and in-situ measurements and observations.

Water depths range between 18 and 61 m (CD) within the Site Development Area, varying also temporally by 2.8 to 5.7 m on hourly timescales resulting from tidal behaviour. The sea bed level may vary naturally on similar timescales in the order of centimetres to decimetres, primarily during storm events and due to bedform migration and the fluidisation / reconsolidation of the sea bed.

With respect to the superficial sediment deposits, the benthic, geophysical and geotechnical surveys (Osiris Projects, 2010; Fugro Geoconsulting, 2011) indicate the presence of a thin (2 m thick or less) veneer of relatively frequently mobile sands, sandy gravels and gravelly sands, underlain by various types of erosion resistant bedrock and/or alluvium.

3.2.3 Impact Assessment

Sediment released into the upper water column during installation works will be transported with ambient tidal currents and will be subject to general processes of dispersion, deposition and re-suspension over time.

To quantify the likely magnitude and extent of the thickness of sediment deposition, currents simulated by the tidal model were used in conjunction with a plume dispersion model. The resulting sediment thickness deposited is calculated as the equivalent sediment volume of particles deposited to the bed in each cell, divided by the grid cell area. The plume model only considers the ability of tidal currents to transport sediments. In practice, storm events will result in additional sediment resuspension and dispersion.

Following completion of the five representative foundation installations into chalk over a 15 day period, as discussed in Section 3.1, bed level changes are observed up to a distance of

approximately 20 km from the release locations (Figure 7). The largest bed level changes are associated with the release of 750 μm sized material, with changes of >0.2 mm occurring in places. However, for the most part the deposited sediment layer will be less than <0.1 mm and it is anticipated that under the prevailing hydrodynamic conditions, this material will be readily re-mobilised.

The effects of foundation related construction activities with respect to seabed levels are considered to be of small magnitude, have only a limited spatial effect and are temporary on short term time-scales. The potential effect is therefore considered of **minor significance**.

3.3 Potential Impact: Increase in Suspended Sediment Concentration, Bed Level Change and Seabed Textural Change Following Re-deposition of Suspended Sediments as a Result of Inter-Array Cable Burial and Export Cable Burial Activities

3.3.1 Overview

Local increases in suspended sediment concentrations may also result from the disturbance of sediment by cable installation activities. This mobilised material may then be transported away from the disturbance by the tidal and wave regimes. According to the source-pathway-receptor model:

- Cable installation is considered as the *source* of potential changes to suspended sediment concentrations in the water column;
- Tides and waves act as the *pathway* for transporting the suspended sediment; and
- The *receptor* is a feature potentially sensitive to any increase in suspended sediments and consequential deposition.

The main concerns resulting from any increases in SSC relate to impacts on pelagic species / fisheries whilst those resulting from accumulations in sediment and changes to sediment type relate to, for example, smothering of benthos. These are covered elsewhere in the ES.

The impact of cable burial operations mainly relates to a localised and temporary resuspension of sediments (BERR, 2008) and the exact nature of this disturbance will be determined by the soil conditions along the cable routes, the length of installed cable, the burial depth and burial method.

3.3.2 Baseline Conditions

Regional assessments of SSC levels within the study area indicate surface values of between 5 to 10 mg/l during winter months and generally <3 mg/l during the summer period (Eggleton *et al.*, 2011). Whilst only within the application site, near-bed (0.5 m above the seabed) SSC levels range between 5 to 10 mg/l, although values exceeding 10 mg/l also frequently occur (EMU, 2011). It is noted that surface values are typically less than those experienced towards, and at, the seabed.

Higher turbidity measurement values are observed in shallower water depths such as those encountered along the export cable corridor. Elevated levels have also been shown to occur during storm events where wave heights in excess of 3 m are shown to increase SSC levels up to 35 mg/l in water depths of 25 m (ABPmer, 2011). It can logically be assumed that in the shallower water depths such events would result in an elevation beyond 35 mg/l.

Maximum seabed depths across cable corridor are up to 23 m (CD) and are observed in the extreme southwest corner (Figure 1) whilst the shallowest depths occur at the cable landfall. The seabed gently dips towards the south-southeast with gradients $<0.5^\circ$. Mega-ripples (which are considered to be active) are present along the cable corridor, whilst sediment transport relict bedforms and geological structures include rock outcrops, rock ridges and a network of steep-sided buried north to south trending palaeochannels.

3.3.3 Impact Assessment

Inter-array cable burial

The inter-array cable infrastructure is ultimately dependant upon the final project design but the current estimates are that the total length of array cables for the 700 MW development will be, approximately, 230 km. Intended cable burial depth is to 1 m. Accordingly, the total volume of sediment released is 115,000 m³. It is anticipated that any SSC plumes (and associated bed level changes) resulting from the installation of inter-array cables will be subordinate to the effects of monopile installation within the zone (173,280 m³ for all 95 foundations), which will occur on different schedules. Accordingly, this aspect of the construction phase is not considered further.

Export cable burial

The export cable corridor runs from the north of the project boundary to the shore and varies in width ranging from 20 km at the project boundary to 500 m at the shore (Figure 1). The route covers a distance of, approximately, 13.75 km. The four cables will be installed with a separation distance of, at least, 50 m and each of the four export cables will be installed separately. The offshore export cable will be buried at a target depth of 1 m below the seabed superficial deposits. Reference to the geophysical and geotechnical surveys suggests that chalk is either at or very near to the surface across the entire cable corridor and it is likely that a trenching tool will be required to achieve the 1 m burial depth in this substrate. It is anticipated that this technique will break the exposed surface layer of chalk into large clasts that will be deposited immediately adjacent to the trench and that any chalk suspended sediment plume will be short lived, of low concentration and very localised.

In places, the chalk is overlain by a mobile Holocene layer of up to 3.7 m thickness and comprised of medium sand, locally with gravel and shell (Fugro Geoconsulting, 2011). Because of the unconsolidated nature of these surficial deposits, it is possible that a jetting tool may be employed to install the cable. This method involves a remotely operated trenching unit which utilises high-pressure water jets to fluidise the sediments within a narrow (0.5 m wide) trench into which the cable is placed. This technique typically results in sediment suspension, introducing a potential for mobilisation over a wider area than for other cable laying techniques

which may be employed during construction. The geological and geomorphological sea bed characteristics will determine the sediment type disturbed during the cable burial operations whilst the degree of mobilisation is also dependant upon the wave and current conditions. For the purposes of this assessment a worst-case scenario is presented whereby the cable is buried in (medium) sand to a depth of 3 m along the entire cable corridor. This represents a highly conservative assessment since (i) for much of the cable route, chalk outcrops at the seabed and surficial sediments are less than 3 m in thickness; and (ii) gravels are also present in the surficial sediment unit and these will settle out immediately adjacent to the cable trench.

Within this study, the effects of cable jetting have been assessed using (i) results from previous monitoring campaigns and (ii) numerical modelling analyses.

Monitoring evidence

SSC monitoring during cable laying operations has been undertaken at Nysted wind farm. During the works, both jetting and trenching were used, where the latter method involves pre-trenching and back-filling using back-hoe dredgers. Superficial sediments within the site were pre-dominantly medium sands, approximately 0.5 m to 3 m in thickness, underlain by clay. SSC was recorded at a distance of 200 m from jetting activities and it was shown that the mean turbidity values over depth remained below the pre-defined threshold (45 mg/l) and that of the average values (15 mg/l).

Cable laying monitoring has also taken place at Kentish Flats where ploughing methods were used to install three export cables (EMU, 2005). CEFAS agreed pre-defined threshold limits against which suspended sediment concentration monitoring would be compared. The monitoring 500 m down-tide, i.e. where the concentrations will be greatest, of the cable laying activities showed:

- Marginal, short-term increases in background levels (approximately a 9 times increase to the modal concentrations); and
- Peak concentrations occasionally reaching 140 mg/l (equivalent to peaks in the natural concentrations).

The observations at Nysted and Kentish Flats provide confidence that cable laying activities do not create a long-term, significant disruption to the background sediment concentrations. Further, it also illustrates that there is little sediment dispersal, indicating that there is unlikely to be any significant deposition on the sea bed at considerable distances from the cable route. This supports previous numerical modelling studies, such as that undertaken for the Cromer wind farm. Here, 90% of the sediment suspended during the cable installation was re-deposited onto the sea bed within a very small distance of the activity. The remaining 10% of suspended sediment were dispersed in concentrations that were negligible when compared to the background concentrations (Posford Haskoning, 2002).

The post-burial impacts of cable burial on sandy sea bed morphology were also considered by BERR (2008) and concluded to be limited in terms of both the thickness of re-deposited sediments and the potential for affecting the surficial sediment type:

“The low levels of sediment that are mobilised during cable laying mean that there will be only low levels of deposition around the cable route. The finer material will generally remain in suspension for longer but will settle and remobilise on each tide with no measurable material left in place. Coarser sediments are expected to settle within a few metres of the cable route and following disturbance are likely to recover rapidly, given similar communities in the vicinity.”

Numerical modelling assessment

Numerical modelling has been used to simulate the effects of the export cable laying activities. Reference to Figure 8 reveals that:

- Peak depth-averaged SSC's are encountered when the installation of the cable is taking place in very shallow (~ 5m CD) water depths close to the shore. Here, maximum concentrations of ~200 mg/l are predicted although these concentrations are typically very localised (i.e. <2 km) to the cable trench;
- In the deeper water depths encountered at the seaward end of the cable corridor, peak depth-averaged SSCs are typically less than 100 mg/l; and
- After 90 hours (and following completion of the cable trenching activities), the plume has dispersed as a result of advection and diffusion with residual concentrations of 5 to 10 mg/l observed at a distance of ~5 km to the east of the cable trench.

To place these findings in perspective, Section 3.3.1 shows that **surface** SSC concentrations are typically:

- Between 5 and 9 mg/l during winter months; and
- Between 1 and 3 mg/l during summer months (Eggleton *et al.*, 2011).

It should be noted that the residual plume concentrations shown in Figure 8 are likely to be overly conservative since the plume dispersion model takes into consideration the potential for re-mobilisation of the sediment arisings into the water column once they have settled to the bed. However, any released sand sized material is predicted to quickly settle out of suspension persisting in the water column for no more than a few tens of minutes. Once this material has settled to the bed, it would quickly be incorporated into the natural mobile bed regime.

Following completion of the cable jetting activity, bed level changes of up to 1.5 mm are observed in close proximity (<200 m) from the cable trench and between 0.5 and 1 mm up to a distance of approximately 3 km from the release locations (Figure 7). However, it is anticipated that under the prevailing hydrodynamic conditions, this medium sand sized material will be readily re-mobilised, especially in the shallow nearshore area where waves will regularly stir the bed.

The effects of cable related construction activities with respect to SSC and bed level changes are considered to be of small magnitude, have only a limited spatial effect and are temporary on temporary on time-scales similar to duration of installation. The potential effect is therefore considered of **minor significance**.

3.4 Potential Impact: Indentations on Seabed Left by Vessels (Vessel Jack-up and Anchoring Operations)

3.4.1 Overview

There is the potential for certain vessels used during the installation of the wind farm infrastructure to directly impact the sea bed. This applies for those vessels which utilise jack-up legs or a number of anchors to hold station and to provide stability for the working platform. Where legs or anchors have been inserted into the sea bed and then removed, there is the potential for an indentation proportional to the dimensions of the object to remain. The volume and dimensions of the depression may reduce over time in proportion to the rate of sediment transport through the area. The presence of such a feature does not necessarily imply a difference in sedimentary environment in the area of effect, but this will depend upon the nature and depth of the sub-surface sediments.

3.4.2 Baseline Conditions

Baseline conditions with regards to water depths, sediment transport and morphological regimes (including natural variability in seabed level) are described in ABPmer (2010).

Of relevance to this particular assessment is the natural spatial variability in water depth within the array. The water depths range between 18 and 61 m (CD), varying also temporally by 2.8 to 5.7 m on hourly timescales resulting from tidal behaviour. The sea bed level may vary naturally on similar timescales in the order of centimetres to decimetres, primarily during storm events and due to bedform migration and the fluidisation / reconsolidation of the sea bed.

Of note is that the character sedimentary environment across the part of the site where turbines will be installed is summarised as: a thin (2 m thick or less) veneer of relatively frequently mobile sandy gravels, underlain by various types of erosion resistant bedrock and/or alluvium (Fugro Geoconsulting Ltd (2011) and Osiris Projects (2010).

3.4.3 Impact Assessment

Jack-ups

The Project Description (Section 2a of the ES) suggests that a single jack-up barge leg will have a footprint of approximately 75 m². The typical estimated penetration depth of a leg is assumed to be 5 m. However, it is important to note that surficial sediment cover across much of the site is thin and in those areas where bedrock is at or close to the surface, leg penetration is anticipated to be much less than 5 m.

As the leg is inserted, the already partially consolidated seabed sediments will primarily be compressed downwards and then displaced laterally sideways. This may cause the seabed around the inserted leg to be raised in a series of concentric pressure ridges. The seabed response is dependant upon the actual dimensions of the leg and the soil's local geotechnical properties.

As the leg is subsequently retracted, the force which is holding the sediments laterally will be reduced. Some of the material that has been previously pushed sideways will return to the hole via mass slumping under gravity. Any loose sediment will avalanche back into the depression until a maximum stable slope angle achieved.

The sedimentary texture of the pit surface is likely to be similar to that of the surrounding seabed because no sediment is introduced or removed by the jack-up leg and the sediment veneer is considered to be relatively uniform within the upper 2 m.

Over the short to medium term, the pits will tend to become shallower and less distinct in response to storm events which will resuspend the raised sediment material around the pit edges and either redeposit it into the pit or transport it elsewhere. Whilst there may be an initial tendency for some sediments being transported through the area to accumulate in the pits, this will reduce rapidly as the pits infill.

Rates of sediment transport associated with a range of combined wave and current conditions normally present within the site have been presented in ABPmer (2011). Here it is shown that, due to tidal control, superficial sediment is mobilised through most tidal states. This timescale would be further reduced during larger wave events which act to enhance sediment mobilisation. Such events occur, approximately, 5 to 20% of the time during the year. It is therefore considered that any pits would be infilled over short- to medium timescales.

The effects of jack-up legs are confined to the array and do not overlap with any coastal process receptors. Accordingly the effects are considered to be of small magnitude, have only a localised effect and are temporary on medium term time-scales. The potential effect is therefore considered of **negligible significance**.

Anchors

It is possible that an array of four to six anchors could be used by work vessels to both hold position and provide stability during on-site operations. Anchors used by such large vessels are typically smaller than the jack-up legs previously described and exert their force differently upon the seabed. It is assumed that, for one anchor, the length-scale of the main body is of the order of 1.5 to 3 m.

The degree of interaction between the anchor and seabed will vary depending upon the particular design of anchor used. The anchor will initially fall to the seabed under its own weight, causing minimal impact disturbance in its own footprint. The anchor will then be pulled horizontally across the seabed for some distance to allow the flukes and crown to penetrate the seabed. This may result in a short, shallow furrow. Once embedded in the seabed, a sediment ridge will arise in front of the anchor in the direction of pull, partially accumulated from the furrow and partially pushed up by the horizontal pressure on the bed from the anchor pull.

To release the anchor, the connecting wire or chain is tensioned vertically, levering the flukes out of the sediment. The anchor is then retrieved through the water column, either to the main vessel or by an anchor handling vessel for redeployment. The act of removing the anchor in

this way will redistribute much of the accumulated sediment back to the seabed around or into any remaining hole.

The footprint of the disturbance remaining soon after an anchor's removal will be approximately similar to the size of the anchor (1.5 to 3 m). The character of the disturbance may be highly variable (chaotic ridges and depressions) within the footprint of effect. In the worst case, the maximum depth of a conical pit with these footprint dimensions (assuming a stable slope angle of 32°) is 0.47 to 0.94 m.

The sedimentary texture of the disturbed surface is likely to be similar to that of the surrounding seabed because no sediment is introduced or removed by the anchor and the sediment veneer is considered to be largely uniform (sand or gravely sand) within the upper 2 m.

In the short to medium term, the disturbed surface will be reworked and flattened to a baseline condition by waves and currents during storm events. No potential to intercept regional sediment transport is expected because the sediment is essentially only locally redistributed in a small footprint.

Rates of sediment transport associated with a range of combined wave and current conditions normally present within the site have been presented in ABPmer (2011). Here it is shown that, due to tidal control, superficial sediment is mobilised through most tidal states. This timescale would be further reduced during larger wave events which act to enhance sediment mobilisation. Such events occur, approximately, 5 to 20% of the time during the year. It is therefore considered that any pits would be infilled over a few tides.

The effects of anchors are confined to the array and do not overlap with any coastal process receptors. Accordingly these are therefore of small magnitude, having only a localised effect and are temporary on short term time-scales. The potential effect is therefore considered of **negligible significance**.

3.5 Potential Impact: Disruption to Coastal Morphology at Export Cable Landfall

3.5.1 Overview

Where the export cable makes landfall, it must transit through the intertidal zone. A variety of methods are available for installing cable in such environments and these will physically disturb or disrupt the present intertidal morphology to differing degrees. The Project Description (Section 2a of the ES) states a preference to use HDD techniques at landfall, in an onshore to offshore direction. At the time of construction, any disturbance will be localised to the landfall site.

3.5.2 Baseline Conditions

The export cable landfall window has been identified at East Worthing (Figure 1). The coastal characteristics are described in ABPmer (2011) and summarised below. Of note is that there are no conservation designations at the point of landfall.

Based upon the imagery shown in Figure 9, it is possible to observe that the beach and intertidal areas are relatively wide and primarily composed of shingle sized material. Areas of exposed rocky ground are visible over discrete areas of the beach within the landfall site, although this is more obvious from the 2005 image rather than the 2001 and 2010 images. It can be inferred that the sediment is mobile at this location. It may be that the 2005 image was taken following a storm event, in which case beach material is more likely to be mobilised away from the shore.

A pipeline and outfall are also shown to the west and east, respectively, of the landfall site which is shown for the period 2001 to 2010 to be in varying levels of exposure.

The distribution of the superficial sediment veneer is evidently spatially variable in thickness and controlled in part by the presence of regular cross-shore groynes (straight wooden structures in 2001) and rubble mound structures (2005 and 2010). As shown in Figure 9, the images are broadly consistent between images taken in 2001, 2005 and June 2010, suggesting that the general distribution of the sediment veneer is not necessarily highly temporally variable. A greater width of sediment accumulation on the eastern side of the groynes is consistent with the conceptual understanding of the area (net sediment transport to the east).

3.5.3 Impact Assessment

Horizontal Directional Drilling (HDD) is historically considered to cause minimal direct disturbance to the existing coastline as, if correctly designed, the works will not interact directly with or leave any infrastructure exposed in the beach's active parts and so will not impact upon littoral processes in these areas. This will require that the offshore exit point of the HDD be located sufficiently far offshore that a sufficient sediment thickness will remain present for the cable's operational lifetime to enable cable burial to the required depth. Provided that the cable remains buried beyond the exit of the HDD, there is no possibility for it to interact with, or have any effect on nearshore beach processes or morphology. The design of the HDD operation will take this into account.

Geophysical (Osiris Projects, 2010) and geotechnical (Fugro Geoconsulting Ltd, 2011) surveys indicate a thin veneer of sediment over the bedrock, which may require for the cable to be inserted into a shallow trench cut into the underlying rock platform (and possibly backfilled or otherwise protected). In this way, if the superficial sediment veneer is reduced or removed by natural processes, the cable will remain flush with or below the lowest possible seabed surface, ensuring no potential for interaction.

Climate change will lead to mean sea level rise and so will not affect the location chosen on the basis of present day bathymetry and water depths.

Whilst a key focus in the assessment of potential cable laying impacts relates to the direct disturbance of sediment from the laying tool there is also a potential for further localised and short-term impacts from vessels and equipment that might be used to support cable burial, especially if the burial tool is not self-propelled and must be pulled through the sediment.

Typical examples might include the use of an anchor barge and support vessels used to manoeuvre the barge. In deeper water these vessels are unlikely to exert any influence onto the seabed other than when anchors are deployed, but in very shallow water, such as areas close to the landfall, then vessel activities may lead to additional sediment disturbance. The significance of these potential impacts cannot be quantified fully at this time as the detailed approach to cable laying and the vessels involved are unknown, however a well-considered cable laying plan should be able to offer sufficient mitigation.

The effects of HDD works upon coastal morphology are therefore of small magnitude, having only a localised effect and are temporary on short term time-scales. The potential effect is therefore considered of **negligible significance**.

4. Coastal Processes Assessment: Operational Phase

4.1 Potential Impact: Scour Effects Due to the Presence of the Turbine Foundations

4.1.1 Overview

Water movements in the marine environment (by currents or wave action, either alone or in combination) will interact with obstacles such as wind farm turbine foundations. These interactions modify the flow, typically resulting in localised patterns of flow acceleration and/or an increase in turbulence. Such effects can lead to a corresponding (relative) increase in sediment transport potential in the affected areas, which ultimately results in the scouring (net removal) of sediments and the development of a scour pit.

The following assessment provides a conservative estimate of the dimensions of scour pits that might potentially develop around unprotected foundations of the type and dimensions proposed for the Rampion Wind Farm. The methods and assumptions used are considered suitable for the purposes of EIA (estimation of area of effect and volumes of sediment mobilised) but are not intended for use in detailed engineering design.

Where it does develop, scour will result in a morphological change (local development of seabed slopes) but will not necessarily change the sediment character in the affected area.

Should scour protection be installed, development of the local scour described in this section will be inhibited; however, the scour protection materials are more likely to represent a modification to the normally present seabed character. The area of seabed directly affected by scour protection is likely to be similar to the area potentially affected by scour and can be estimated on this basis for the purposes of EIA. Depending on the materials used, scour protection may also interact with any flows present, potentially causing 'secondary' scouring of the surrounding sediments. The depth of secondary scour is not easily predicted but is typically of a much smaller magnitude than primary scour (in proportion to the dimensions of the obstacle) and so is not considered further in this section.

4.1.2 Baseline Conditions

The geotechnical (Fugro Geoconsulting Ltd, 2011) and geophysical (Osiris Projects, 2010a; 2010b; 2010c) surveys indicate that the character of the sedimentary environment across the part of the site where turbines will be installed can be summarised as a thin (2 m thick or less) veneer of relatively frequently mobile sandy gravels, underlain by various types of erosion resistant bedrock and/or alluvium.

Scour to the northeast and southwest of a number of wrecks has been identified within the geophysical survey within the northern sector of the project area (Osiris Projects, 2010), indicating that scour is an active process within the study area and requires consideration for infrastructure that interacts with the seabed. The extent of the scour is ultimately dependant upon the dimensions of the wreck, its orientation to the tidal flow and the availability of erodible

sediment. Of interest is a large wreck measuring 800 m wide and 10 m high, observed to the south of the project area in water depths typically greater than 40 m (LAT). It is lying perpendicular to the dominant flow and in an area of relatively deep superficial sediments where sandy gravel sediments are up to 20 m thick. Here, recorded scour extent and depths are of the order of up to 120 m wide and 18 m deep, with its direction related to the tidal flow orientation (Osiris Projects, 2010).

4.1.3 Impact Assessment

This section provides a summary of the scour assessment undertaken, for full details the reader is referred to Appendix B.

Scour depth at each turbine foundation is likely to be limited to the thickness of the locally present marine sands (up to 2 m) by the presence of relatively erosion resistant underlying soils. This assumption also leads to a corresponding limitation on the likely extent, area and volume of seabed affected by scour pits.

Individual scour pits will be generally characterised as a local modification to bathymetry (typically a depression) around an unprotected foundation base with associated sloping sides. The texture of the seabed surface in the pit will likely be a mixture of exposed bedrock and/or sediment with a greater proportion of coarser material than previously present. The actual nature and proportion of each will depend on the thickness and particle size distribution of the marine sediments locally present. Scour pit dimensions might be smaller than predicted in those parts of the site where a significant proportion of gravel is present in the marine sediments, due to the development of a gravel lag layer which may armour the pit surface as finer sediment is winnowed away.

Tables 9 and 10 show that the dimensions of individual scour pit features are predicted to be relatively smaller than the scale of the associated foundations. As such, individual scour pits are considered unlikely to coalesce between foundations and possibly even also between individual members of some larger multi-member foundations. Long scour tails extending from any local scour pits have been observed at Scroby Sands wind farm, created by tidal asymmetry and associated with very rectilinear tidal current patterns. Due to the fact that the tidal currents rotate (around 30 °) during each half tidal cycle at the Rampion Wind Farm site, there is considered to be very little likelihood of this occurring in this location. Therefore it is considered unlikely that the scour related to each foundation will remain separate with the absence of any group scour.

Cumulatively, scour pits will affect only a small proportion of the seabed area in the vicinity of the turbine array (typically <0.15% for slender member foundation types and <0.3% for GBS and suction caisson foundations).

The potential for scour effects resulting from the presence of foundation structures on the seabed are considered to be of limited magnitude, have only an array scale spatial effect and are permanent on medium term time-scales. The potential effect upon sediment dynamics is therefore considered of **minor significance**.

Table 9. Estimated scour pit dimensions at the Rampion Wind Farm

Parameter	Structure											
	Monopile		Jacket		Twisted Jacket		Tripod		Gravity Base		Suction Caisson	
	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest
Equilibrium Scour Depth (m)												
Local	2.0	2.0	1.1	1.1	1.4	1.2	0.8	0.8	2.0	2.0	2.0	2.0
Group			0.9	0.9	0.9	1.1	1.2	1.2				
Scour extent from footprint** (m)	5.5	6.2	2.9	2.9	3.0	2.9	2.8	2.8	15.2	20.0	15.7	20.7
Scour footprint** (m ²)												
Local (exec. structure)	170	238	187	187	172	183	151	151	1,872	3,350	2,008	3,622
Group (exec. structure)	-	-	573	1,190	1,005	2,028	595	595	-	-	-	-
Structure alone	15.9	28.3	16.6	16.6	8.7	14.3	21.2	21.2	452.4	881.4	490.9	962.1
Scour volume** (m ³)												
Local (exec. structure)	218	322	128	723	132	183	86	86	3,229	5,994	3,480	6,509
Group (exec. structure)	-	-	527	622	591	2,028	713	713	-	-	-	-
Total (exec. structure)	218	322	655	1,345	723	2,211	799	799	3,229	5,994	3,480	6,509
Bed prep. volume (m ³)	668	1,470	565	622	622	1,247	657	848	905	1,763	2,945	6,735
* Bed prep volume negligible if corner piles are inserted without drilling. ** Based upon the local scour for steady currents. Footprint and volume values per foundation.												

Table 10. Total estimated foundation and scour pit footprint at the Rampion Wind Farm

Parameter	Structure											
	Monopile		Jacket		Twisted Jacket		Tripod		Gravity Base		Suction Caisson	
	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest
Number of foundations	175	100	175	100	175	100	175	100	175	100	175	100
Seabed footprint of all foundations (m ²)	2,783	2,827	2,908	1,662	1,518	1,433	3,711	2,121	79,168	88,141	85,903	96,211
Proportion of total site area (%)	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.047	0.053	0.051	0.058
Seabed footprint of local scour (m ²)	29,819	23,767	32,778	18,730	30,086	18,272	26,506	15,146	327,600	335,012	351,324	362,239
Proportion of total site area (%)	0.018	0.014	0.020	0.011	0.018	0.011	0.011	0.009	0.196	0.201	0.210	0.217
Seabed footprint of group scour (m ²)	-	-	100,280	119,026	175,855	202,800	104,046	59,455	-	-	-	-
Proportion of total site area (%)			0.060	0.071	0.105	0.121	0.062	0.036				
Seabed footprint of all foundations and scour (m ²)	32,602	26,594	103,188	120,687	177,372	204,233	107,757	61,575	406,768	423,153	437,227	458,450
Proportion of total site area (%)	0.020	0.016	0.062	0.072	0.106	0.122	0.065	0.037	0.244	0.253	0.262	0.275

4.2 Potential Impact: Scour Effects Due to the Exposure of Inter-array and Export Cables and Cable Protection Measures

4.2.1 Overview

Any structure introduced into the marine environment which is located near or onto the seabed will interact with the hydrodynamic and sedimentary regimes, potentially resulting in the occurrence of sediment scour. Sediment removal from underneath a section of cable exposed on the seabed could result in free-spanning and further sediment erosion. Exposed cables are also at greater risk of physical damage. Exposure and scour is primarily an engineering risk which is often mitigated using cable burial and scour protection.

It is currently considered within the Project Description (Section 2a of the ES) that cable burial will reach the target depth of 1 m *below* the superficial seabed sediments, which could reach 3 m below the seabed. Should burial not be achieved, some protection may be required. There are two known redundant telecommunication cables within the project area, although the geophysical survey was unable to detect any linear features relating to these (Osiris Projects, 2011). It is considered that any sections of these cables which interact with the inter-array or export cables will be removed (Section 2a of the ES).

The source of the potential impacts considered in this section are the interaction between the naturally present metocean regime (waves and currents) and sections of cable or cable protection measures exposed on the seabed surface during the operational phase of the development.

Cable exposure has the potential to cause localised sediment scouring resulting in a depression and/or a relative change in sediment character that will persist until the cable is either buried or otherwise removed. The scour extent and depth may vary over time and may be limited under certain physical conditions; however, a conservative approach will be applied to calculating the maximum expected dimensions independent of other factors. Depending upon the nature of the seabed surface sediments, the presence of a depression does not necessarily imply a difference in sedimentary environment in the area of effect.

Cable burial can be undertaken to reduce the risk of snagging or other direct contact damage and therefore normally, and as planned for this project (Section 2a of the ES), no scour risk exists. Cable burial may not be possible at the j-tube exits of the foundations, in areas with unsuitable seabed soil conditions, or at crossing points with other cable or pipeline infrastructure. In these situations, scour protection measures are typically used to mitigate the risk of scour and other damage and will largely prevent scour developing. However, the area occupied by the scour protection might also be considered as a modification to the sedimentary environment and may result in localised secondary scour or (depending on the dimensions and orientation) pose an obstacle to local sediment transport pathways.

4.2.2 Baseline Conditions

Scour to the northeast and southwest of a number of wrecks has been identified within the geophysical survey within the northern sector of the project area (Osiris Projects, 2010),

indicating that scour is an active process within the study area and requires consideration for infrastructure which interacts with the seabed. Scour features associated with existing exposed cable and outfall structures have not been shown to be present within the baseline environment (Osiris Projects, 2010). Details have been provided in previous sections for the baseline tidal, wave, sedimentary and morphological environments.

4.2.3 Impact Assessment

Export and inter array cables will range between 0.1 and 0.21 m in diameter (Section 2a of the ES)).

Whitehouse (1998) summarises various studies that provide empirical estimates of equilibrium scour depth underneath pipelines (which can be considered similar in principle to cables). The predicted scour depth is primarily dependant upon the cable diameter. Of note is that the cable must be almost entirely exposed for any local scour to occur and that an oblique orientation of the cable to the ambient hydrodynamic conditions will also reduce the predicted effect.

Should cable exposure occur, scouring of the underlying sediments may occur. If the cable is taut or stiff, cable sections may become elevated relative to the lowered bed level. If the cable is neither taut nor stiff then it will drop, remaining in contact with the seabed, irrespective of how much scour occurs. In these cases, cables and pipelines have been observed to self bury due to sediment accumulation in the depression, partially burying the obstruction, causing further scour to cease and allowing ambient sediment transport to refill the scour depression. Given the cable weight, if exposed, it is unlikely to be moved on the seabed by the naturally present hydrodynamic regimes.

The resulting equilibrium scour dimensions may vary under different circumstances and depending on the dominant forcing. A conservative estimate for all cases is that the maximum scour depth will be between one and three times the cable diameter (i.e. 0.11 to 0.63 m) and the maximum scour horizontal extent will be up to fifty times the cable diameter (i.e. 5 to 10.5 m). Any depression created will not necessarily be steeply sided. In predominantly sandy areas, the scour pit surface will be of similar character to the ambient bed. However, in more gravelly areas, a gravel lag veneer may initially form as finer sands are preferentially winnowed which then becomes buried with predominantly sandy material following seabed recovery (should self burial occur).

The effects of scour potentially resulting from the exposure of export and inter-array cables are considered to be of a small magnitude relative to the range of naturally occurring variability. Effects are also largely localised to the cable route, short term and temporary. The potential effect upon sediment dynamics is therefore considered of **negligible significance**.

4.3 Potential Impact: Changes to the Tidal Regime Due to the Presence of the Array Infrastructure

4.3.1 Overview

Modelling scenarios of the tidal properties for baseline and post-development conditions have been used to investigate the potential changes to the hydrodynamic regime and any consequential impacts upon sediment transport.

Locations across within the near and far-field were selected to investigate potential changes to hydrodynamic conditions under post development conditions. The hydrodynamic characteristics investigated include water level and current speed conditions.

As described in Section 2, the tidal regime acts as a pathway of change rather than a receptor. Consequential impacts of these changes to the tidal regime upon sediment transport are discussed in later sections.

4.3.2 Baseline Conditions

The baseline characteristics of the tidal regime, as detailed within ABPmer (2011), are summarised within this section. The baseline interpretation has been based on information derived from the metocean site surveys and additional data sources.

Water level

- On a west to east axis through the site and at the coastline, the tidal range increases by approximately 0.2 m. On a north to south axis, from the coastline to within the application site, the mean spring range decreases by approximately 0.3 m. Further observations on tidal range properties suggest that the variability in water levels is driven primarily by the tidal wave which propagates from west to east with increasing amplitude;
- The region is characterised by a macro tidal regime (maximum or typical tidal range between 4 and 6 m), based on a spring mean and maximum tidal range of 5.9 m and 7 m respectively; and
- There are small variations in the tidal regime across the OWF application site and far-field region, demonstrated through available co-tidal and co-range tidal information and metocean observations.

Current speed

Current speeds can be summarised as:

- The main current flow is directed along an east-northeast to west-southwest axis, where the flood tide is from the former and the ebb from the latter;
- Depth-averaged current speeds across the site are typically in excess of 1 m/s, with higher speeds in the southern part. Spring tide depth-averaged peak speeds of ~ 1.25 m/s are encountered at L3, compared to 1.04 m/s and 1.05 m/s at L1 and L2

- respectively (Figure 3). During neap tides, depth-averaged peak current speeds are typically half of those observed on spring tides, ranging between 0.4 and 0.5 m/s; and
- Marginally higher speeds are observed on the flood tide showing that the site is flood-dominant, with an associated flood residual particularly under spring conditions.

4.3.3 Assessment of Potential Changes to the Baseline Conditions

Turbine foundations have the potential to impact on the tidal regime as flows interact with the structures, affecting the tidal height (water levels), current speeds and directions. Any changes to the tidal regime may have a resultant impact on the sediment transport regime and therefore these potential changes require careful consideration. This section evaluates the potential impact of post development conditions on the tidal regime.

To quantify the likely magnitude and extent of interaction between operational schemes and the hydrodynamic regime, the Delft3D numerical model was run over a typical spring-neap tidal cycle (approximately 15 days). The model is capable of providing an accurate description of the potential changes to the hydrodynamic regime (water levels and currents) as a result of the proposed developments. Furthermore, the modelling reflects the realistic worst case development scenario as described in Section 2.8 and as such the results are conservative. Descriptions of these changes are described below.

Water levels

An understanding of the potential changes to water levels has been developed through a comparison of post-construction and baseline water levels. The changes predicted throughout the entire study area are all less than 0.01 m. When compared to those water level changes that may result from the natural process of sea level rise, which as described in the baseline is predicted to increase mean sea level by up to 0.5 m by the end of the century (Lowe *et al.*, 2009), it is clear that the potential effects of the proposed development are considerably smaller. These changes are therefore considered to be of **negligible significance**.

Currents

An understanding of the potential changes to current speeds is based upon the analysis of the spatial results over the entire spring-neap tidal cycle (Figure 10). However, potential changes to peak flow speeds are of particular importance because it is at these times that there is the greatest potential for sediment transport and the largest sized material may be subject to mobilisation.

Current speeds are shown to change throughout the tidal cycle within the array. A summary of the changes is presented below:

- The largest magnitude current speed changes occur as flow reductions, of up to 0.01 m/s, immediately in the lee of the gravity base structures. Reductions resulting from the monopile structures are smaller (i.e. less than 0.01 m/s). Reductions of this magnitude will not be measurable in practice.

- The greatest spatial extent of change occurs at the time of slack water (i.e. HW and LW). However, even at this time flow speed changes of 0.01 m/s are typically restricted to within the array boundary;
- The magnitude and spatial scale of the changes in flow speeds is marginally higher at times of peak flood. This is as a direct result of the relative magnitude of the baseline currents at these tidal states;
- Changes in flow direction (not shown) are extremely minor, and do not exceed 5 °; and
- Changes to current speed are not predicted to extend to the coast (far-field) and are limited to the near-field.

The effect of these potential changes to the flow regime upon sediment transport pathways within the offshore environment are considered further in Section 4.5.

4.4 Potential Impact: Changes to the Wave Regime Due to the Presence of the Array Infrastructure

4.4.1 Overview

Modelling scenarios of the baseline and post-development conditions have been used to investigate the potential changes to the wave regime. The wave characteristics investigated include the wave height, period and direction and have been considered for a range of locations within the array as well as across the far-field.

As described in Section 2, the wave regime acts as a pathway of change rather than a receptor. Consequential impacts and associated significance of potential changes to the wave regime upon sediment transport are discussed in later sections.

4.4.2 Baseline Conditions

The baseline characteristics of the wave regime, as detailed within ABPmer (2011), are summarised within this section. It has been based on information derived from metocean site surveys, additional wave records and numerical modelling, at a total of five individual locations (Figure 3), over periods ranging from 2 months to 13 years.

Observed properties of the wave regime, over the near- and far-field, are:

- The most frequent wave height throughout the near- and far-field is between 0.5 to 1 m (accounting for between 36 and 53% of the wave record);
- Maximum wave heights range from 5.61 m, as shown from the Seastates model seaward of the application site, to 3.26 m, as recorded by the metocean campaign;
- Wave direction changes occur from the offshore to onshore as a result of refraction effects as the waves approach shallow water. In the offshore, directions are most

commonly from the west-southwest to southwest and further onshore from the southwest. These dominant directions account for 30 to 40% of the wave record at all locations; and

- Whilst a wind-wave regime predominates, as demonstrated by the metocean campaign, swell conditions also occur within the study area (Bovington and Amos, 2010).

4.4.3 Assessment of Potential Changes to the Baseline Conditions: Wind-wave Regime

Waves which move past a structure placed at sea have the potential to interact with the structure. These interactions may include effects such as reflection of waves and scattering, the diffraction of waves around the structure and the drag effects on waves created by skin friction (structural resistance).

The scale of these interactions around an individual structure will vary depending on both the property of the incident waves (principally wave height and period) and the property of the structure (e.g. type of foundation, size and shape). At the array scale, further considerations are the spacing between multiple structures in row, the spacing between subsequent rows and the number of rows.

The effect of a foundation on individual waves is typically not measurable in practice but the cumulative effect of many foundations is generally accepted to be a slight reduction in wave energy (height and period). The baseline assessment (ABPmer, 2011) identified that the wave climate has an influence on sediment transport within the shallower water depths. Therefore, persistent changes to waves and currents may have a net effect over time on net patterns of sediment transport (rates and directions).

The detailed investigation of changes to the wave regime has been supported by the application of a spectral wave model linked to the tidal model. The wave data obtained from the metocean site surveys, long-term deployments at Rustington and Seaford and the ABPmer Seastates model output at the GLV position have been used to support the model calibration (Figure 3). Further details about the wave model are presented in Appendix A.

Modelling scenarios using waves from varying incident directions are used to investigate the potential change and impact, post development. This section addresses the conditions modelled within the (i) near-field (within and in close proximity to the application area); and (ii) far-field (at greater distances from the application area, including the adjacent coast).

Assessment scenarios

As derived from both the long-term and metocean survey data sets, the most common wave directions are from the southwest, south-southwest, west-southwest and south-southeast. Of these, the long-term data sets indicate that waves from the southwest predominate in shallower waters (accounting for 41% of the record at Rushington; Figure 3) whilst waves from the west-southwest are dominant in deeper waters (accounting for 39% of the ABPmer Seastates record). Therefore, in order to provide a comprehensive indication of the potential impact of the

proposed development upon the wave regime, all wave directions have been assessed for three different return periods; 10 in 1 year, 1 in 1 year and 1 in 10 year events. In assessing these three events, a range of conditions were investigated from the frequent, low-energy events to the infrequent, high-energy events, such that the:

- 10 in 1 year event can be considered as a typical winter storm;
- 1 in 1 year event can be considered as an extreme annual storm; and
- 1 in 10 year event can be considered as an extreme storm event.

The characteristics of these wave conditions are presented in Table 11. An assessment of the potential effects of the development upon swell waves is presented in Section 4.4.

Table 11. Most common wave directions and associated wave properties

Return Period (years)	Direction (°N)							
	SSE (Scenario A)		SSW (Scenario B)		SW (Scenario C)		WSW (Scenario D)	
	Hs(*) (m)	Tz(**) (sec)	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)	Hs (m)	Tz (sec)
0.1	1.20	3.7	3.44	6.3	3.37	6.2	1.64	4.4
1	2.51	5.4	4.61	7.3	4.37	7.1	2.13	5.0
10	3.30	6.2	5.29	7.8	4.81	7.5	2.36	5.2
(*) Significant wave height								
(**) Associated average wave period								

To investigate changes to the baseline wave regime, model assessment points were selected to inform the spatial variation of the wave conditions (Figure 3), which are then used to describe the results of the model scenarios.

Scenario A: South-southeast waves

This scenario considers the waves generated more locally to the array within the English Channel and as such is for those waves of a shorter fetch length.

Very similar results are obtained for all the wave model runs from this direction, which includes variations of the three return periods and four tidal states (Table 12). (The full suite of quantified changes is provided in Appendix C). Table 12 shows that:

- The greatest reductions in wave height and period occur within the array and immediately adjacent to the structures, immediately north of the development area. These changes reduce in magnitude with distance from the array;
- Wave height changes within the near-field are less than 7.5%, equivalent to a reduction of 0.1 m. A similar magnitude of variation is observed at all tidal states (i.e. high and low water and at peak flood and ebb conditions).
- There is a slight reduction (less than 5%) in significant wave heights in the lee of the array to the north and north-northwest of the application site. Measurable changes do

not extend further than, approximately, 6 km from the array boundary with the furthest spatial extent of change being observed during High Water conditions;

- Reductions in wave period are less than 2% (0.1 s), with a decrease in the wave period occurring in the lee of the array. The largest wave period reductions occur immediately adjacent to the array but quickly dissipate towards the coast where no measurable changes are predicted. It is noted that the largest wave period changes occur during low water and for the 10 in 1 year wave condition. At other tidal states and for other return periods, changes are typically less than 1%; and
- Changes in wave direction are anticipated to be very small and are commonly less than a 1%. At the coast, the wave direction remains unchanged.

Table 12. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario A (SSE)

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	1.20	146	3.7	-0.05 (-4%)	2 (2%)	-0.1 (-2%)
	1 in 1	2.47	149	5.0	-0.06 (-2%)	1 (1%)	0.0 (-1%)
	1 in 10	3.26	150	5.7	-0.06 (-2%)	1 (1%)	0.0 (-1%)
16	10 in 1	1.18	146	3.6	-0.06 (-5%)	1 (0%)	-0.1 (-2%)
	1 in 1	2.43	149	4.9	-0.06 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	3.20	150	5.6	-0.07 (-2%)	1 (0%)	-0.1 (-1%)
18	10 in 1	1.22	146	3.7	-0.02 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	2.47	149	5.0	-0.04 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	3.25	150	5.7	-0.06 (-2%)	0 (0%)	0.0 (-1%)
Far-field							
3	10 in 1	1.18	157	3.4	-0.01 (-1%)	1 (0%)	0.0 (0%)
	1 in 1	2.20	158	4.7	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.78	158	5.4	-0.01 (0%)	0 (0%)	0.0 (0%)
4	10 in 1	1.09	153	3.4	-0.01 (-1%)	1 (0%)	0.0 (-1%)
	1 in 1	2.10	157	4.7	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	2.72	159	5.4	-0.02 (-1%)	0 (0%)	0.0 (0%)
6	10 in 1	1.09	151	3.4	-0.01 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	2.08	152	4.7	-0.01 (0%)	0 (0%)	0.0 (-1%)
	1 in 10	2.66	153	5.4	-0.02 (-1%)	0 (0%)	0.0 (-1%)
7	10 in 1	1.13	149	3.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	2.19	153	4.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.82	155	5.4	-0.01 (0%)	0 (0%)	0.0 (0%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period Shown at the time of High Water. * The location of the observations points within this table are displayed on Figure 3.							

Scenario B: South-southwest waves

This scenario considers the potential for the development to modify waves approaching from the south-southwest (i.e. almost normal to the shore).

Very similar results are obtained for all the wave model runs from this direction, which includes variations of the three return periods and four tidal states (Table 13). (The full suite of quantified changes is provided in Appendix C). Table 13 shows that:

- The greatest wave height reductions are local to the array structures although differences between baseline and scheme predictions quickly reduce towards the array boundary.
- The maximum change in significant wave height away from the structures is of the order of 5% (located at the arrays northern boundary), which is equivalent to a wave height reduction of 0.1 m.
- A reduction in significant wave heights is predicted in the lee of the array, to the immediate north of the application site.
- No changes extend beyond, approximately, 3 km from the northern boundary. At this distance from the array, changes are of the order of 2.5%.
- The spatial extent of change is greater for conditions of peak flood as a consequence of the tidal flow passing through the array in a similar direction as the waves.
- Changes to wave period are limited in magnitude, with a maximum reduction of 1% (0.1 s) typically being observed within the array and at the coast; and
- Only minor (i.e. less than 0.5%) changes are observed in the wave approach direction.

Table 13. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario B (SSW)

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.24	199	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.26	198	6.5	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.81	196	7.0	-0.01 (0%)	0 (0%)	0.0 (0%)
16	10 in 1	3.15	198	5.6	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.15	197	6.3	-0.06 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.67	195	6.8	-0.06 (-1%)	0 (0%)	0.0 (0%)
17	10 in 1	3.16	201	5.6	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.19	199	6.3	-0.08 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	4.73	198	6.8	-0.09 (-2%)	0 (0%)	0.0 (-1%)
18	10 in 1	3.18	202	5.6	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	4.26	202	6.4	-0.11 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.85	201	6.9	-0.12 (-2%)	0 (0%)	0.0 (-1%)
Far-field							
5	10 in 1	2.93	195	6.0	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.38	191	6.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.46	188	7.2	0.00 (0%)	0 (0%)	0.0 (0%)
6	10 in 1	2.79	191	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.44	188	6.6	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.62	185	7.0	0.00 (0%)	0 (0%)	0.0 (0%)
8	10 in 1	2.93	196	5.5	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.80	194	6.2	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.20	192	6.7	-0.04 (-1%)	0 (0%)	0.0 (-1%)
9	10 in 1	3.08	199	5.6	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	4.03	197	6.3	-0.03 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.49	195	6.7	-0.04 (-1%)	0 (0%)	0.0 (0%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period Shown at the time of High Water. * The location of the observations points within this table are displayed on Figure 3.							

Scenario C: Southwest waves

This scenario represents the most frequent approach direction as identified from the baseline assessment of the metocean observations accounting for 31% of the record at metocean deployment site L3 (Figure 3) (ABPmer, 2011).

Very similar results are obtained for all the wave model runs from this direction, which includes variations of the three return periods and four tidal states (Table 14 and Figure 12 (which shows the significant wave height for the 1 in 1 year return period event)). (The full suite of quantified changes is provided in Appendix C). Table 14 and Figure 12 show that:

- For all return periods and tidal states, the greatest reductions in wave height remain local to the array and reductions in wave height do not exceed 5%;

- There is typically a reduction in the significant wave height in the lee of the array, to the north-northeast of the application site. These reductions remain within, approximately, 5 km of the array boundary;
- The spatial extent of change is greater for conditions of peak flood as a consequence of the tidal flow passing through the array in a similar direction as the waves; and
- Negligible changes occur to wave period within the array and at the coast, with maximum changes of the order of 1% predicted. It is noted that the percentage difference is similar for all return periods. A similarly small magnitude of change is predicted for the wave direction.

Table 14. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario C (SW)

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.23	218	5.9	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.15	216	6.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.57	215	6.8	0.00 (0%)	0 (0%)	0.0 (0%)
16	10 in 1	3.04	216	5.6	-0.05 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	3.94	213	6.2	-0.05 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.32	212	6.5	-0.05 (-1%)	0 (0%)	0.0 (0%)
17	10 in 1	3.10	219	5.6	-0.05 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	4.01	217	6.2	-0.07 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	4.39	216	6.5	-0.08 (-2%)	0 (0%)	0.0 (-1%)
18	10 in 1	3.02	221	5.5	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	3.92	218	6.1	-0.09 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.30	218	6.3	-0.11 (-3%)	0 (0%)	-0.1 (-1%)
Far-field							
5	10 in 1	2.97	205	6.3	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.39	201	7.3	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.46	200	7.6	0.00 (0%)	0 (0%)	0.0 (0%)
6	10 in 1	2.82	202	6.1	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.44	197	6.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.60	195	7.3	0.00 (0%)	0 (0%)	0.0 (0%)
8	10 in 1	2.72	211	5.4	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	3.46	208	6.0	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.77	207	6.3	-0.03 (-1%)	0 (0%)	0.0 (0%)
9	10 in 1	2.90	214	5.5	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.71	211	6.1	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.06	210	6.3	-0.03 (-1%)	0 (0%)	0.0 (-1%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period Shown at the time of High Water. * The location of the observations points within this table are displayed on Figure 3.							

Scenario D: West-southwest waves

This scenario also represents the second most frequent approach direction as identified from the baseline assessment of the metocean observations (ABPmer, 2011), accounting for 30% of the record at metocean deployment site L3 (Figure 3). It also represents the direction with the longest fetch approaching the development array, with waves originating from the North Atlantic.

Very similar results are obtained for all the wave model runs from this direction, which includes variations of the three return periods and four tidal states (Table 15 and Figure 13 (which shows the significant wave height for the 1 in 1 year return period event)). (The full suite of quantified changes is provided in Appendix C). Table 15 and Figure 13 show that:

- The greatest reductions in height occur within and immediately to the north to north-northeast of the array. Typical wave height changes are of the order of 5% along the array's northern boundary, with changes reducing to around 2%, approximately, 5 km from the boundary. A maximum wave height change of 4% is observed along the coastline at spatially discrete locations for a 10 in 1 year event under Peak Flood conditions only;
- Whilst wave period changes are predicted to occur, these are generally limited in magnitude with the greatest reductions (~ 3%) occurring at specific locations within the array. Wave period changes do not exceed 2% at the coast
- Directional changes are negligible and do not exceed 1%.

Table 15. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario D (WSW)

Observation Point*	Return Period (yrs)	Baseline			Actual Difference due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	1.59	229	4.6	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	2.08	230	5.0	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.32	229	5.3	0.00 (0%)	0 (0%)	0.0 (0%)
17	10 in 1	1.44	232	4.2	-0.04 (-3%)	1 (0%)	-0.1 (-1%)
	1 in 1	1.90	232	4.7	-0.04 (-2%)	1 (0%)	0.0 (-1%)
	1 in 10	2.13	231	4.9	-0.04 (-2%)	1 (0%)	0.0 (-1%)
Far-field							
7	10 in 1	1.25	216	4.1	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	1.62	215	4.6	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	1.79	213	4.8	-0.01 (-1%)	0 (0%)	0.0 (0%)
8	10 in 1	1.28	223	4.0	-0.02 (-2%)	1 (0%)	0.0 (-1%)
	1 in 1	1.67	223	4.4	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	1.85	222	4.7	-0.02 (-1%)	0 (0%)	0.0 (-1%)
9	10 in 1	1.32	228	4.0	-0.03 (-2%)	0 (0%)	-0.1 (-2%)
	1 in 1	1.73	228	4.4	-0.03 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	1.93	227	4.6	-0.02 (-1%)	0 (0%)	0.0 (-1%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period Shown at the time of High Water. * The location of the observations points within this table are displayed on Figure 3.							

Summary

Overall, the effects of the realistic worst case layout for the proposed wind farm are similar for all the wave directions assessed. As the majority of waves originate from the seaward of the array, the greatest effects are noted both within the array and landward of the application area. Typically, the greatest spatial extent of change occurs under conditions of Peak Flood when the tide and wave are travelling in the same direction. Small reductions in wave height are observed at the coast with all scenarios and these changes equate to a reduction in the amount of energy reaching the shore. This is of relevance for sediment transport at the coast which is discussed further in Section 4.7. Only very small changes are observed in wave period and direction. Although minor, any changes to these parameters also have the potential to influence rates and direction of sediment transport in the littoral zone.

At this juncture, it is important to note that longer-term changes in storminess have occurred in northwest Europe (e.g. Alexandersson *et al.*, 2000). Moreover, future changes to the wave climate as a consequence of climate change are predicted to occur as an increase of ~0.5 of the mean annual maxima significant wave height (between 1960 and 1990, to 2070 and 2100) (Lowe *et al.*, 2009). It follows that any wave height reductions which may be introduced by the wind farm development may potentially be partially or fully offset by any increases resulting from climate change.

4.5 Potential Impact: Changes to the Surfing Resource Due to the Presence of the Array Infrastructure

4.5.1 Overview

An assessment of the potential effects of the development upon swell waves has been undertaken in order to address stakeholder concerns regarding the potential interruption of offshore wave transmission and reduction in offshore swell energy. An issue raised for consideration during the consultation phase (Section 2.1) has been the potential impacts of the proposed wind farm as an ‘*interruption of offshore wave energy transmission and a reduction in offshore swell energy*’ such that surfing conditions are compromised. Further guidance provided by SAS (2009) states that:

the potential for offshore renewable energy development to have a significant impact on surfing wave resources depends principally on two factors:

- (1) a development's potential to change the baseline wave climate offshore to the extent that wave breaking characteristics are changed where surfing takes place; and*
- (2) a development's potential to change the baseline hydrodynamic and sedimentary regimes offshore and in the coastal zone to the extent that the seabed's bathymetry and morphological features are changed where surfing takes place.*

Following consultation with SAS, the primary concern in the context of this project is potential changes to surfing conditions (Point 1 above). (Potential alterations to the morphological regime are presented in Section 3.6).

Along the South Coast of England the surfing waves are described to be of a low quality, low consistency but very high in popularity (SAS, 2009; 2010). In order to determine typical swell conditions within the study area, observed long period waves and their corresponding heights and directions at the Rustington wave buoy were considered. At this location, long period waves typically have a period of between 10 and 11 seconds, associated significant wave heights of between 1.0 m and 1.33 m and an approach direction from the southwest.

Based on an analysis of the wave observations from the Rustington wave buoy, a wave height of 1.29 m and wave period of 11 s was chosen to represent typical swell conditions approaching from the southwest. Further to these conditions, and to directly address concerns raised by the SAS, an additional three surf conditions were simulated as specified by the SAS and as detailed in Table 16.

Table 16. Surf conditions simulated within the coastal processes assessment.

Surf Condition		Wave Characteristics				
ID	Description (as provided by SAS)	Hs (m)	Hmax (m)	Tp (sec)	Tz (sec)	Dir (°N)
S1*	n/a	-	1.29	11	-	225
S2**	'Very small but rideable 1 foot (1 to 2 foot face cross-shore wind swell)'. Recorded 12.09.2012 11:30	0.73	1.19	6.3	3.7	221
S3**	'Average 2 foot clean day (3 foot face, offshore - no wind swell)'. Recorded 30.08.2012 12:00	1.36	1.85	9.1	5.2	221
S4**	'Good wave: Breaking wave 4 foot (6 foot face)'. Recorded 09.12.2009 15:00.	1.24	1.77	18.2	7.3	194
Hs Significant Wave Height; Hmax Maximum Wave Height Tp Peak Wave Period; Tz Mean Absolute Wave Period Dir Mean Wave Direction * Conditions specified following analysis of the Rushington wave buoy ** Conditions specified by SAS following consultation discussions						

In addition to considering changes within the study area, SAS requested changes be considered at 11 specific surf locations within the study area:

- | | |
|---------------------|-------------------------|
| 1. Worthing | 7. Brighton Marina |
| 2. Lancing Green | 8. Rottingdean |
| 3. Shoreham Harbour | 9. Telscombe Cliffs |
| 4. Hot Pipe | 10. Tide Mills, Seaford |
| 5. West Pier | 11. Birling Gap |
| 6. Brighton Pier | |

Following consultation with SAS, it has been agreed that reductions in wave height of less than 7 % are not considered to be detrimental to the surfing resource. Accordingly, changes of less than 7% may be regarded as not significant.

4.5.2 Assessment of Potential Changes to the Baseline Conditions: Swell Regime

The wave model described in Section 4.4 was used to consider potential changes to the typical swell waves described above (Table 16). Quantification of the predicted changes to the surfing resource (wave heights; directions; periods) at the 11 sites is provided in Table 17 at High Water, with Appendix C detailing the changes at these locations at Low Water. Figures 14 to 17 illustrate the wave height change at all four tidal states.

On the basis of the evidence presented in Table 17, it is found that wave height reductions of more than 7% are not observed at any of the 11 sites shown in Figure 13. Therefore changes to the surfing resource due to the presence of the array infrastructure is considered to be of **minor significance**.

A description of the changes along the coastline at the 11 sites surfing locations identified by SAS is provided below:

- Scenario S1:
 - o Reductions at the 11 sites does not exceed 7% and is more typically less than 2%; and
 - o Wave period and directional changes exceeding 2.5% are not predicted. Typically changes of less than 1% are shown.
- Scenario S2:
 - o Wave height reduction is only observed at Seaford under the conditions of Peak Flood. These changes are less than 2.5% in magnitude. At all other sites, no significant wave height changes are predicted; and
 - o Wave period changes exceeding 2.5% are not predicted. Directional changes are minimal (typically less than 1%), though some localised changes of 5% are predicted.
- Scenario S3:
 - o There are no wave height reductions; and
 - o Wave period and directional changes exceeding 2.5% are not predicted. Typically changes of less than 1% are shown.
- Scenario S4:
 - o Between Brighton and Seaford, wave height reductions occur under all tidal states and particularly at Peak Flood. A maximum change of 5% is modelled at Peak Flood to the west of Tide Mills, Seaford (Site 10). More typical changes are of the order of 2.5%; and
 - o Wave period and directional changes exceeding 2.5% are not widespread. Localised wave period changes of the order of 4% do occur at Brighton Marina and Tide Mills (Sites 9 and 10). Typically changes of less than 1% are shown.

Table 17. Quantification of potential changes (in percent) to the four specified surf scenarios due to the Rampion Wind Farm (High Water)

Surfing Location	Scenario 1 (S1)			Scenario 2 (S2)			Scenario 3 (S3)			Scenario 4 (S4)		
	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm
1 (Worthing)	0	0	0	1	0	-1	-1	0	1	0	0	-2
2 (Lancing Green)	0	0	0	0	0	-1	0	0	0	1	0	-1
3 (Shoreham Harbour)	0	0	0	0	0	-1	0	0	0	1	0	0
4 (Hot Pipe)	0	0	0	-1	0	-1	0	0	0	1	0	-1
5 (West Pier)	0	0	0	-2	0	-1	0	0	0	1	0	-2
6 (Brighton Pier)	0	0	0	-1	0	-1	0	0	0	1	0	-3
7 (Brighton Marina)	0	0	0	-2	0	-1	-1	0	0	0	0	-4
8 (Rottingdean)	-1	0	0	-2	0	-1	-1	0	0	0	0	-4
9 (Telscombe Cliffs)	-4	0	0	-1	0	-2	-1	0	0	0	0	-4
10 (Tide Mills, Seaford)	-1	0	0	-2	0	-2	-2	0	-1	0	0	-4
11 (Birling Gap)	0	0	0	-1	0	-2	-1	0	0	1	0	-3
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period												

Summary

Changes in swell waves at the coast are only predicted to occur in the immediate lee of the array, with no observable changes occurring outside the frontage between Brighton and Seaford. At the locations specified by SAS and shown in Figures 13 to 16 wave height reductions do not exceed 5%. Wave period changes are less than 4%, and more typically less than 2%. Wave directional changes are typically less than 0.5%.

SAS consider that changes in wave height of less than 7% are not detrimental to the surfing regime. On this basis, the potential for changes to the surfing conditions resulting from the presence of the wind farm infrastructure are considered to be of low magnitude, have a limited spatial effect although are present over the life-time of the wind farm. The potential effect is therefore considered of **minor significance**.

4.6 Potential Impact: Changes to the Sediment Transport Regime Due to the Presence of the Array Infrastructure

4.6.1 Overview

As previously stated, both the tide and wave regimes influence sediment transport within the study area (ABPmer, 2011):

- The tidal regime provides the primary control upon sediment transport; and
- The wave regime provides some influence on sediment mobility in the shallower water depths although has only limited control upon sediment transport in the greater water depths.

Any changes to either the tidal or wave regime due to the presence of the turbine foundations may have consequential effects upon the sediment transport regime.

Here the source-pathway-receptor model (Section 2) should be considered as the:

- Foundation structure and support column being considered as the *source* of a potential effect on the waves;
- Tides and waves acting as the *pathway* for transporting sediment; and
- *Receptor* being a feature identified as being potentially sensitive to any change in sediment movements, for example coastal regions.

4.6.2 Baseline Conditions

The baseline characteristic of the sediment transport regime, as detailed within ABPmer (2011), is summarised within this section. The baseline interpretation is based on outcomes of geophysical site surveys and morphological analysis carried out on the geophysical survey data.

Near-field

The transport pathways through the application site and study region are primarily to the east and east-northeast, in relation to the flood dominant tidal currents, confirmed through field studies and numerical modelling. The tidal regime is responsible for sediment transport, with an existing but limited influence from waves. On an annual basis, the occurrence of waves with the potential to disturb seabed sediments occurs, approximately, 5 to 20% of the time (Paphitis *et al.*, 2010).

The tidal energetic regime leads to the formation of well-sorted distributions and tide-dominant bedform features, which include sandbanks and areas of sand and gravel waves and megaripples. The geophysical survey from the OWF application area identifies large areas of sand waves and megaripples, where the crests are aligned to the northeast with a transport pathway in this direction. The dominance of tidal activity and the availability of finer sand and silt sediments suggest that the dominant transport mechanism in the offshore region is as suspended sediment. However, the presence of bedforms and the described asymmetry confirms also the occurrence of bedload transport.

Far-field

The drift direction at the coast is predominantly influenced by the prevailing wave conditions, which originate from the west-southwest to southwest. Consequently along the coastline, there is a dominant west to east net drift due to waves. Tidal currents at the shore are generally not strong enough to move gravels observed at the coast.

Existing broad-scale mapping suggests gravels, sandy gravels and sand are the expected dominant sediments that make up the seabed at the coast. The coastline between Selsey Bill and Beachy Head has a 'hold-the-line' policy which is prevalent along much of the frontage. The management strategies in place, as detailed in the SMP (SDCG, 2004), range from beach nourishment activities to the installation and maintenance of groyne structures. There is an observable sediment accumulation up-drift of these structures.

Sediment is transported at the coast primarily as bedload transport in relation to the wave conditions. Shoreward of the wind farm, sediment transport rates are seen to be variable in relation to the amount of energy and sediment available and the presence of barriers to flow, such as groynes or harbour sinks (SCOPAC, 2004). No large-scale bedform features are observed at the coastline, although there is the known abundance of shingle for transport.

4.6.3 Impact Assessment

The sediment transport regime has been defined within the baseline in terms of sediment transport at the bed (bed load transport), sediment transport within the water column (suspended sediment transport) and sediment transport at the coast (longshore sediment transport). These three components comprising the sediment transport regime are considered separately here.

(i) Sediment Transport at the Bed

With regards to the assessment of potential change to the sediment transport regime, particular consideration must be given to any scheme induced change to baseline sediment transport pathways as well as the potential rate at which material is transported across the application area and through this region of the English Channel. As described above, the key driver of bed-load sediment transport in this region is tidal currents. In this region, waves primarily contribute to sediment transport by stirring the bed, causing fine grained material to enter into suspension enabling it to then be transported by tidal currents. (This component of the sediment transport regime is discussed in the next section).

Reference to Section 4.3 reveals that away from the immediate vicinity of the foundations (where currents may be disturbed due to wake effects from individual structures), changes to flow speed and direction are predicted to be extremely minor (i.e. less than 0.01 m/s and less than 1°). This is true for all stages throughout the tidal cycle and changes of this magnitude will be largely immeasurable in practice. It follows from this that any changes in the rate and direction of bed-load sediment transport will also be very small and restricted to the near field.

As previously described in Section 4.3, the presence of the foundations will cause a general retardation of flow through the array and this will result in small reductions in bed shear stress in most locations. Very small flow speed increases may also be expected to the north and south of the site as a consequence of flow acceleration around the array. Such changes will result in very small increases in bed shear stress in these areas. Differences in these predicted bed shear stress values have been quantified using standard empirical formula presented in Soulsby (1997) and using current data extracted from the numerical model. Comparisons between predicted values of bed shear stress under the baseline and post-development scenario for the times of peak flow are shown in Table 18 and Figure 18.

Table 18. Potential Sediment Mobility (due to Tidal Currents only) Before and After Development

Potential Sediment Mobility (due to Tidal Currents only) Before and After Development						
Location*	Scenario	Mobility % Time for each Sediment Fraction				
		Very fine sand (94 µm)	Fine sand (187 µm)	Medium sand (375 µm)	Coarse sand (750 µm)	Very coarse sand (1500 µm)
Analysis Location L1	Baseline	51	43	31	7	0
	Realistic worst case	51	43	30	7	0
Analysis Location L2	Baseline	37	28	16	4	0
	Realistic worst case	38	28	16	4	0
Analysis Location L3	Baseline	48	38	28	11	0
	Realistic worst case	48	38	28	11	0
*See Figure 18						

With regards to potential changes in tidal current induced bed shear stress, the results presented in Table 18 and Figure 18 confirm that very little change is predicted to occur within the near-field, following construction of the array. These very minor changes will not be measurable in practice. Moreover, any differences between baseline and post-development predictions will only reduce with increased distance from the array. Accordingly, no changes to baseline values of tidal bed shear stress are anticipated to occur in the far-field.

Critically Table 18 and Figure 18 show that the changes in bed shear stress within the application site are not sufficient to change the size of material that is mobilised nor the duration of the tidal cycle over which this material is mobile. It is therefore concluded that the predicted changes to the tidal regime resulting from the presence of the array would not appreciably affect sediment mobility and consequently the existing seabed form.

The potential for changes to the bed-load sediment transport regime resulting from the presence of the wind farm infrastructure is considered to be of small magnitude, have only an array scale spatial effect are present over the lifetime of the wind farm. The potential effect upon sediment dynamics and thus the existing seabed infrastructure is therefore considered of **minor significance**.

(ii) Sediment Transport within the Water Column

In theory, any changes to the hydrodynamic regime caused by the wind farm would have the potential to:

- Alter the rate at which suspended sediment is transported;
- Alter the direction in which material is transported; and
- Change the concentration of sediment suspended in the water column.

However, given the extremely minor predicted changes to the speed and direction of tidal currents with the array in place, it is considered very unlikely that measurable differences to the rate and direction of suspended sediment transport will occur within this region.

The seabed within shallower areas of the site may be stirred by storm waves, causing a short-term and localised increase in SSCs. As shown at metocean location L2 (Figure 3), over a six month survey with maximum recorded wave heights of 4.08 m, only the finer sediments are mobile and then only for, approximately, 1% of the time (ABPmer, 2011). The presence of the array would cause a small reduction in wave heights within and nearby to the site and it is therefore possible that there would be a very marginal reduction in the degree to which sediment at the bed is mobilised during these larger wave events.

The potential for changes to the suspended-load sediment transport regime resulting from the presence of the wind farm infrastructure is considered to be of small magnitude, have only an array scale spatial effect and are present over the lifetime of the wind farm. The potential effect upon sediment dynamics and thus the existing seabed infrastructure is therefore considered of **minor significance**.

(iii) Sediment Transport at the Coast

Overview

The results from the numerical wave modelling analyses (Section 4.4) indicate that although the development does not influence the approaching wave direction, it has the potential to very slightly (i.e. no greater than 5%) influence the wave height and period arriving at the coast. The extent to which these slight changes to waves may influence the longshore sediment transport regime is investigated here.

Background

The coastline between Selsey Bill and Beachy Head has a 'hold-the-line' policy along much of the frontage. The shoreline is characterised as an eroding coastline, with a few areas exhibiting accretion attributed to the presence of coastal defence schemes (SDCG, 2004). The management strategies in place, as detailed in the Shoreline Management Plans (SMP) (SDCG, 2004), range from beach nourishment activities to the installation and maintenance of groyne structures. However, it is noted that at certain locations, for example between Peacehaven Heights to Harbour Heights, that no defences exist and instead the natural presence of shingle ridges acts to protect the shoreline and cliffs (SDCG, 2004).

Between the headlands of Selsey Bill and Beachy Head the dominant south-westerly wave direction drives the net longshore drift in this coastal cell in an easterly direction. Annual rates of sediment transport and erosion will be influenced by a range of factors including:

- The percentage occurrence of wave events from each directional sector;
- The magnitude and frequency of storm events; and
- The rate of sediment input into the coastal cell.

The actual transfer of sediment along this stretch of coastline is considerably less than the natural potential, principally due to a lack of fresh sediment input and current management intervention. There is also a chance for some sediment and other locally eroded material to be transported around Beachy Head and further to the east (beyond the coastal cell). However, due to the lack sediment supply, it is considered that there is limited transport around this headland (SDCG, 2004).

Assessment

Theoretical rates of baseline and post-development longshore sediment transport have been estimated using the Coastal Engineering Research Centre (CERC) longshore sediment transport formula (Smith *et al.*, 2004), combined with outputs from the numerical wave model. These calculations provide a means to assess the sensitivity of longshore sediment transport to slight changes in wave characteristics. The comparison between the baseline and post-development scenario is then considered as a relative change.

Longshore sediment transport rates have been calculated and aggregated into two main geographical sectors; the first between Selsey Bill to Shoreham -by-Sea and the second between Shoreham -by-Sea to Beachy Head. These sectors have been defined according to their orientation. The sensitivity of longshore sediment transport has been tested using quite frequently occurring storm wave conditions (10 in 1 year) and extreme (1 in 1 year and 1 in 10 year) return period wave events, for a series of different wave approach directions (Table 19). This selection of events is considered to contain the primary conditions responsible for longshore drift with lesser magnitude events providing a lesser contribution. (These lesser magnitude events are also anticipated to be less affected by the presence of the array.)

It should be noted that the calculations undertaken here do not account for the presence of shoreline management schemes (for example groyne structures and beach re-nourishment) and also assume a full supply of sediment. Accordingly, the CERC formula only provides information on *potential* rates rather than *absolute* rates of sediment transport.

Table 19. The sensitivity of longshore sediment transport to post-development changes in wave climate

	Wave Return Period	Direction	Baseline		Post Scheme		% change LST	Direction of transport
			Average Hs	Average Tm	Average Hs	Average Tm		
Selsey to Shoreham-by-Sea	10:1	WSW	1.30	4.45	1.30	4.45	0.1	Easterly
		SW	2.26	5.40	2.26	5.41	0.1	Easterly
		SSW	2.30	5.48	2.28	5.47	1.8	Easterly
		SSE	1.05	3.29	1.04	3.28	1.3	Westerly
	1:1	WSW	1.65	5.10	1.64	5.08	1.3	Easterly
		SW	2.59	5.98	2.59	5.99	0.2	Easterly
		SSW	2.62	6.08	2.62	6.07	0.6	Easterly
		SSE	1.88	4.67	1.87	4.64	1.7	Westerly
	1:10	WSW	1.84	5.57	1.84	5.58	0.2	Easterly
		SW	2.68	6.18	2.67	6.20	0.0	Easterly
		SSW	2.73	6.31	2.73	6.31	0.3	Easterly
		SSE	2.29	5.30	2.28	5.27	1.1	Westerly
Shoreham -by-Sea to Beachy Head	10:1	WSW	1.25	3.94	1.24	3.88	4.3	Easterly
		SW	2.61	5.32	2.59	5.29	2.0	Easterly
		SSW	2.80	5.51	2.75	5.48	3.7	Easterly
		SSE	1.12	3.45	1.11	3.44	0.8	Westerly
	1:1	WSW	1.61	4.40	1.59	4.35	4.0	Easterly
		SW	3.28	6.01	3.26	5.98	2.1	Easterly
		SSW	3.50	6.23	3.46	6.21	2.6	Easterly
		SSE	2.16	4.77	2.15	4.76	1.3	Westerly
	1:10	WSW	1.79	4.64	1.77	4.60	3.3	Easterly
		SW	3.57	6.28	3.52	6.24	2.8	Easterly
		SSW	3.89	6.65	3.87	6.61	1.6	Easterly
		SSE	2.76	5.40	2.75	5.38	1.0	Westerly

It is found that:

- For any given extreme wave event, the effect of the array is to very marginally reduce associated rates of longshore sediment transport;
- The most change in potential longshore sediment transport rates during these extreme storm events occur along the coastline between Shoreham-by-Sea to Beachy Head;
- Regardless of the wave return period or prevailing wave direction, average percentage reductions in potential longshore sediment transport rates within this coastal cell do not exceed 5% and are more typically less than 2%.

Given that net longshore sediment transport along this stretch of coast is (on average) towards the east and the rate of sediment input into this coastal cell is unlikely to change with the development in place, the following may be hypothesised:

- The most likely change (if any) between Selsey Bill and Shoreham-by-Sea would be a net overall increase in the movement of sediment to the east. This change could occur because any periodic transport to the west caused by waves from the southeast could potentially decrease due to a reduction in wave height. (Waves from the southwest which reach this stretch of coastline would be unaltered from baseline conditions since they do not have a fetch pathway through the array);
- The most likely change (if any) between Shoreham-by-Sea and Beachy Head would be a net overall decrease in the movement of sediment to the east. This change could occur because waves from the southwest could potentially decrease in height, reducing rates of easterly sediment transport. (Waves from the southeast which reach this stretch of coastline would be unaltered from baseline conditions since they do not have a fetch pathway through the array.)
- Due to the lack sediment supply, under baseline conditions it is considered that there is limited transport around Beachy Head (SDCG, 2004). Accordingly, absolute changes in the rate of longshore sediment transport here (and to the east of this location) are likely to be very low.

It is worth noting here that actual rates of longshore sediment transport will also vary temporally, on a seasonal and annual basis. Inspection of the wave record from Rustington reveals that during the period 2003 to 2010, annual variability in average wave height and period deviated by approximately $\pm 10\%$ and $\pm 3\%$ respectively from the average for this period. Changes in wave characteristics of this magnitude are considerably greater than those predicted to occur from the array. It follows from this that associated changes in the rate of longshore sediment transport resulting from the presence of the array will be less than that which have occurred naturally over the past decade.

More generally, past changes in significant wave height are known to have occurred in response to changes in the North Atlantic Oscillation (e.g. Leggett, 2007). It is probable that these changes will have manifest in small changes in rates of longshore sediment transport

within this coast cell. Moreover, in this region future changes to the wave climate as a consequence of climate change are predicted to occur as an increase of ~ 0.5 of the mean annual maxima significant wave height (between 1960 and 1990, to 2070 and 2100) (Lowe *et al.*, 2009). These predicted changes to the wave climate are counter-directional to those predicted to occur as a consequence of the development (i.e. larger storm waves are expected as a consequence of climate change whereas slightly smaller storm waves may reach the coast with the development in place) and it is likely that any changes in the wave climate as a consequence of climate change may also influence existing rates of sediment erosion, transport and deposition. It is considered unlikely that any scheme induced changes to longshore sediment transport will be clearly discernable from the changes that will have occurred in the past and that are likely to occur in the future.

Summary

The presence of the offshore wind farm removes a small fraction of the incident wave energy reaching the coast, potentially causing small reductions in rates of longshore sediment transport. Sensitivity tests have been carried out to further understand the relationship between slight and isolated changes in wave height and period and potential rates of longshore sediment transport along the coast between Selsey Bill and Beachy Head. These analyses are conservative because (i) the offshore wind farm has been described using the realistic worst case layout, resulting in maximum possible changes to the wave (and hence longshore sediment transport) regime; and (ii) they assume an unmanaged coastline. (Management measures are likely to make the coastline less sensitive to any small changes in wave conditions since natural rates of transport will tend to be moderated by their presence.) It is found that changes in potential rates of longshore sediment transport during storm events will typically be less than 2% and will not exceed 5%. It is considered unlikely that overall changes in rates of longshore sediment transport will be clearly discernable from the changes that will have occurred in the past and that are likely to occur in the future as a result of climate change.

The potential for changes to the longshore sediment transport regime resulting from the presence of the wind farm infrastructure are considered to be of small magnitude, have only a far-field spatial effect although will occur over the lifetime of the wind farm. The potential effect upon shoreline sediment morphology and is therefore considered of **minor significance** over the period during which the wind farm is installed. However, the confidence in this assessment is low.

5. Cumulative and In-Combination Effects

5.1 Overview

There are no other wind farm sites in proximity to the Rampion OWF application site. The closest offshore wind farm development in UK Continental Waters is Navitus Bay. It is located, approximately, 75 km to the west of the Rampion site and beyond the process divide created by the Isle of Wight landmass.

There are, however, 25 licensed aggregate sites, west of the application site, with a further three under application, one of which intersects with the application site. These together make up the Owers Bank and Inner Owers aggregate sites (Figure 2). It is noted that the intensity of activity within these sites varies.

Such activities all have the potential to alter the physical environment, including currents, waves, sediment transport pathways and seabed morphology. As such, the in-combination effects with the wind farm needs to be evaluated and are discussed further below.

5.2 Potential Impact: Increase in Suspended Sediment Concentration (Drill Arisings and Bed Preparation for Turbines and Cables)

5.2.1 Overview

For the in-combination effects, it is primarily the potential for sediment plumes arising from aggregate extraction at the Owers Bank sites to combine with any plumes arising from the wind farm foundation and export cable installation or operational activities that is most relevant. This element assesses the risk of the interaction creating a greater affect than either solitary activity.

A relatively large body of information is available regarding the characteristics of sediment plumes at the Owers marine aggregate dredging sites. The Owers Bank study (HR Wallingford, 1996) is of particular relevance here. This study consisted of a field measurement campaign with the aims of understanding and quantifying the increase in sediment concentrations due to resuspension by dredging operations; and tracking the spread and dispersion of the plumes of re-suspended material. Measurement of the suspended solids for the Arco Severn and the City of Rochester dredgers (both of 1,300 m³ capacity), showed that the plume decayed to background levels within 300 to 500 m of the dredger. The same measurements indicated that the concentration increases caused by the plume had reduced to below 50 mg/l within 130 m, and to below 20 mg/l within 200 m, of the City of Rochester dredger.

The South Coast Regional Environmental Assessment (HR Wallingford, 2010) is also of value and provides a series of modelling outputs based on sediment release scenarios from dredgers operating at Owers Bank. It is found that:

- The predicted increases in suspended sediment concentration, that will be experienced outside each of the proposed licence areas, will be less than 20 mg/l above background except when dredging occurs close to the boundary of a Licence Area;

- Even when dredging occurs at the boundary of licence areas, suspended sediment concentrations more than 50 mg/l above background levels are only likely to be experienced within 200 m of the Licence Area boundary and concentrations more than 20 mg/l above background levels are only likely to be experienced within 1 km of the licence area boundary;
- Increases in SSCs will be experienced only while dredging occurs and only in the streamline of the dredger. As a result for the vast majority of the time over the licensing period at any given point in the study region there will be no increases in suspended sediment concentration above background levels; and
- Even when concentration increases, which can be characterised as a few tens of mg/l above background levels, occur, these concentrations are less than the increases which occur naturally as a result of variation in tidal conditions and waves (HR Wallingford, 2010).
- The literature has been analysed to identify potential footprints of fine sand dispersion of up to 4 km (changes in substrate) and 2.5 km (bedforms) which may arise from dredging; and
- Consideration of the potential for interaction of fine sand dispersion between Licence Areas identified the possibility for some interaction of the dispersion of sand to occur offshore of Worthing, in the vicinity of Areas 122/1A, 123A, 124/1A, 122/1C, 123C, 124/1C, 122/1D, 123D, 124/1D, 122/1E, 123E, 124/1E, 396/1, 396/2, 435/1, 435/2, 453 and 488.

Rampion foundation installation and aggregate dredging

During the scoping and consultation phase it was agreed that for the assessment of potential in-combination effects, only those aggregate areas within a distance one spring tide excursion ellipse from the Rampion development would be considered. This is because outside of this distance, the potential for significant plume interaction is considered to be very limited. Those Aggregate Areas within one spring tidal excursion ellipse of the Rampion development are listed in Table 20.

Table 20. Aggregate dredging areas within one spring tidal excursion ellipse of the Rampion development

Area Name	Status	Company	Overlap with Cable Corridor?
122/1A	Licensed Area	Tarmac Marine Dredging Ltd	Yes
122/1B	Licensed Area	Tarmac Marine Dredging Ltd	No
122/1D	Licensed Area	Tarmac Marine Dredging Ltd	No
122/1E	Licensed Area	Tarmac Marine Dredging Ltd	No
123E	Licensed Area	Cemex UK Marine Ltd	No
124/1E	Licensed Area	Hanson Aggregates Marine Ltd	No
123D	Licensed Area	Cemex UK Marine Ltd	No
124/1D	Licensed Area	Hanson Aggregates Marine Ltd	No
123A	Licensed Area	Cemex UK Marine Ltd	Yes
124/1A	Licensed Area	Hanson Aggregates Marine Ltd	Yes
123B	Licensed Area	Cemex UK Marine Ltd	No
124/1B	Licensed Area	Hanson Aggregates Marine Ltd	No
122/1F	Licensed Area	Tarmac Marine Dredging Ltd	No
123/F	Licensed Area	Cemex UK Marine Ltd	No
124/1F	Licensed Area	Hanson Aggregates Marine Ltd	No
435/2	Licensed Area	Hanson Aggregates Marine Ltd	Yes
499	Application Area	Hanson Aggregates Marine Ltd	No

Area 122/ 1B, Area 123B and Area 124/1B cover the same geographical area (Figure 2) and are the closest aggregate sites to Rampion. At their closest point, they are located 280 m away from the western boundary of the development (Figure 2). It is considered that sediment plumes arising from aggregate dredging here will have the highest potential for interaction with foundation installation at Rampion. For this reason, the plume modelling analyses presented in this section have focused on this in-combination scenario and consider the 'worst-case' option of sequential foundation installation along the western margin of the Rampion development occurring concomitantly with dredging at Area 122/ 1B, Area 123B and Area 124/1B. It should be noted here that the lay out shown in Figure 4 does not involve the installation of turbines immediately adjacent to Area 122/ 1B, Area 123B and Area 124/1B. However, the Site Development Area does extend along the western margin of the application area (Figure 1) and therefore to simulate a worst-case scenario, the analyses presented here consider foundation installation at the closest point to the aggregate areas (i.e. 280 m) away.

Details of foundation installation nearby to Area 122/ 1B, Area 123B and Area 124/1B

A range of turbine foundations are currently under consideration and have been detailed within the Project Description (Section 2a of the ES). The worst-case scenario with regards to in-combination effects will usually be associated with the foundation type that has the potential to displace the greatest amount of material during installation. At the Rampion Wind Farm, both the GBS and monopile structures have the potential to release similar sediment volumes during installation (Section 2.8.2). However, along the western margin of the development site (in the vicinity of Area 122/ 1B, Area 123B and Area 124/1B) surficial seabed sediments are dominated by sands and gravels (ABPmer, 2011). It is anticipated that were gravity base structures to be installed here, this relatively coarse material will settle out in very close proximity to the installed foundations. By contrast, the sub-soils in this area contain a high percentage of fine material down to a depth of ~50 m (Fugro, 2011). These fine sediments will be prone to dispersion over a much wider area than sands and gravels and for this reason, the installation of monopiles is considered to represent the worst-case option with regards to the assessment of in-combination effects with nearby aggregate extraction operations.

The main input parameters used in the modelling analyses are described in Table 21 and Table 22. As with the plume modelling associated with the installation of monopiles into chalk, a 'worst-case scenario' is assumed whereby the monopile foundations are installed using drilling (even though it is expected that the majority of foundations will be installed using piling). The same sediment spill volumes from the foundations are also considered, along with the previously described rates at which the foundations are installed. Along the western margin of the Rampion development, in the vicinity of Area 122/ 1B, Area 123B and Area 124/1B, the shallowest depth at which chalk is encountered is below ~47 m from the seabed and Tertiary sediments belonging to the Lambeth Group dominate almost the entire profile (Fugro Geoconsulting, 2011). The Lambeth Group sediments comprise inter-bedded layers of stiff to very hard sandy clay and dense to very dense clayey silty sand, as well as hard to very hard sandy silt and sandstone. On the basis of the site geotechnical report (Fugro Geoconsulting, 2011), borehole BH-17 is considered to be representative of soil conditions encountered along the western margin of the development, nearby to Area 122/1B. A summary of the soil types encountered in Borehole BH-17 are shown in Table 22.

Table 21. Summary of plume modelling input parameters for monopile installation

Variable		Input Parameter
Sediment Spill volume		1,470 m ³ **
Pile penetration into seabed		52 m
Pile external diameter		6 m**
Minimum time to install one monopile		8 hours
Minimum time between monopile installations		72 hours**
Release point for arisings		Bed
Total duration of model run (days)		15 days
Total number of plume releases		5
Sediment type		Variable (clay, silt and sand)
Dry Sediment Density*		1,760 kg/m ³
Approximate relative moisture content*		25%
Approximate rate of (dry) sediment release	0-21 m depth	16 kg/s
	21-29 m depth	34 kg/s
	29-52 m depth	40 kg/s
* Derived from Fugro (2011)		
** Of note is that some variables have been modified following engineering considerations made since this coastal process assessment. 1,824 m ³ of sediment may now be released for a pile diameter of 6.5 m. It is also now considered that the minimum time between monopile installations is 48 hours.		

Table 22. Summary of soil types encountered in Borehole BH-17

Soil Unit	Approximate Depth (m)	Thickness (m)	Approximate Percentage Soil Type			
			Clay (2 µm)	Silt (40 µm)	Sand (375 µm)	Gravel (>2,000 µm)
Very sandy CLAY	0-21	21	20	40	40	0
Slightly sandy CLAY	21-29	8	25	55	20	0
Silty fine silica SAND	29-45	16	5	20	75	0
Borehole located in the western extent of the Site Development Area						

(Source taken from: Fugro Geoconsulting, 2011)

Details of aggregate dredging at Area 122/ 1B, Area 123B and Area 124/1B

(The following information has been obtained through informal discussions with the licensed operators at Area 122/ 1B, Area 123B and Area 124/1B).

The target resource at Area 122/ 1B, Area 123B and Area 124/1B is sandy gravel with an 'all-in cargo' is the normal operating procedure. Cemex, Hanson and Tarmac are all licensed to operate at this site and there is no limit on the total number of dredgers that may be operating here at any given time. However, as the site is co-operated between three producers, there would generally be no more than three dredgers present. The duration of the dredging cycle (i.e. time from loading at the site, to unloading at the wharf and back to the site) is 12 hours if the material is landed at Shoreham or Bedhampton. However, this may rise to 48 hours if landed in London. On this basis, the worst case scenario of 12 hours has been considered here, with each dredging episodes synced to coincide with foundation installation.

One set of parameters that control aggregate sediment plume intensity (i.e. SSC distribution and degree of sedimentation) is the sediment release rate from overflow and/or screening from the dredging vessel. This is highly variable, being governed by the type, size and pumping power of the dredger and the characteristics of the material on the bed. The dredger used for

the basis of this study is the Arco Dijk, an H-Class trailing suction hopper dredger (TSHD) owned by Hanson Aggregates Marine Ltd. The Arco Dijk represents one of the largest dredgers in the UK aggregate fleet, with a capacity of approximately 4,800 m³ (see Table 23), and has been the standard size used for establishing representative 'footprints' for Marine Aggregate Regional Environmental Assessments (MAREA) studies in other regions (i.e. Anglian, Thames and South Coast Regions). The use of this dredger specification therefore provides for a 'worst case' scenario for in-combination effects with aggregate dredging.

Table 23. Properties of the Arco Dijk (H-Class) TSHD

Owner	Hanson Aggregates Marine Ltd
Length (m)	113.2
Beam (m)	20.1
Maximum draught (m)	7.7
Minimum draft (m)	4.5
Discharge system	Bucket wheel & conveyor
Discharge speed (tonnes/hr)	2,000
Approx cargo tonnes (as dredged ballast)	8,200
Approx cargo tonnes (sand)	7,700
Cargo hold volume (m ³)	4,794
Max dredging depth (m)	52.5
Dredge pipe diameter (mm)	700 (1 pipe)
Dredge pump capacity (tonnes/hr)	2,943
Type of screening	Tower/wire mesh
Loading capability	All-in/screened BAD/screened sand

During a study undertaken by HR Wallingford (2011b) to assess the plume dispersion arising from aggregate dredging by a large TSHD, a peak sediment discharge rate of 50kg/s was predicted using Turbidity Assessment Software (TASS) (Aarninkhof *et al.*, 2010) for a total sediment loss of about 5.5% from the sediment overflows from the dredger. If this proportion of loss is considered consistent over a period of 4 hours to load the Arco Dijk then the average sediment discharge (release) in the overflow would be ~30 kg/s.

No detailed PSA data was available from the Aggregate Areas. However, to determine the size distribution of the sediment to be modelled, typical overflow distributions have been obtained from similar studies looking at dredging of sandy gravel with all-in cargoes (e.g. ABPmer, 2011). Only the distribution of sediments below 500 µm (microns) has been considered on the basis that coarser sediments in the overflow are likely to settle out quickly in the immediate vicinity of the dredger. Three particle sizes and associated settling velocities were chosen to characterise the particle size distribution for modelling purposes. These individual parameters, the proportion of the overflow distribution they have been taken to represent and the proportion of the total overflow discharge are shown in Table 24.

Table 24. Model inputs for dredging discharges

Particle Size (µm)	Relative Contribution of Released Sediment (%)	Settling Velocity (m/s)	Source Flux (kg/s)
40	20	0.001	6
100	20	0.007	6
350	60	0.045	18

This distribution represents about 20% silt (less than 63 μm), about 20% fine sand (63 to 125 μm) and 60% fine/medium sand (above 125 μm).

In order to simulate the worst-case in-combination scenario, each of the three dredgers was assumed to be stationary during dredging operations and aligned, (according to the tidal axis) with the particular foundation being installed.

Numerical modelling assessment

On the basis of Figure 18, it is evident that:

- Some interaction does occur between dredging plumes from Area 122/ 1B, Area 123B and Area 124/1B with foundation installation at Rampion;
- Peak concentrations are dependant on the timing of release relative to the state of the tide. The highest observed concentrations are between 80 and 100 mg/l and are observed over a distance of ~ 2 km from the release locations;
- After ~ 13 days (and following installation of the fifth foundation), the plumes from the foundation installations and dredging activities have dispersed away from the release locations due to advection and diffusion. This has resulted in elevated SSCs at a distance of up to ~25 km inshore from the foundations and dredging areas. Within this region of elevated SSCs, peak concentrations are typically less than 20 mg/l.

Engineering considerations undertaken following the numerical simulation of the 6 m diameter monopiles have resulted in, approximately, a 20% increase in the sediment volume that could be released per monopile should drilling methods be used for installation. A similar increase in the resultant SSC values from foundation installation methods would be expected, such that orders of magnitude remain as modelled and presented above. In addition, the minimum length of time between installations has reduced from 72 hours to 48 hours. Of note is that a shorter time period between successive sediment releases will only affect the finer sediments. A consideration of sediment mobility within the study area indicates that coarser sediments will fall out of suspension relatively quickly, with this material only being mobile under peak spring periods (ABPmer, 2011).

The highly conservative assessment discussed in Section 3.1.3 would indicate that, away from the foundation locations, SSC are unlikely to be significantly elevated beyond that modelled. Dispersion of the suspended sediments away from both the sediment source (foundation) and array occurs after, approximately, 48 hours following the commencement of works. It is the dispersion of any elevated concentrations (above background levels) that has a greater potential to increase.

Following installation of the five foundations, bed level changes of up to ~1 mm are observed to the east-northeast of the release locations whilst changes of between ~0.2 and 0.5 mm are observed up to a distance of approximately 20 km from the release locations (Figure 7). However, it is anticipated that under the prevailing hydrodynamic conditions, the deposited material will be re-mobilised.

Rampion export cable installation and aggregate dredging

Those aggregate areas within one spring tidal excursion ellipse of the Rampion export cable corridor are listed in Table 20. The closest of these Areas (Area 122/1A; 123/A; and 124/1A) are ~3.8 km to the west. Reference to HR Wallingford (2010) reveals that even when dredging occurs at the boundary of Licence Areas, suspended sediment concentrations more than 50 mg/l above background levels are only likely to be experienced within 200 m of the Licence Area boundary and concentrations more than 20 mg/l above background levels are only likely to be experienced within 1 km of the licence area boundary. On this basis, the potential for substantial interaction between plume(s) arising from aggregate dredging activities and the likely plume from any jetting along the cable route is considered minimal.

5.3 Potential Impact: Changes to Wave and Current Regimes – Affecting Patterns of Far-field (Coastal) Sediment Transport

5.3.1 Tides

Due to the foot print of the proposed wind farm development and the licensed and application aggregate sites, there is almost certain to be some overlap with the flow speeds changes from the wind farm site. The effect of the wind farm development is predicted to decrease current flow speeds within and in close proximity to the array under peak conditions and low water, with the reverse at high water (Figure 10). Conversely, dredging at aggregate sites attends to cause a reduction in flow speed within the immediate area of dredging activities, with associated increases in the surrounding areas (South Coast REA (EMU, 2010). On this basis, it is more likely that the effects of the flow speed reduction due to the array would be minimised by the associated increase in flow speeds in association with the dredging area. This pattern is predicted to occur at nearly all tidal states, except under high water during the slack period. The increase in flow speed at this period is predicted to be still less than 0.03 m/s; therefore, any compounding effects due to increasing flow speeds from the wind farm development and dredging area would be minimal. The discussed effects are only predicted to be local to the wind farm area and aggregate sites, with very little to no change extending to the coast.

5.3.2 Waves

In terms of the potential in-combination effect with the licensed dredging areas to the west of the array, there is again the potential for some overlap of changes to the wave conditions, due to the location of the activities. Results of numerical modelling with the potential development, demonstrate that wave heights would predominantly be reduced at all tidal states and for the 10 in 1, 1 in 1 and 1 in 10 year return period wave conditions within and towards the lee of the development area (Figures 11 and 12). This is case for all directions except from the west-southwest waves, where there is still a decrease in significant wave heights to the north (or lee) of the development site, but an increase within the array. Changes to the significant wave height in relation to dredging activities are understood to increase wave height in the lee of the dredge site. Therefore the decrease in the significant wave height in relation to the wind farm development would theoretically be counteracted by the increase in wave heights from the dredge site.

5.3.3 Sediment Transport

Sediment transport in this region has been identified to be driven predominantly by the tidal regime through the English Channel. It is therefore in relation to the tidal properties that the potential for the in-combination effects of the wind farm development and dredging activities on sediment transport will be addressed. Due to the recognised potential of in-combination effects for the tides as discussed in Section 5.3.1, there is therefore a similar potential for sediment transport as a consequence. It was presented in Section 5.3.1 that the decrease to flow speeds in relation to development array would be cancelled out by the associated increase in flow speeds in association with the dredging area. Therefore, it is also likely that the consequent influence on sediment transport would be negated by the tidal flow properties. The effects of changes in sediment transport are again considered to be local to the wind farm area and aggregate sites, with very little to no change extending to the coast.

6. Summary of Potential Impacts

6.1 Construction and Decommissioning Phases

Over the period of construction there is likelihood for discrete short-term disturbances on the seabed as the wind farm infrastructure is installed sequentially across the development site. These disturbances will be due to activities related to foundation installation and cable laying and have the potential to release seabed sediments into the water column which have the potential to result in the formation of sediment plumes. The decommissioning phase of an offshore wind farm is generally considered to be of similar or lesser impact than the initial construction phase. The potential impacts of the Rampion Wind Farm during the construction and decommissioning phases is summarised below and listed in Table 25.

The installation of monopile foundations has the greatest potential to cause change to the natural regime should drill-drive installation techniques be required. Numerical modelling analyses have been presented which demonstrate that these changes are likely to be of limited duration for both cable and foundation installation works. Suspended sediment concentrations are elevated, above natural background levels, by no more than 5 mg/l following completion of the foundation installation activities. Natural variation is shown to increase near seabed (0.5m above the bed) SSC levels by up to 35 mg/l. Any suspended sediments can be expected to rapidly disperse due to tide and wave forcing. Other foundation options under consideration and which have different installation techniques will involve smaller sediment volumes for dispersion. Correspondingly, this will yield lower suspended sediment concentrations. Also, the actual composition of the sediment released is likely to be greater than that modelled here which represents a very conservative scenario of 100 % chalk release.

Away from the immediate vicinity of the foundation structures, bed level changes are likely to be extremely small.

The export cable landfall installation could potentially elevate suspended sediment concentrations *temporarily* in the immediate vicinity of the trenching operation, with the greatest increases being observed in the shallower waters for the duration of the works. Evidence for the short-term, localised impacts of such activities from other wind farm developments is well documented (BERR, 2008). Background suspended sediment concentrations in this region are likely to be in the order of at least 200 mg/l less than 2 km from the trench with elevated concentrations remaining below 10 mg/l immediately following the completion of works. Natural variation is shown to increase near seabed (0.5m above the bed) SSC levels by up to 35 mg/l. It is expected that these levels will rapidly reduce as a result of wave and tidal forcing following completion of the works.

In-combination effects arising from the construction of the Rampion Wind Farm and aggregate dredging within the vicinity of the array and cable route have also been considered. Sediment plume modelling analyses undertaken within the current study and ABPmer (2005b) suggest that there is little chance of substantial interaction between plumes and as such, in-combination effects are regarded to be of minor significance.

6.2 Operational Phase

The greatest potential for changes to the tidal and wave regimes occurs during the operational stage, which is defined as 25 years (Section 2a of the ES). The layout containing 80 4 MW GBS structures and 95 monopile structures (175 structures in total) presents the realistic worst case scenario and will cause the greatest departure from baseline conditions. Other foundation types are expected to have lesser effects. The potential impacts of the Rampion Wind Farm during the operational phase is summarised below and listed in Table 25.

Away from the immediate vicinity of the foundations (where currents may be disturbed due to wake effects from individual structures), changes to flow speed and direction are predicted to be extremely minor (i.e. less than 0.01 m/s and less than 1°). This is true for all stages throughout the tidal cycle and changes of this magnitude will be largely immeasurable in practice. It follows from this that any changes in the rate and direction of bed-load sediment transport (which is driven by tidal currents) will also be very small and restricted to the near field. The morphology of the bed is therefore unlikely to be altered during the operational phase of the wind farm.

Modifications to the wave regime are shown, under certain return periods and tidal states, to extend to the shore. However, at this distance from the array, changes to wave height are typically less than 2.5% whilst longshore sediment transport changes to the wave period and direction are shown to be negligible and generally less than 1%. These small-scale changes in wave conditions at the coast have the potential to cause change to the rate of longshore sediment transport. The most likely location in which a reduction in beach volume (i.e. erosion) would occur is along the coast to the east of the array, in the vicinity of Beachy Head. However, the predicted changes in wave conditions at the coast as a result of the development are less than the inter-annual variability observed in historic records and the predicted changes in future wave climate as a result of climate change. Accordingly, it is considered unlikely that any scheme induced changes to longshore sediment transport will be clearly discernible from the changes that will have occurred in the past and that are likely to occur in the future.

An assessment of the potential effects of the development upon swell waves has been undertaken in order to address concern expressed by surfers regarding the potential interruption of offshore wave transmission and reduction in offshore swell energy at the coast. Following consultation with SAS, it has been agreed that reductions in wave height of less than 7 % are not considered to be detrimental to the surfing resource. On the basis of the numerical wave modelling analyses, it is found that wave height reductions of more than 7% are not observed at any location along the coast. Accordingly, changes to the surfing resource due to the presence of the array infrastructure is considered to be of minor significance.

Scour development is expected around the base of the structures, but will remain localised to the foundation structures. Further the depth of scour becomes restrained due to the limited depth of the erodible sediments. It is not anticipated that the scour features associated with the individual structures will combine to cause group scour.

In addition to the changes which may result from the presence of the wind farm, there are those which will be introduced through both the natural variability of the system, including climatic changes. These would occur regardless of the development of the wind farm. Natural variability will result from, for example, changing wave conditions experienced on an inter-annual, annual and decadal scale. Climatic changes which are valid for the study area are:

- Sea level rise. It is suggested that by 2050, relative sea level in the application site and surrounding area will have risen by 0.22 m based on the medium emissions scenario at the 50% percentile (Lowe *et al.*, 2009). It has been concluded that this rise will continue to increase the risk of flooding in coastal areas (Defra, 2012);
- Increase in storm surge magnitude. For a 'medium emissions' scenario, the 1 in 50-year storm surge event will increase by 0.43 mm/yr (values apply until 2099) (Lowe *et al.*, 2009); and
- Increase in storminess. The UKCIP indicates that in the English Channel, in the vicinity of the proposed development, the mean annual maxima significant wave heights between 1960 and 1990 and 2070 and 2100 will increase by 0.5 to 1 m (Lowe *et al.*, 2009).

Table 25. Summary of potential impacts of the proposed Rampion Wind Farm upon coastal processes

Phase	Potential Impact	Significance of Impact
Construction	Increase in suspended sediment concentrations as a result of foundation installation activities	Minor
	Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	Minor
	Increase in suspended sediment concentration, bed level change and seabed textural change following re-deposition of suspended sediments as a result of inter-array cable burial and export cable burial activities	Minor
	Indentations left on the seabed by jack-up vessels and large anchors	Minor
	Disturbance of coastal morphology at the export cable landfall site	Minor
Operation	Scour effects due to the presence of the turbine foundations	Minor
	Scour effects due to the exposure of inter-array and export cables and cable protection measures	Minor
	Changes to wave and current regimes affecting patterns of near-field (offshore) sediment transport due to the presence of the turbine foundations	Minor
	Changes to wave and current regimes - affecting patterns of far-field (coastal) sediment transport due to the presence of the turbine foundations	Minor
	Changes to swell conditions adversely impacting recreational surfing	Minor
Decommissioning	Increase in suspended sediment concentrations and accumulation of sediment and change of sediment type at the seabed as a result of wind farm decommissioning activities	Minor
	Indentations left on the seabed by jack-up vessels and large anchors	Minor
	Changes to wave and current regimes affecting patterns of near- and far-field sediment transport due to the removal of the turbine foundations	Minor
Cumulative / In-combination	Increase in suspended sediment concentrations due to interaction of sediment plumes	Minor
	Changes to wave and current regimes affecting patterns of near-field (offshore) and far-field (coastal) sediment transport	Minor

6.3 Consideration of Coastal Process Receptors

A consideration of the potential effects of the proposed Rampion Wind Farm with respect to the coastal process themes identified in Section 2.3 is offered below. This is based upon the coastal process assessment reported previously, and as summarised in Table 24.

6.3.1 Seabed infrastructure, including pipelines and cables

An assessment of the effects upon the hydrodynamics and sediment transport has been made. It is those effects during the operational phase which may influence this receptor, as detailed in Section 4.

It is shown that over the near-field (within the array boundary and where the tidal regime becomes dominant over the wave regime with respect to sediment transport (Section 4.5.1 and ABPmer (2011)) that the effects of the development remain limited:

- Flow speed changes are small (typically ranging between 0.1 m/s and 0.003 m/s, the former being a local response to the presence of the GBS and the latter a response along and immediately adjacent to the array boundary (Figure 10);
- Wave height changes are limited, typically less than a 5% reduction in significant wave height (Section 4.4 and Appendix C). Wave period and directional changes are typically negligible, being less than 3% and more commonly in the range 0% to 1%; and
- Consequently effects upon sediment transport are shown to be small, as illustrated through the negligible effects to the potential for sediment mobility to the different material types (Section 4.5).

It is shown that over the far-field (away from the array and towards the shoreline), where the wave regime becomes dominant over the tidal regime with respect to sediment transport (Section 4.5.1 and ABPmer (2011)), that the development:

- Does not effect the flow (tidal) regime (Figure 10);
- Has limited effect upon the wave regime, with significant wave height, period and directional changes being negligible (Section 4.4 and Appendix C);
- Results in little change to the direction of longshore sediment transport based on the below 1% change to wave direction; and
- Results in limited changes to the potential longshore sediment transport between Selesy Bill and Beachy Head, particularly in the east of the region (Section 4.6).

Therefore, it is considered that it is unlikely that any seabed infrastructure will be affected by the presence of the wind farm, as a response to any changes the development may have upon the wave, tidal and sediment transport regimes.

6.3.2 Aggregate Sites

There are a number of aggregate sites located to the west of the Rampion Wind Farm, with one located within the application site (Figure 2).

The coastal process theme here requires a consideration of the potential for plume interaction from aggregate activities during installation works. As presented in Section 5.1, for plume(s) resulting from:

- Aggregate and cable installation activities, there is only a small potential for any interaction; and
- Aggregate and foundation installation activities, there is a potential for interaction but peak concentrations remain dependant upon the timings of any works.

Of key importance here is that any works relating to cable and foundation installation remain short-term. Therefore whilst longshore sediment transport aggregate dredging activities are likely to remain active over the license period, 15 years, cable and installation works would remain active over a period of months. The period of these works is dependent upon available weather windows.

Therefore, it is considered unlikely that there will be long-term, wide spread impacts between the aggregate industry and the Rampion Wind Farm.

6.3.3 Coastline of Sub-Cell 4d

An assessment of the effects upon sediment transport at the coast has already been undertaken in Section 4.6. It is considered that the Rampion Wind Farm will have a slight influence upon sediment transport in the nearshore region (shoreline). A small reduction in longshore sediment transport rates are shown between Selsey Bill and Beachy Head, and as such will slightly affect the transport of material in an easterly direction. The small change in longshore sediment transport is likely to be comparable or less than the natural variability in rates which result from changing wave conditions experienced on an inter-annual, annual and decadal scale.

6.3.4 Designated sites

A number of designated sites (Table 2; Figure 2) are located within the far-field extent. Importantly, the assessment of potential impacts to nearby designated sites focuses upon the potential for significant modification of the naturally occurring physical processes that could indirectly impact the habitats they support. The further assessment of effects on other EIA topics will be informed by these results, but will be reported in other chapters.

Pagham Harbour: SPA and Ramsar

The Pagham Harbour SPA has been designated on the basis of the qualifying species which are present within the site. The presence of these species is dependant upon the habitats which support them; 'estuarine basin that comprises an extensive central area of saltmarsh and intertidal mud-flats, surrounded by lagoons, shingle, open water, reed swamp and wet permanent grassland' (JNCC, 2001).

No significant changes to the wave and tidal regimes are predicted to occur at this location. Correspondingly, there are no significant effects anticipated to occur to the habitats located here.

Beachy Head West: rMCZ

The habitats proposed for designation within this site are:

- Moderate energy intertidal rock and coarse sediment; and
- Subtidal sand, mud and mixed sediments.

There are no significant changes to the wave and tidal regimes along this frontage, with slight changes to the shoreline sediment transport regime indicated as reductions in the longshore sediment transport rates to the east (Section 4.6). Further discussion on the potential implications of this slight reduction is presented in Section 6.3.3.

Kingmere: rMCZ

The habitat proposed for designation within this site is:

- Subtidal mixed sediments.

It is the tidal regime which dominates sediment transport within this site. No changes to this regime as a response to the presence of the Rampion Wind Farm are predicted. Only negligible changes to the wave regime are predicted within this site (typically less than 2%, 0.5% and 1% for significant wave heights, directions and periods, respectively).

Offshore Overfalls and East Meridian: rMCZ

The habitats proposed for designation within Offshore Overfalls are:

- Subtidal coarse, sand and mixed sediments.

There is currently no information available regarding the habitats proposed for designation within East Meridian (Balanced Seas, 2012).

Both of these sites lie seaward of the Rampion Wind Farm. No significant changes to the wave, tidal and sediment transport regimes are predicted at these two locations.

Various locations: SSSI

The following locations have been designated as SSSI:

- | | |
|----------------------|-------------------------------|
| ▪ Pagham Harbour | ▪ Adur Estuary |
| ▪ Bognor Reef | ▪ Brighton to Newhaven Cliffs |
| ▪ Selsey, East Beach | ▪ Climping Beach |
| ▪ Felpham | ▪ Seaford to Beachy Head |

There are no significant changes to the wave and tidal regimes between Selsey Bill and Beachy Head. Slight changes to the shoreline sediment transport regime are indicated, as reductions in the longshore sediment transport rates particularly to the east (Section 4.6). Further discussion on the potential implications of this slight reduction is presented in Section 6.3.3.

6.3.5 Surfing Sites

An assessment of the effects upon sediment transport at the coast has been undertaken in Section 4.6. On the basis of the numerical modelling evidence presented in Table 17, it is found that wave height reductions of more than 7% are not observed at any of the 11 surfing sites identified by SAS (shown in Figure 2). On this basis, changes to the surfing resource due to the presence of the array infrastructure is considered to be of minor significance.

7. References

ABPmer, 2011. Rampion Wind Farm: Coastal Processes Baseline Assessment. ABP Marine Environmental Research Ltd, Report No. R.1853 (draft).

ABPmer, 2008. Coastal Processes Scoping Zone EON02, South Coast. ABP Marine Environmental Research Ltd, Report No. R.1476.

ABPmer, 2004. English Channel Extreme Tidal Level Review. ABP Marine Environmental Research Ltd, Report No. R.1085.

Alexandersson, H., Tuomenvirta, H., Schmith, T., Iden, K., 2000. Trends of storms in NW Europe derived from an updated pressure data set. *Climate Research*, 14, 71 – 73.

Balanced Seas, 2012. <http://www.balancedseas.org/page/RSG%20Resources.html>

Barne, J. H., Robson, C. F., Kaznowska, S. S., Doody, J. P., Davidson, N. C. and Buck, A. L., 1998. Coasts and seas of the United Kingdom. Region 8 Sussex: Rye Bay to Chichester Harbour. Peterborough, Joint Nature Conservation Committee. (Coastal Directories Series.)

BERR, 2008. Review of cabling techniques and environmental effects applicable to the offshore wind farm industry.

Bovington, J., and Amos, D., 2010. Strategic Regional Coastal Monitoring Annual Report 2010 – Beachy Head to Selsey Bill. Project Report AR 62.

COWRIE, 2009. Coastal Process Modelling for Offshore Wind Farm Environmental Impact Assessment.

Department of Energy and Climate Change (DECC) 2011a. Overarching National Policy Statement for Energy (EN-1). The Stationery Office. London. 121pp

Department of Energy and Climate Change (DECC) 2011b. Overarching National Policy Statement for Renewable Energy (EN-3). The Stationery Office. London. 82pp

Department for Environment, Food and Rural Affairs (Defra), Centre for Environment, Fisheries and Aquaculture Science (CEFAS) and Department for Transport (DfT), 2004. 'Offshore wind farms: guidance note for Environmental Impact Assessment in respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) requirements: Version 2'.

Department for Environment, Food and Rural Affairs (Defra), 2005. Nature Conservation Guidance on Offshore Wind Farm Development.

Eggleton, J., Dolphin, T., Ware, S., Bell, T., Aldridge, J., Silva, T., Forster, R., Whomersley, P., Parker, P., Rees J., 2011. Natural Variability of Turbidity in the Regional Environmental

Assessment (REA) Areas. Project 09-P114. Cefas, Lowestoft, 41pp.

E.ON Climate and Renewables, 2012. Rampion Wind Farm - Project Design Statement. Issue 3, Version B1. February 2012. 191pp.

E.ON Climate and Renewables, 2011a. Rampion Wind Farm - Project Design Statement. Issue 3.1 Draft. July 2011. 126pp.

E.ON Climate and Renewables, 2011b. Rampion Wind Farm - Project Design Statement, Chapter 3: Foundations. December 2011. 26pp.

EMU, 2011a. Rampion Offshore Wind Farm Benthic Survey Test Results. Survey for E.ON Climate and Renewables UK Rampion Offshore Wind Limited. J1031836.

EMU, 2011b. Rampion Offshore Wind Farm Metocean Survey and Assessment. Survey report for E.ON Climate and Renewables UK Rampion Offshore Wind Limited. Report 11/J/1/01/1743/1156.

Fugro Geoconsulting Ltd, 2011. Rampion Wind Farm Site Investigation, Quadrant 99 for E.ON Climate and Renewables. Report reference J11056-3.

Fugro-Seacore 2012. Principles of Reverse Circulation Drilling

HR Wallingford 1996. Dispersion studies at Owers Bank, HR Wallingford Report EX 3335, February 1996.

HR Wallingford 2010. South Coast Dredging Association MAREA: High-level Plume Study. Technical Note DDR4323-03.

Infrastructure Planning Commission, 2010. Scoping Onion - Proposed Rampion Wind Farm. October 2010. 300pp.

Infrastructure Planning Commission (IPC), 2011. Using the Rochdale Envelope. Advice note nine: Rochdale Envelope. 10pp

Infrastructure Planning Commission (IPC), 2011. Using the Rochdale Envelope. Advice note nine: Rochdale Envelope. 10pp.

James, J. W. C.; Coggan, R. A., Blyth-Skyrme, V.J., Morando, A., Birchenough, S. N. R., Bee, E., Limpenny, D. S., Verling, E., Vanstaen, K., Pearce, B., Johnston, C. M., Rocks, K. F., Philpott, S. L. and Rees, H. L., 2007. The Eastern English Channel Marine Habitat Map. Science Series Technical Report, Cefas Lowestoft 139. 191pp.

James, J. W. C., Pearce, B., Coggan, R. A., Arnott, S. H. L., Clark, R., Plim, J. F., Pinnion, J., Barrio Frójan, C., Gardiner, J. P., Morando, A., Baggaley, P. A., Scott, G., Bigourdan, N., 2010. The South Coast Regional Environmental Characterisation. British Geological Survey Open Report OR/09/51. 249 pp.

- JNCC, 2001. SPA review site accounts. <http://jncc.defra.gov.uk/default.aspx?page=2044>
- Judd 2011. Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. DRAFT. Cefas contract report: ME5403 - Module 15.
- Kenyon N. H. and Cooper W. S. 2005. Sand banks, sand transport and offshore wind farms. DTI Strategic Environmental Assessment Area 6 technical report.
- Lowe, J., Howard, T., Pardaens, A., Tinker, J., Holt, J., Wakelin, S., Milne, G., Leake, J., Wolf, J., Horsburgh, K., Reeder, T., Jenkins, G., Ridley, J., Dye, S., Bradley, S., 2009. UK Climate Projections Science Report: Marine and coastal projections. Met Office Hadley Centre: Exeter.
- McMillan, A., Batstone, C., Worth, D., Tawn, J., Horsburgh, K. and Lawless, M., 2011a. Coastal flood boundary conditions for UK mainland and islands. Project SC060064/TR2: Design sea levels. Environment Agency, Flood and Coastal Erosion Risk Management Research and Development Programme.
- McMillan, A., Johnson, A., Worth, D., Tawn, J., Hu, K., 2011b. Coastal flood boundary conditions for UK mainland and islands. Project SC060064/TR3: Design swell waves. Environment Agency, Flood and Coastal Erosion Risk Management Research and Development Programme.
- Office of the Deputy Prime Minister, 2001. Guidance on Environmental Impact Assessment in Relation to Dredging Applications, HMSO, London.
- Osiris Projects, 2010a. E.ON Climate and Renewables Rampion Wind Farm Definitive Geophysical Survey, Volume 1 - Operations Report. Report C10011.
- Osiris Projects, 2010b. E.ON Climate and Renewables Rampion Wind Farm Definitive Geophysical Survey, Volume 2 - Section 1 Report. Report C10011.
- Osiris Projects, 2010c. E.ON Climate and Renewables Rampion Wind Farm Definitive Geophysical Survey, Volume 3a - Section 2 Report. Report C10011.
- Paphitis, D., Bastos, A. C., Evans, G. and Collins, M. B., 2010. The English Channel (La Manche): evolution, oceanography and sediment dynamics - a synthesis. In, Whittaker, J. E. and Hart, M. B. (eds.) Micropalaeontology, Sedimentary Environments and Stratigraphy: A Tribute to Dennis Curry (1912-2001). London, GB, Geological Society of London, 99-132.
- Royal Haskoning and Posford Haskoning, 2002. Eastern English Channel Regional Environmental Assessment.
- RSK Ltd (2011). Offshore Impact Assessment Tables.
- SDCG (South Downs Coastal Group), 1997. South Downs Shoreline Management Plan: Selsey Bill to Beachy Head.

SDCG (South Downs Coastal Group), 2004. Beachy Head to Selsey Bill Shoreline Management Plan First Review.

Smith, E. R., Ebersole, B. A., Wang, P., 2004. Dependence of Total Longshore sediment transport Rates on Incident Wave Parameters and Breaker Type. September 2004, US Army Corps of Engineers report ERDC/CHL CHETN-IV-62.

Surfers Against Sewage (SAS), 2010. The WAR Report. Waves are Resources. August 2010.

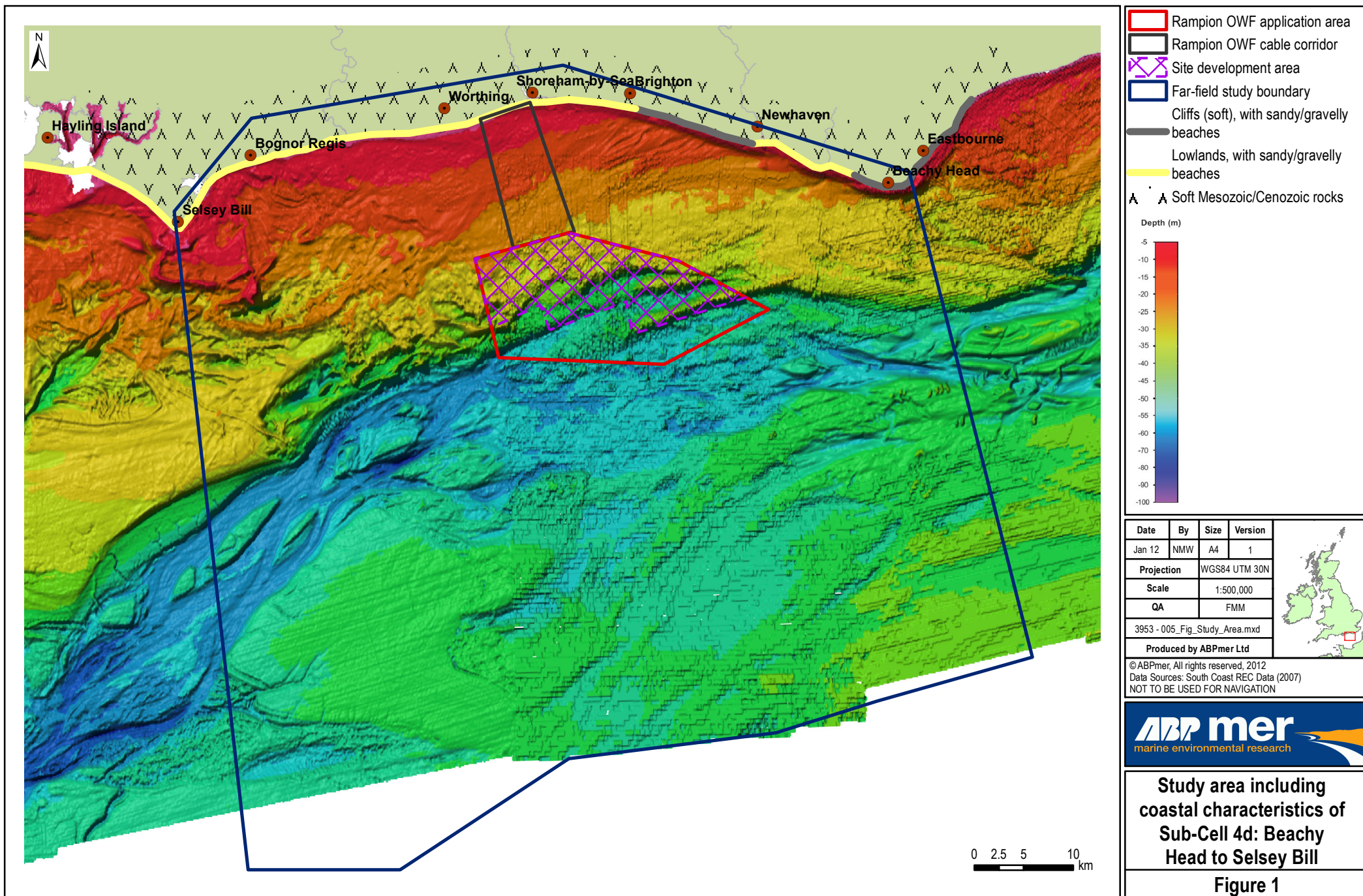
Surfers Against Sewage (SAS), 2009. Guidance on Environment Impact Assessment of Offshore Renewable Energy Development on Surfing Resources and Recreation. June 2009. 63pp.

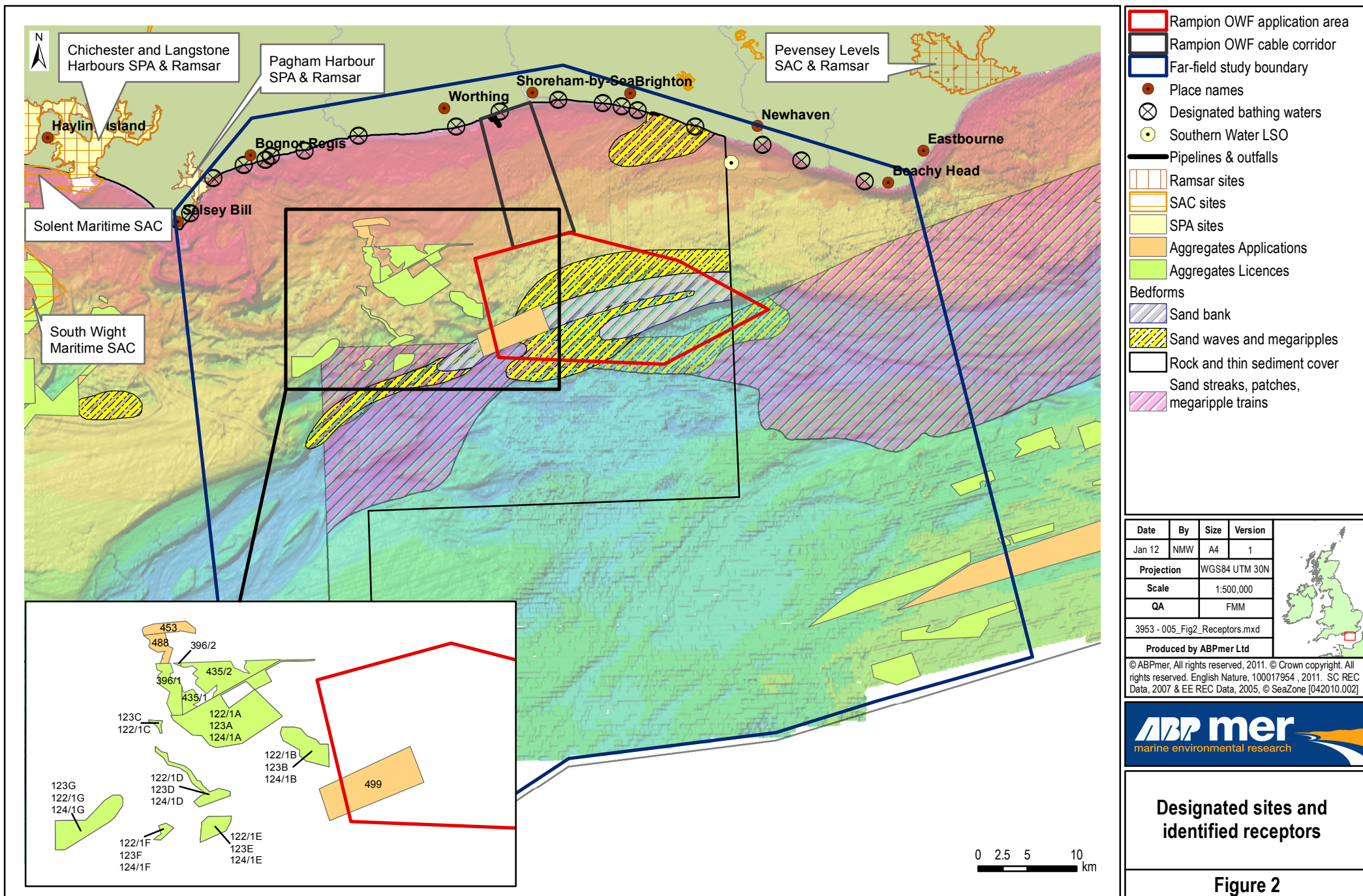
Tappin, D. R., Mason, T. and Rocks, K., 2007. DTI Strategic Environmental Assessment Area 8 Geology. Superficial Seabed Processes and Hydrocarbon Prospectivity. British Geological Survey Commissioned Report, CR/07/075.

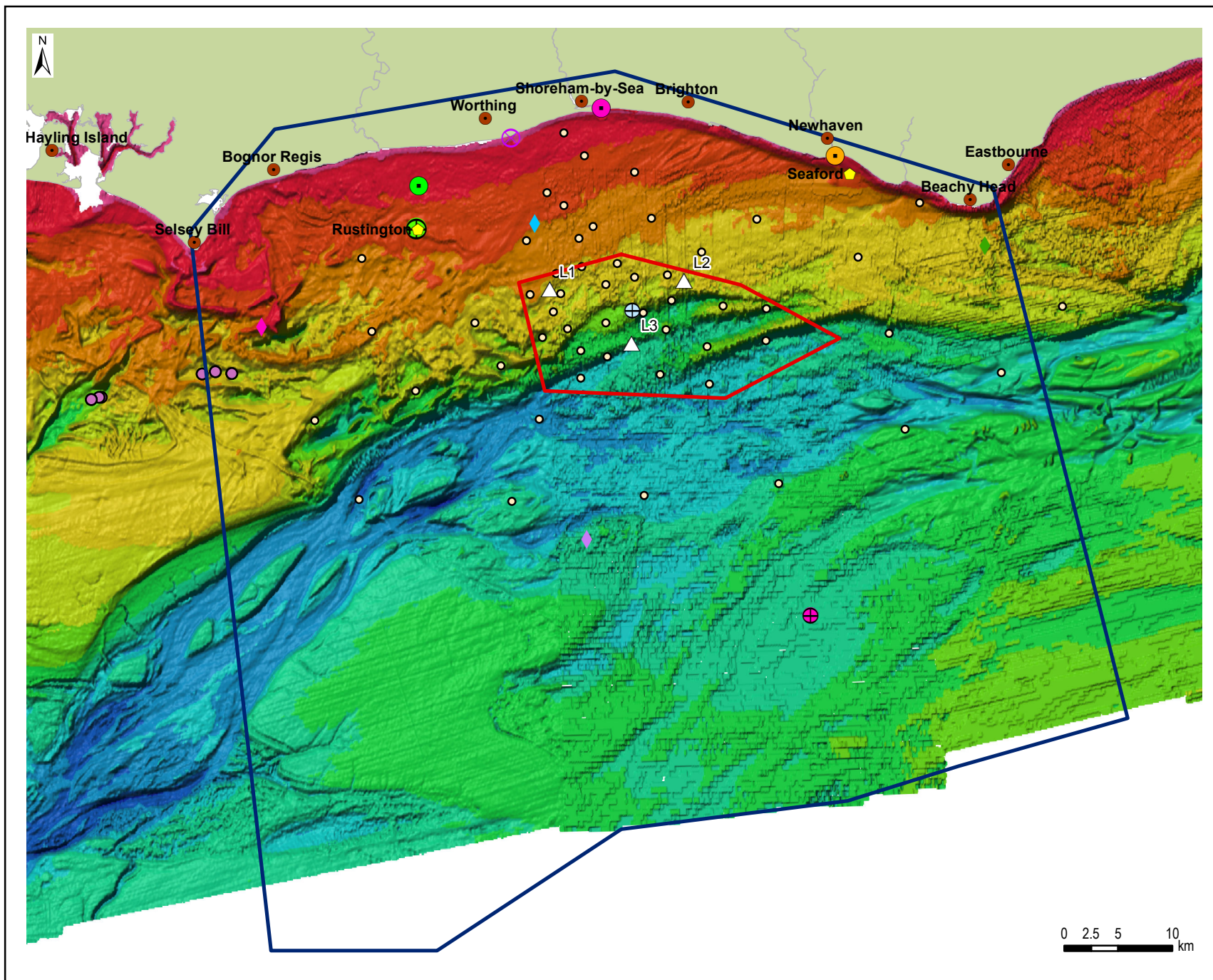
Whitehouse, R.J.S., 1998. Scour at marine structures: A manual for practical applications. Thomas Telford, London, 198 pp.

Figures

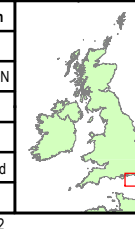


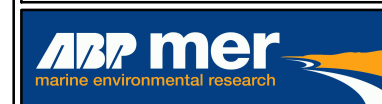






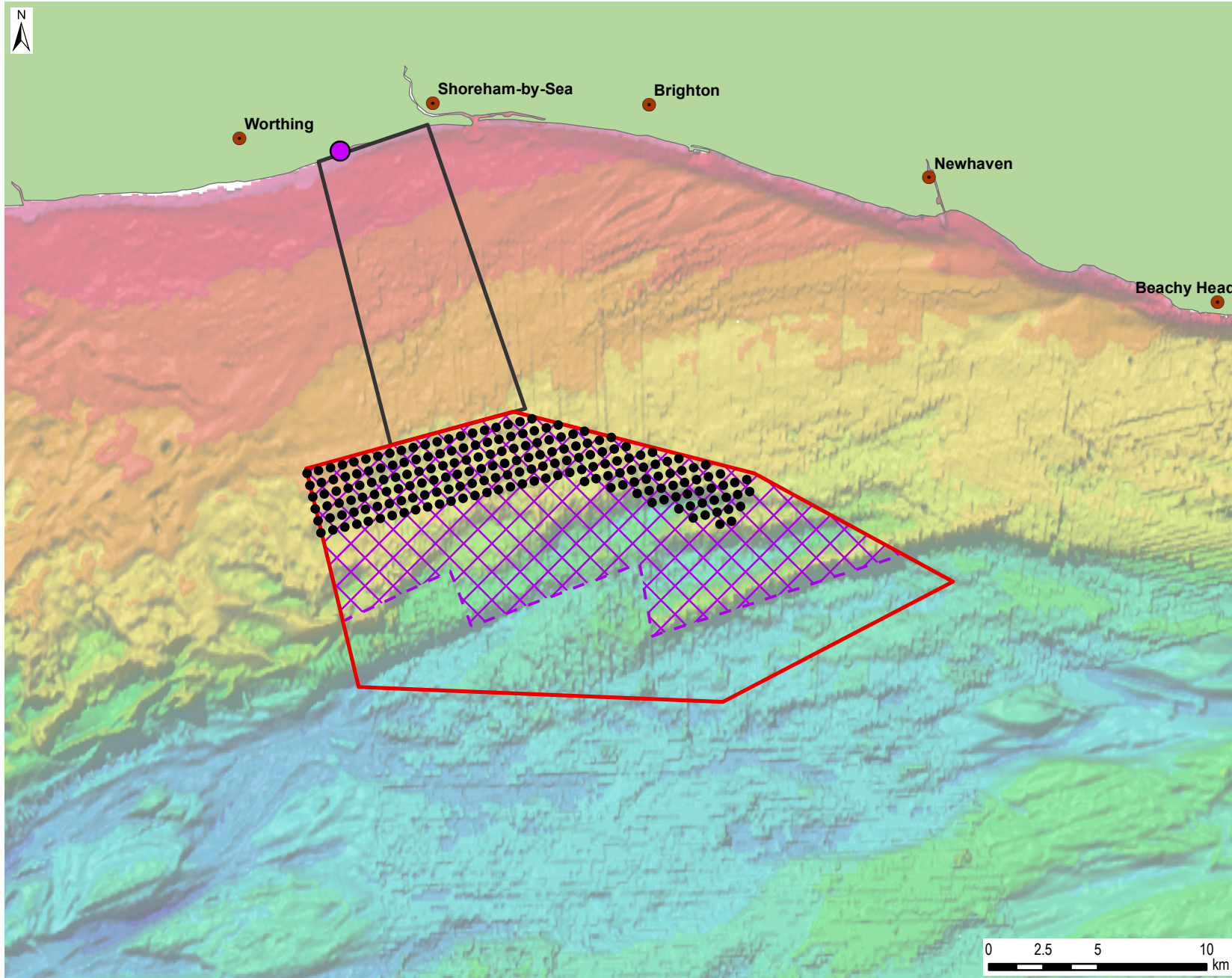
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- ⊕ Seastates offshore
- ⊕ Seastates nearshore
- ◆ Tidal diamond A
- ◆ Tidal diamond D
- ◆ Tidal diamond H
- ◆ Tidal diamond N
- ⊕ BODC data locations
- Tide gauges
 - ⊕ Arun Platform
 - ⊕ Newhaven
 - ⊕ Shoreham
 - ⊕ Worthing Pier met station

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**Data locations and
sources**

Figure 3



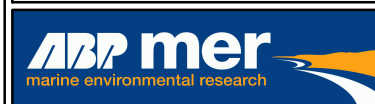
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- Rampion OWF cable corridor
- Anticipated landfall
- Turbine layout for realistic worst case assessment
- ▨ Site development area

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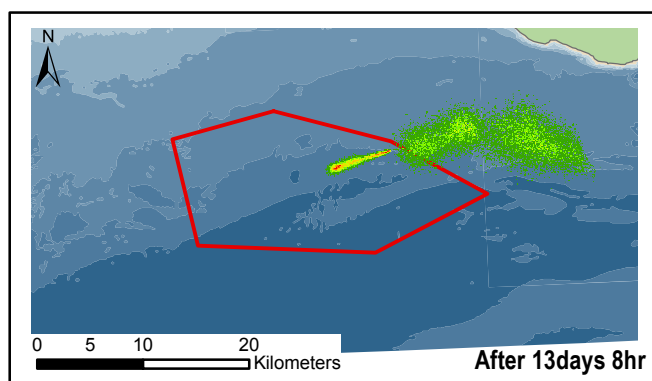
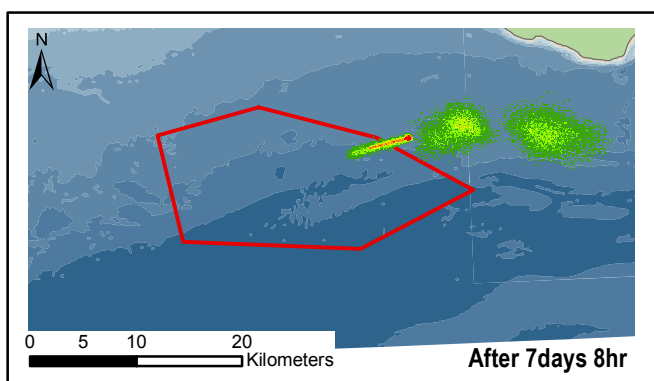
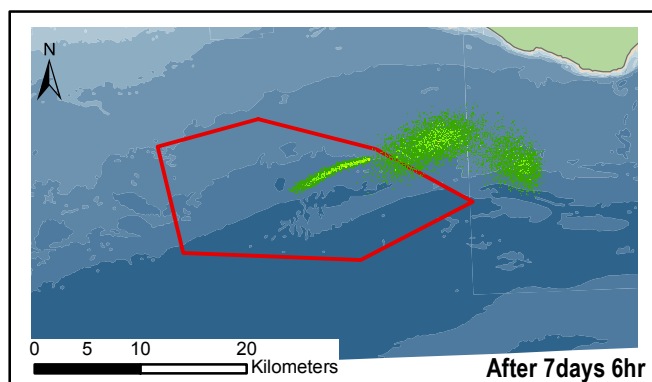
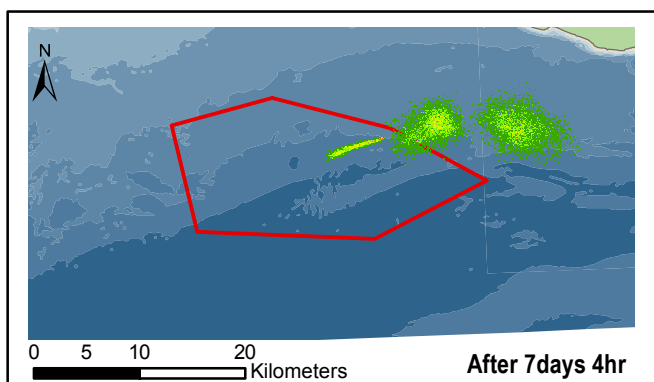
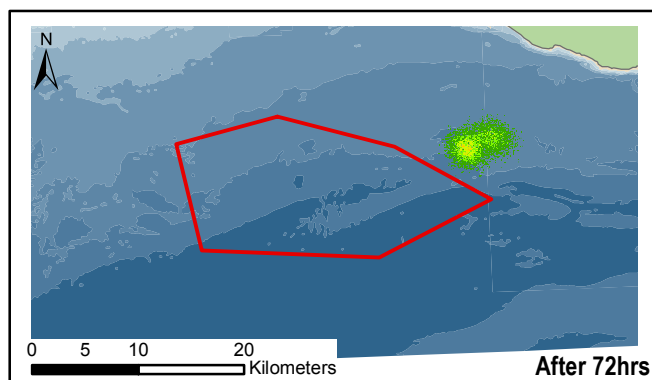
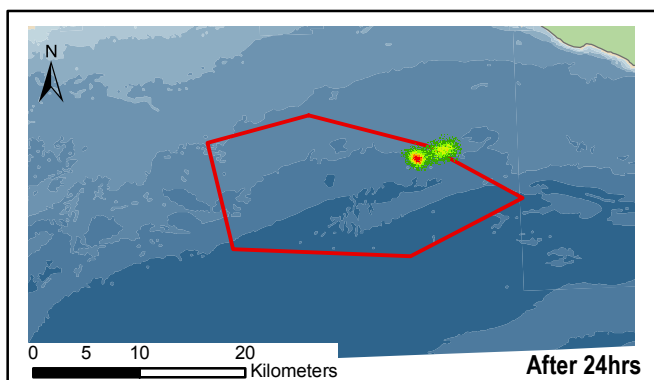
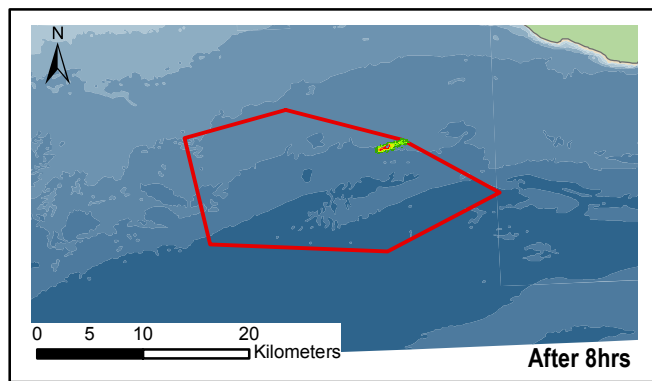
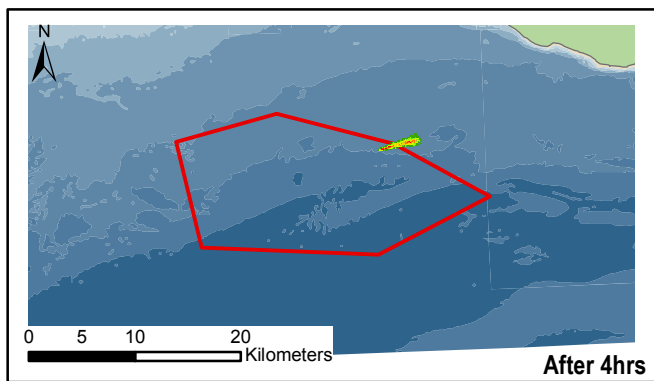
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Turbine layout and cable corridor, with a point for anticipated landfall

Figure 4



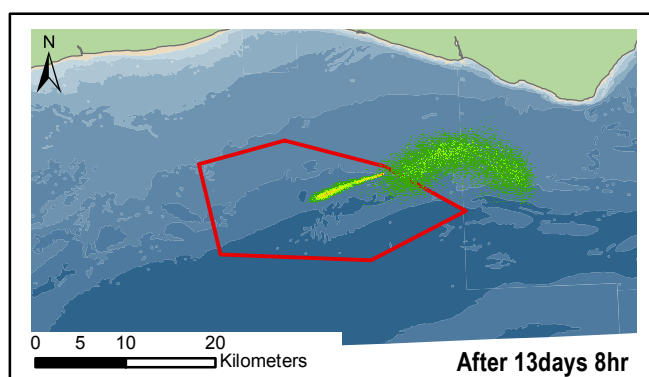
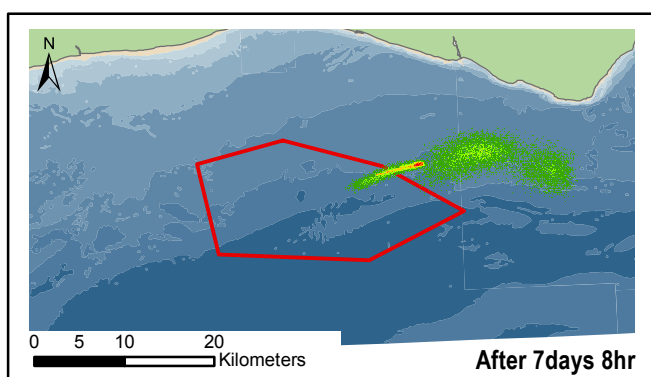
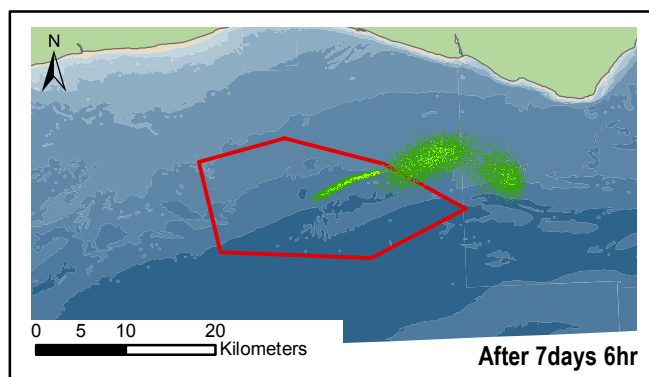
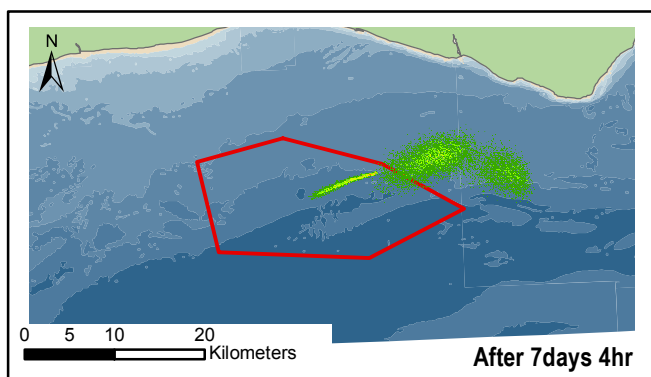
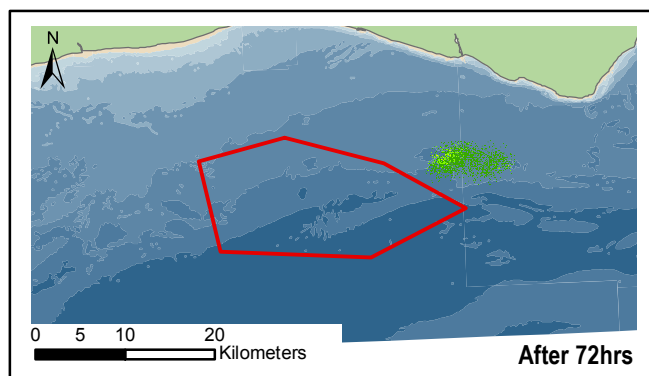
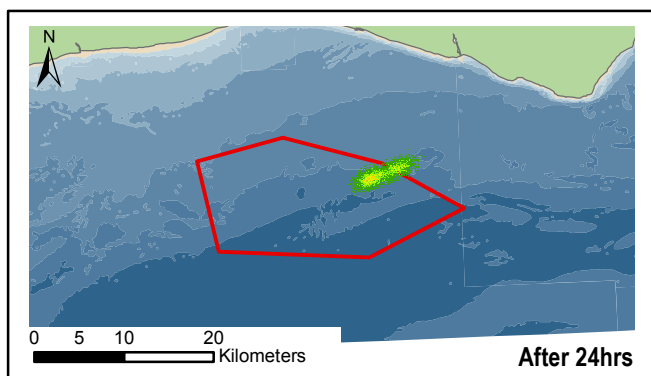
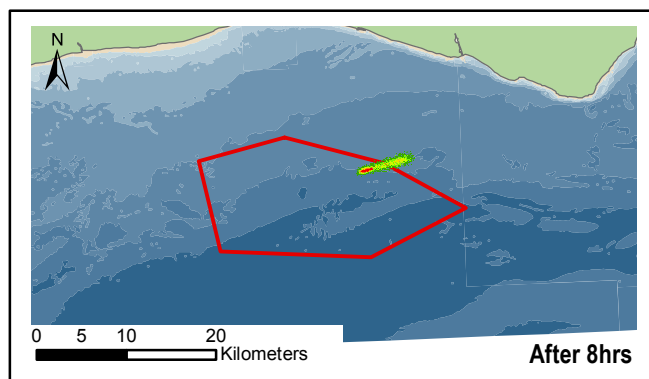
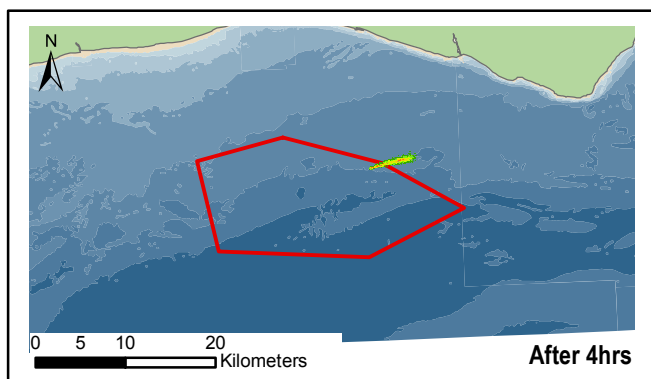
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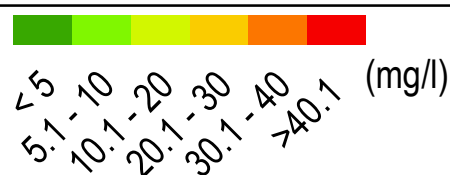
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Rampion OWF application site

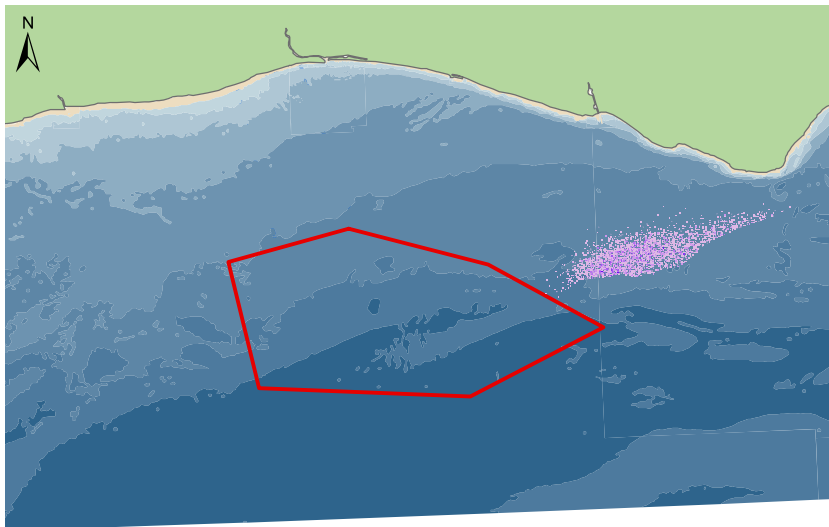


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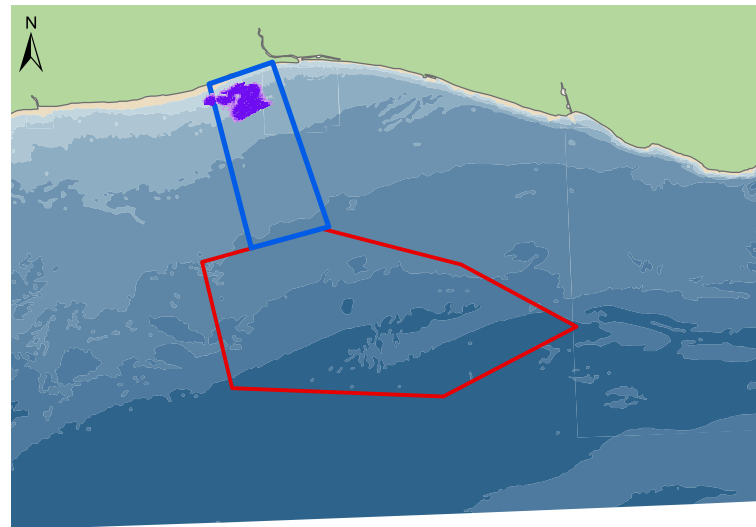


Rampion OWF application site



Bed Thickness Changes Associated With the Installation of Five Foundations Into Chalk (20µm)

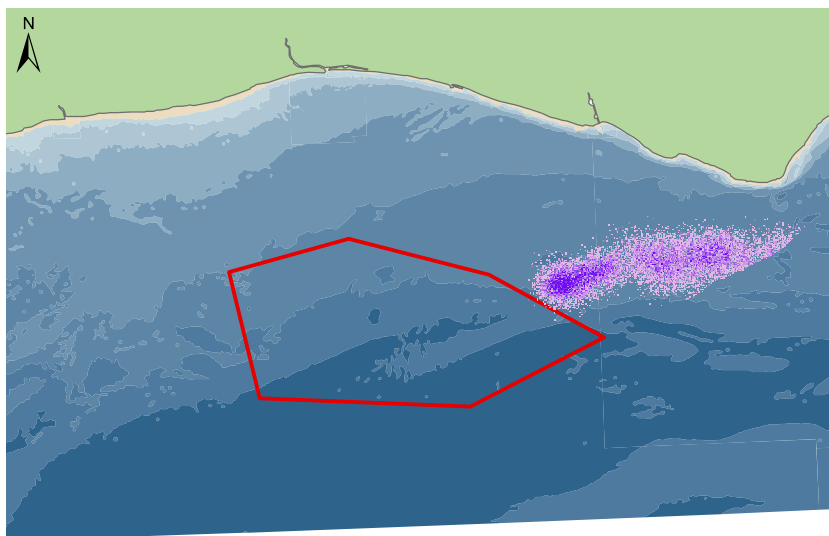
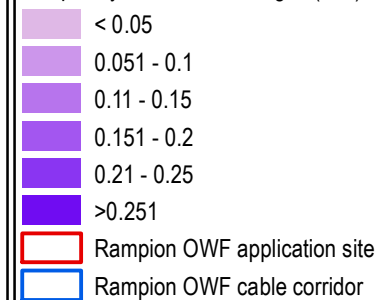
0 2.5 5 10 km



Bed Thickness Changes Associated With Cable Installation (375µm)

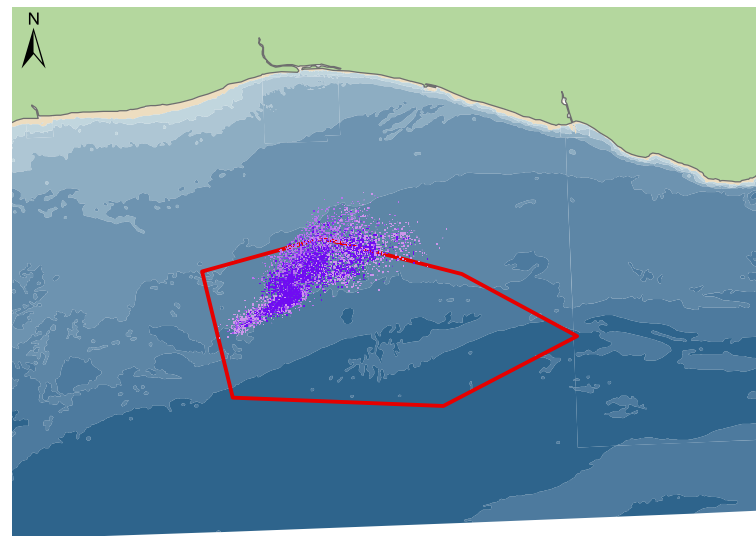
0 2.5 5 10 km

Temporary Thickness Changes (mm)



Bed Thickness Changes Associated With the Installation of Five Foundations Into Chalk (750µm)

0 2.5 5 10 km



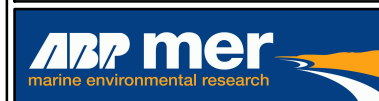
Bed Thickness Changes Due to the Combined Effects of Foundation Installation And Aggregate Dredging

0 2.5 5 10 km

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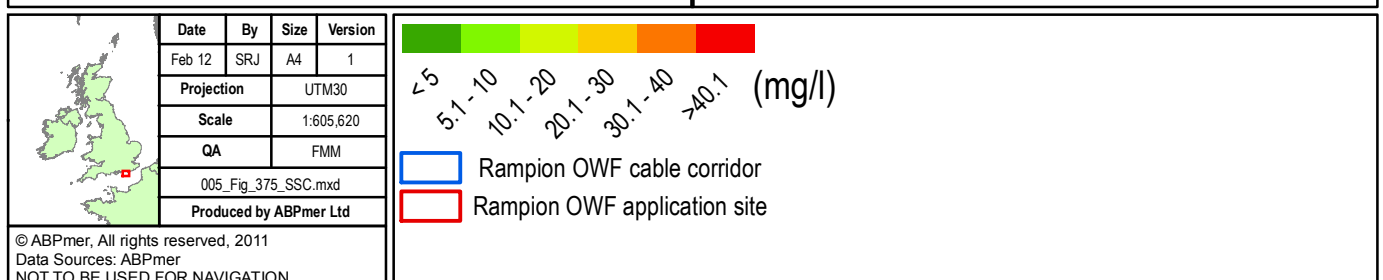
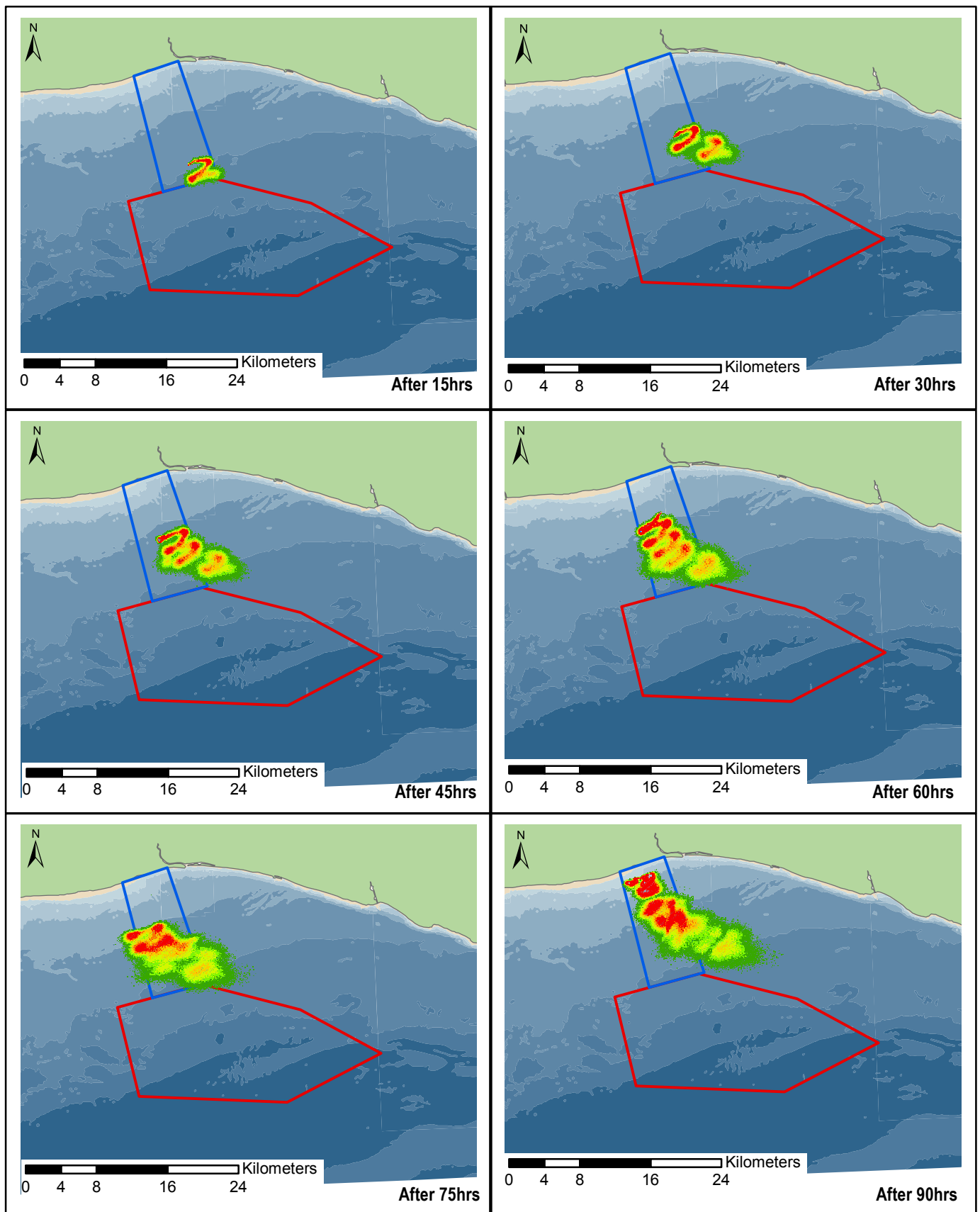
A map of the United Kingdom, including Great Britain and Ireland, is shown in green. A small red square is located in the southwest of England, indicating the specific area covered by the data.

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Data Sources: ABPmer



Bed Level Changes (mm)
Following Foundation and Cable
Installation

Figure 7





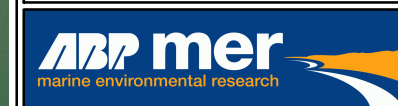
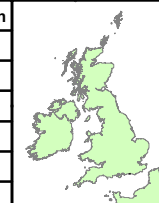
█ Export cable boundary
█ MLW



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QA		FMM	
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Produced by ABPmer Ltd			

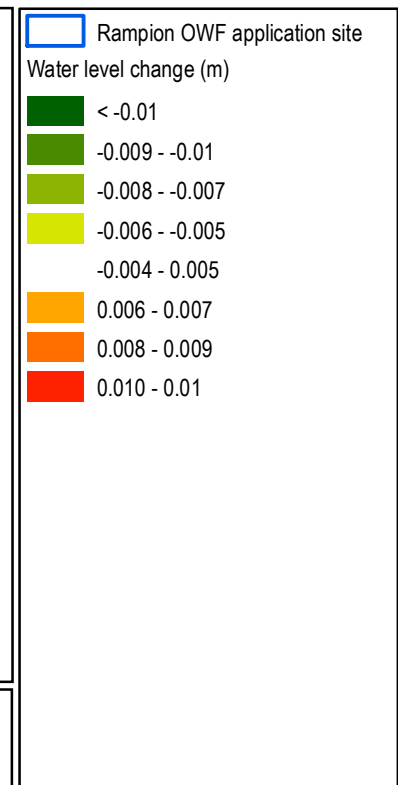
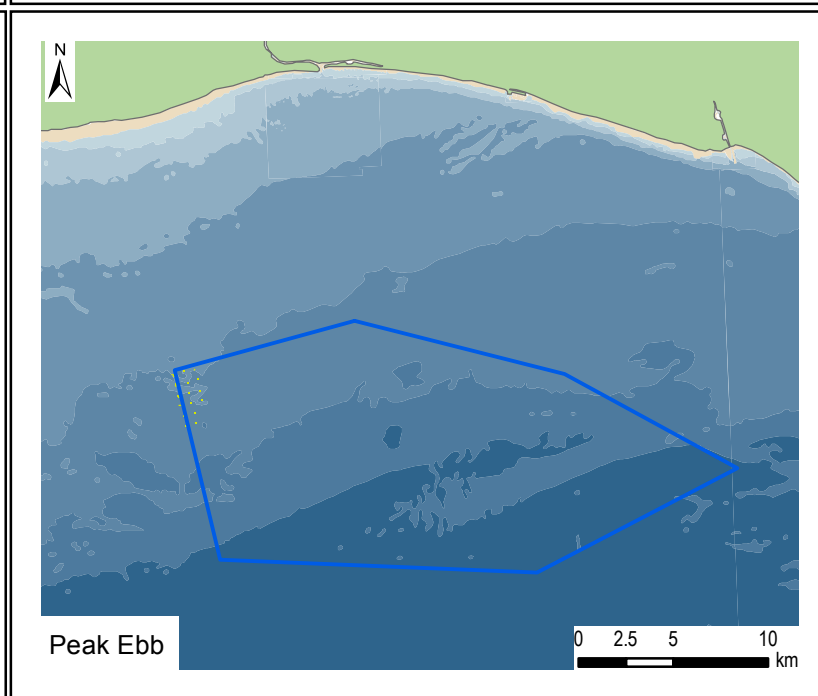
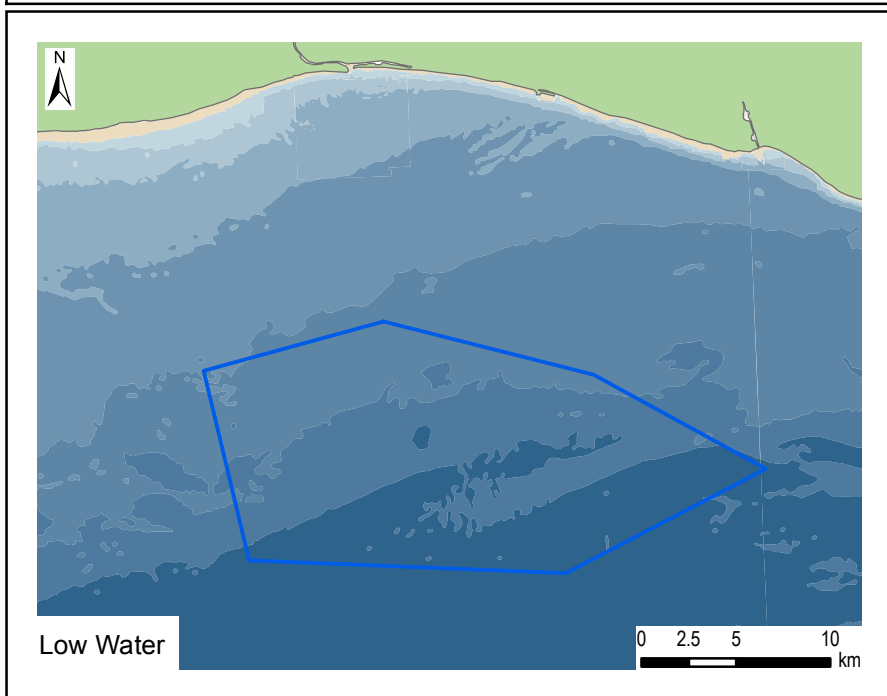
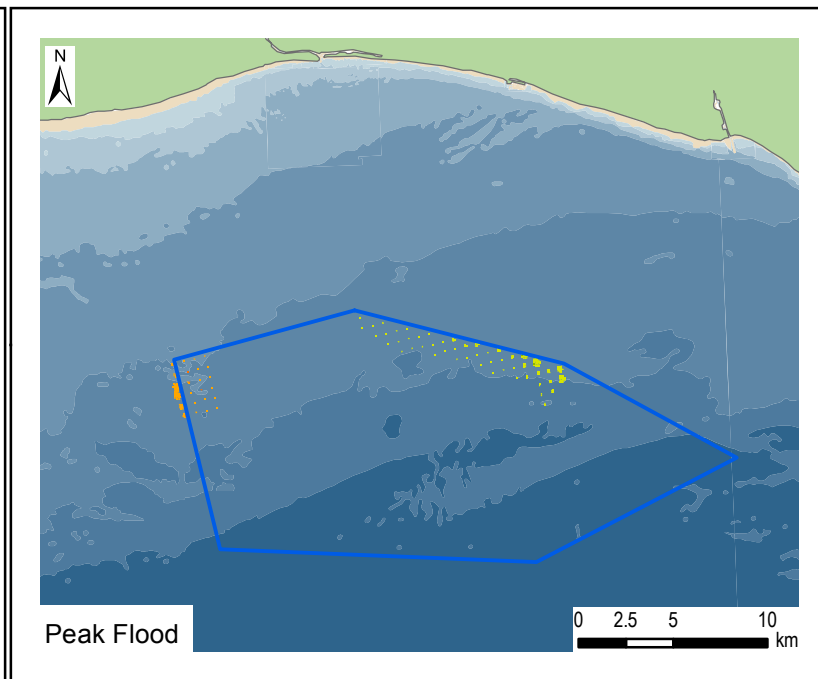
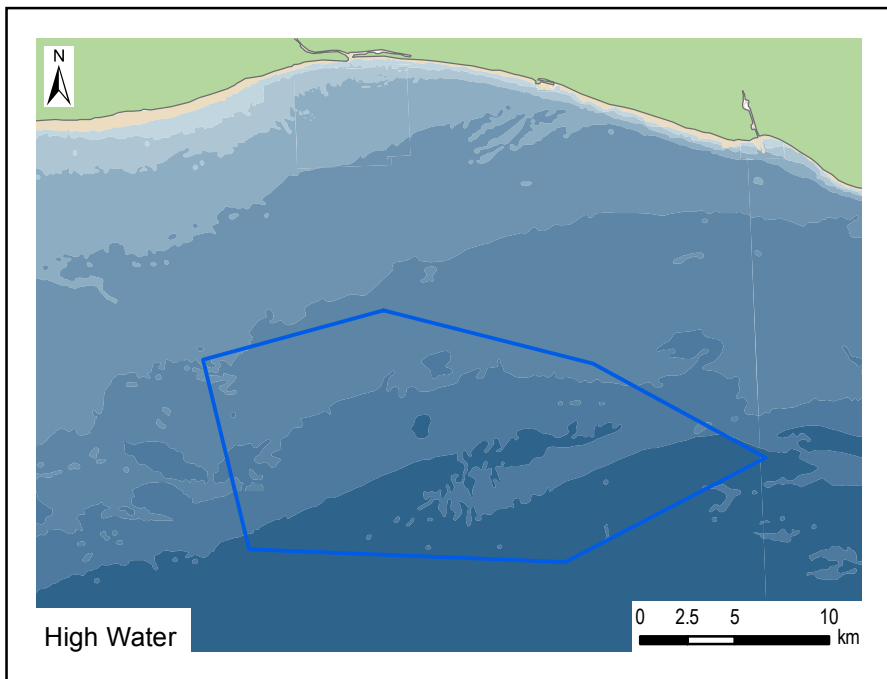


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© Bing Maps, 2012

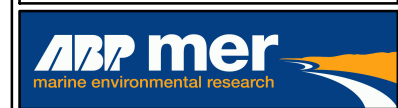


Cable landfall: historical imagery

Figure 9

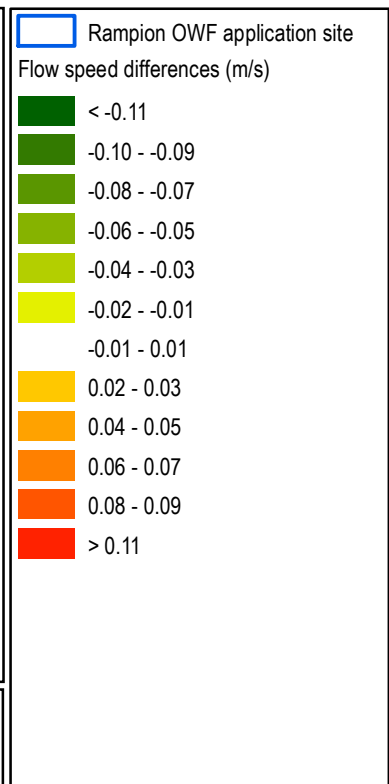
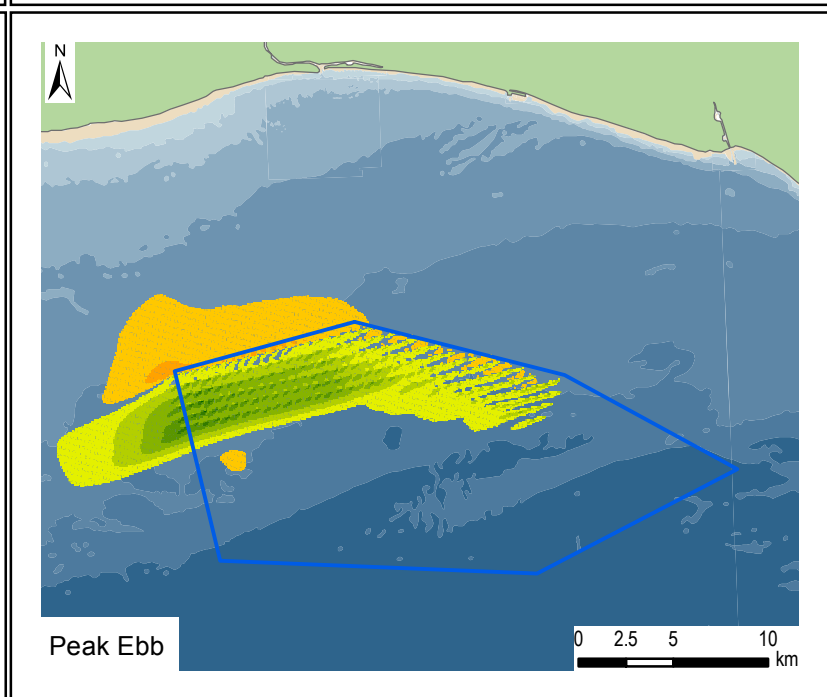
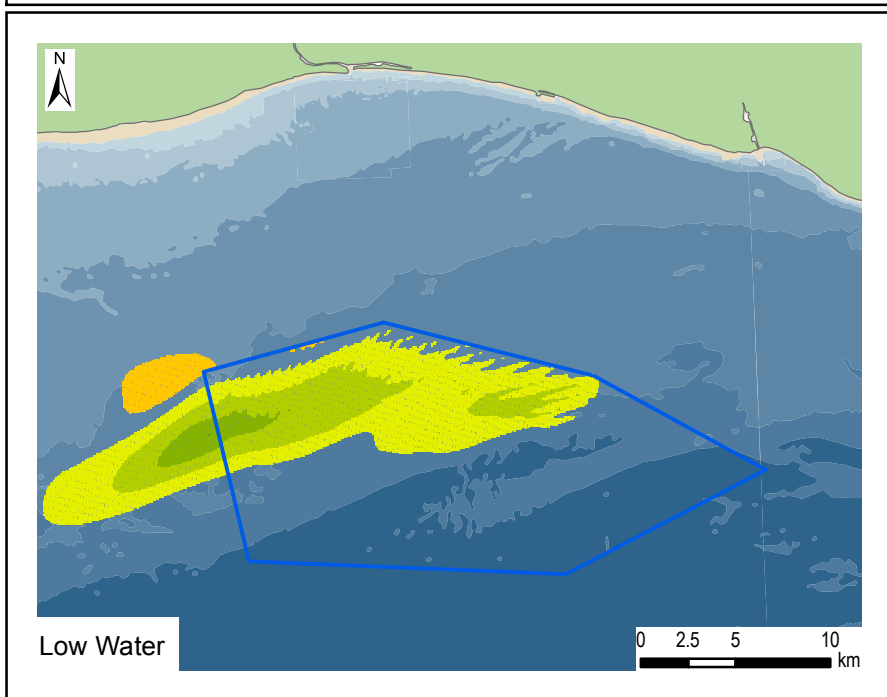
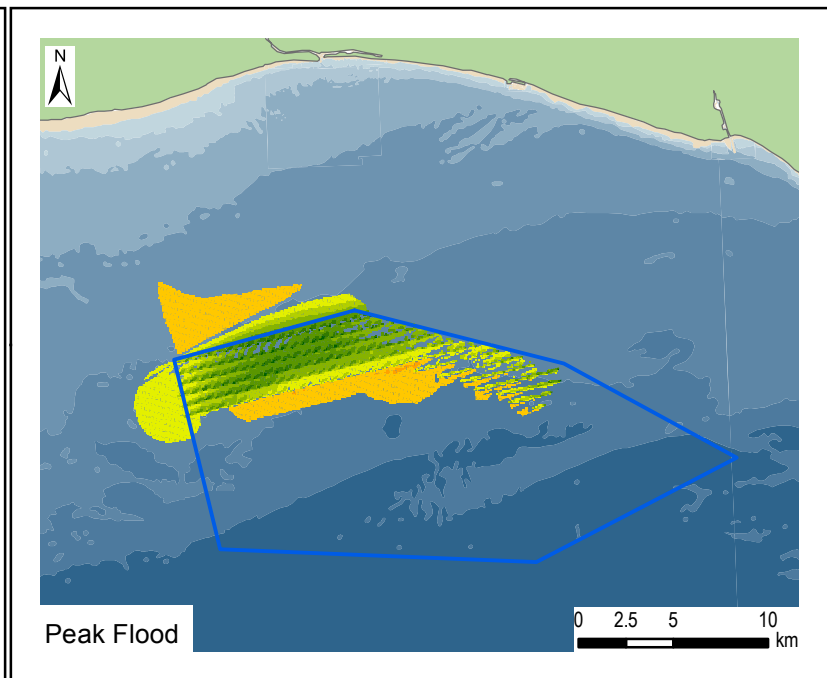
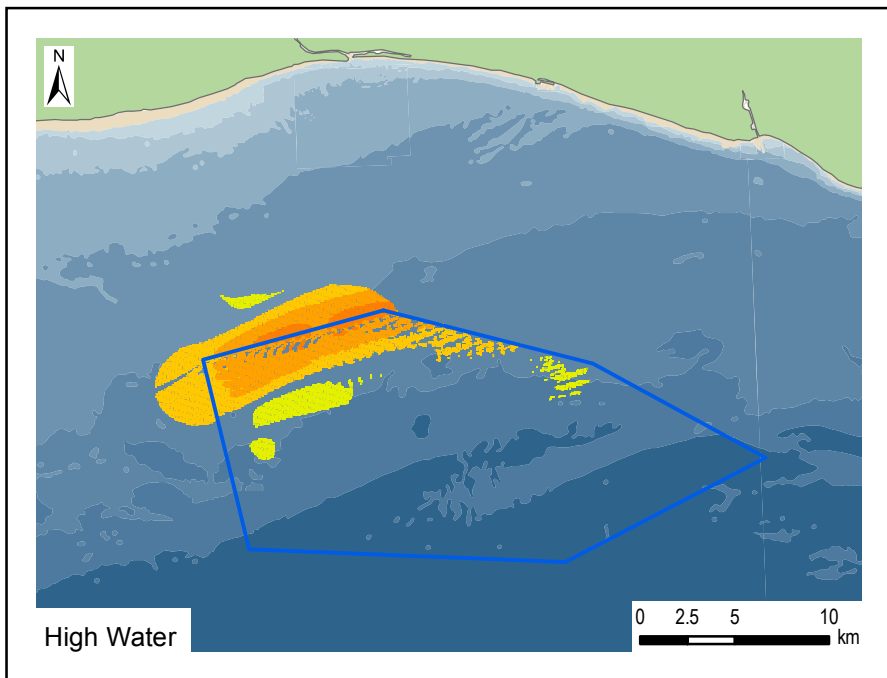


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QA		FMM		
3953 - Fig10_Water_Levels				
Produced by ABPmer Ltd				
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Potential water level changes

Figure 10



Date	By	Size	Version
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Projection		UTM 30N	
Scale		1:400,000	
QA		FMM	
3953 - Fig11_Flow_Diff.mxd			
Produced by ABPmer Ltd			

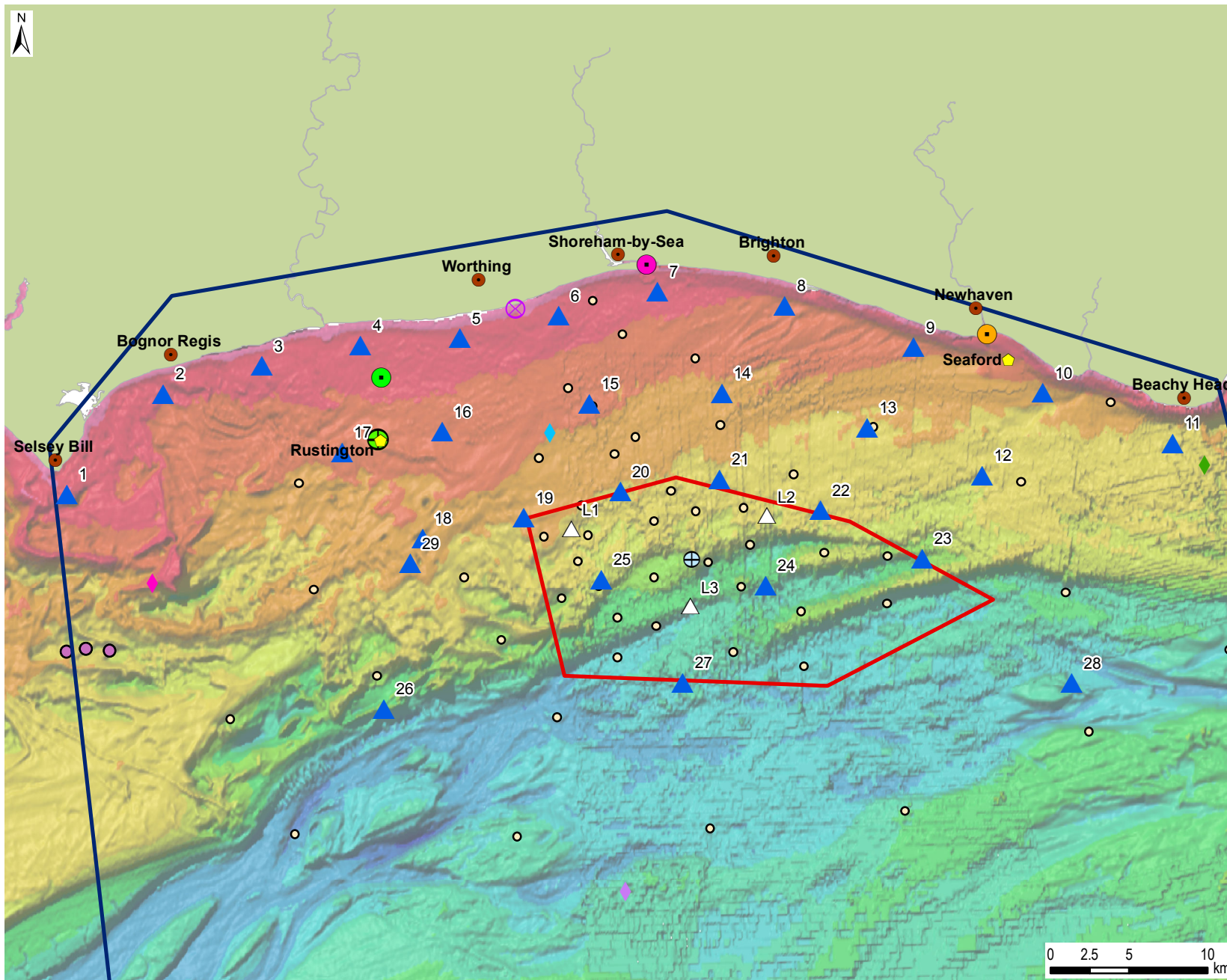


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Potential flow speed changes

Figure 11

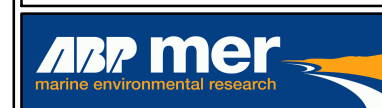


- Legend:**
- Rampion OWF application site
 - Far-field study boundary
 - Observation Points
 - Place names
 - PSA sample locations
 - CCO wave buoys
 - Metocean survey locations
 - Seastates application site
 - Seastates offshore
 - Seastates nearshore
 - Tidal diamond A
 - Tidal diamond D
 - Tidal diamond H
 - Tidal diamond N
 - BODC data locations
- Tide gauges:**
- Arun Platform
 - Newhaven
 - Shoreham
 - Worthing Pier met station

Date	By	Size	Version
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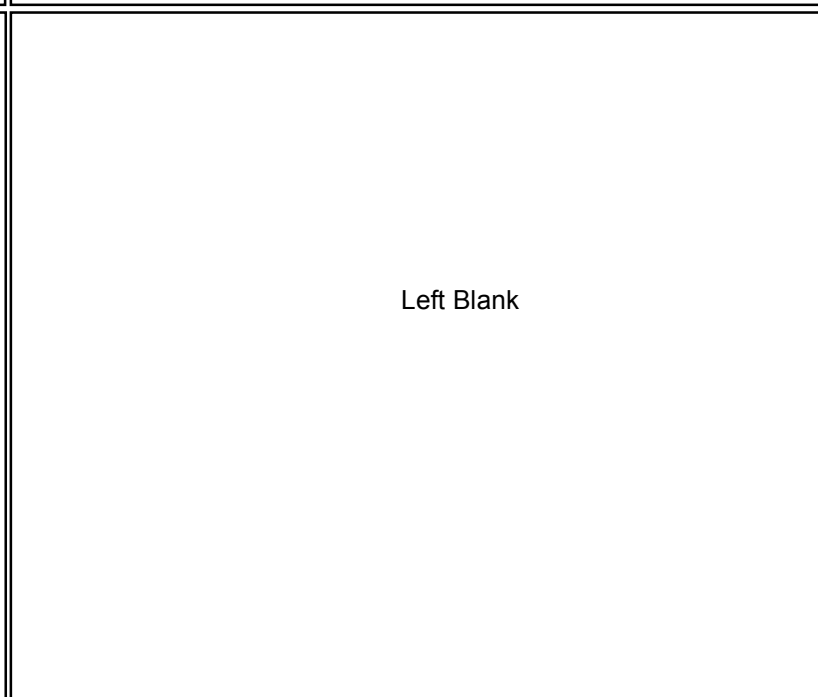
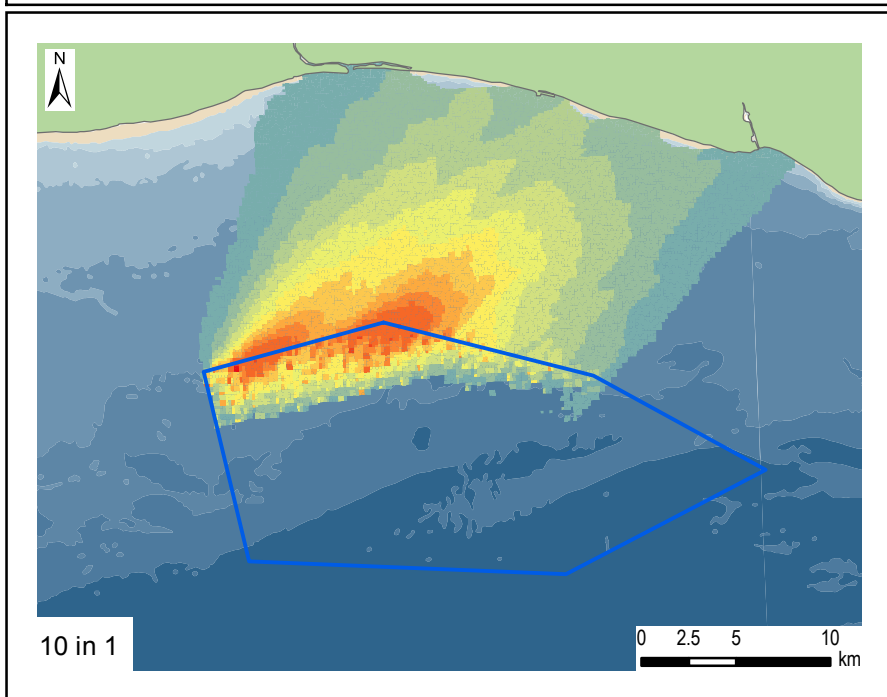
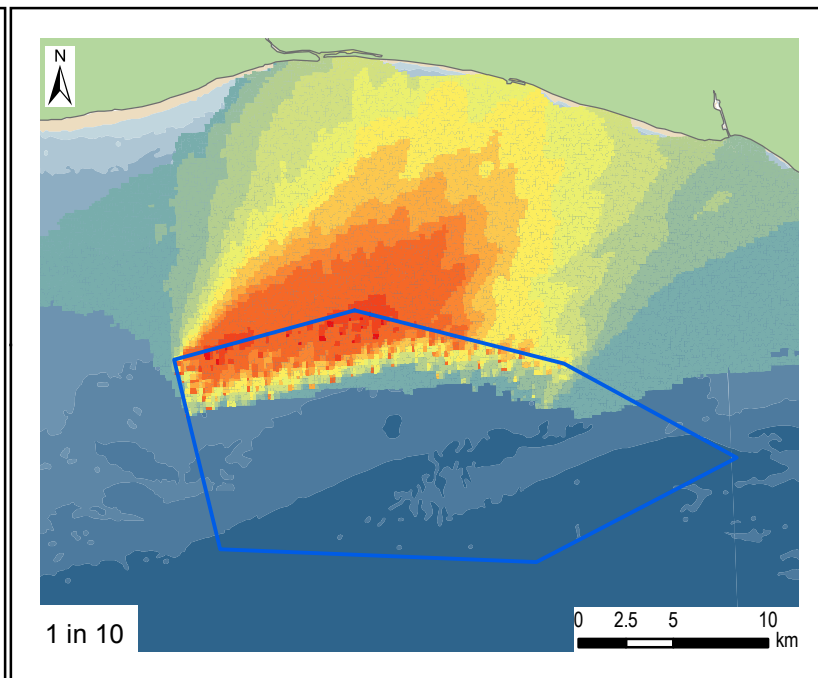
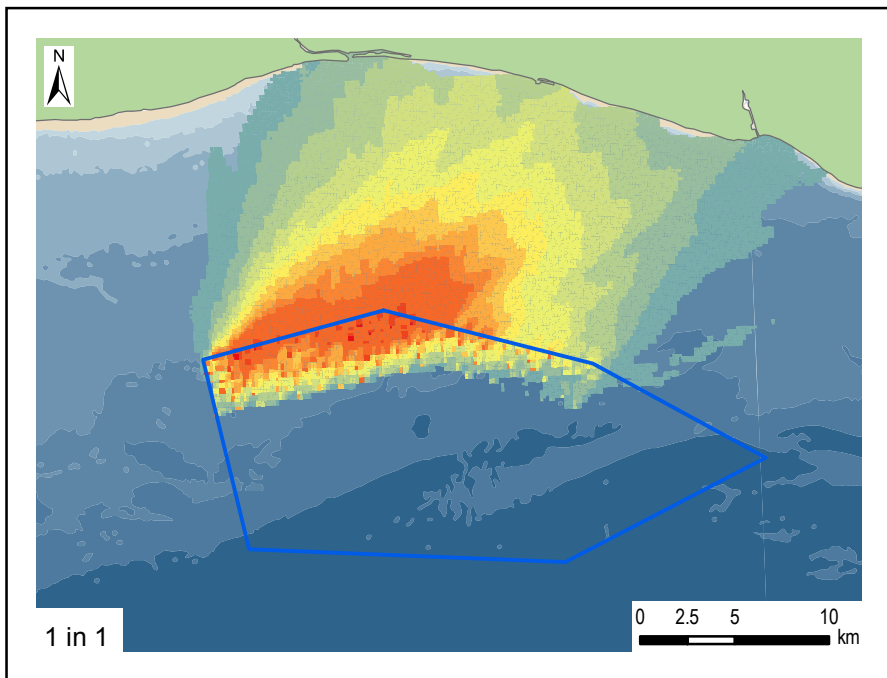
A map of the United Kingdom is shown to the right of the table. A red rectangular box is located in the south of England, indicating the specific area covered by the data in the table.

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Data Sources: C REC Data, 2007
NOT TO BE USED FOR NAVIGATION



**Data and deployment
locations within and
nearby to the OWF
application site**

Figure 12



Rampion OWF application site

Wave height difference (m)

- < -1.00
- 0.99 - -0.75
- 0.74 - -0.50
- 0.49 - -0.45
- 0.44 - -0.40
- 0.39 - -0.35
- 0.34 - -0.30
- 0.29 - -0.25
- 0.24 - -0.20
- 0.19 - -0.15
- 0.14 - -0.10
- 0.09 - -0.05

Notes: Southwest waves
At the time of High Water

Date	By	Size	Version
Feb 12	SRJ	A4	1

Projection UTM 30N

Scale 1:400,269

QA FMM

3953 - Fig13_SW_waves

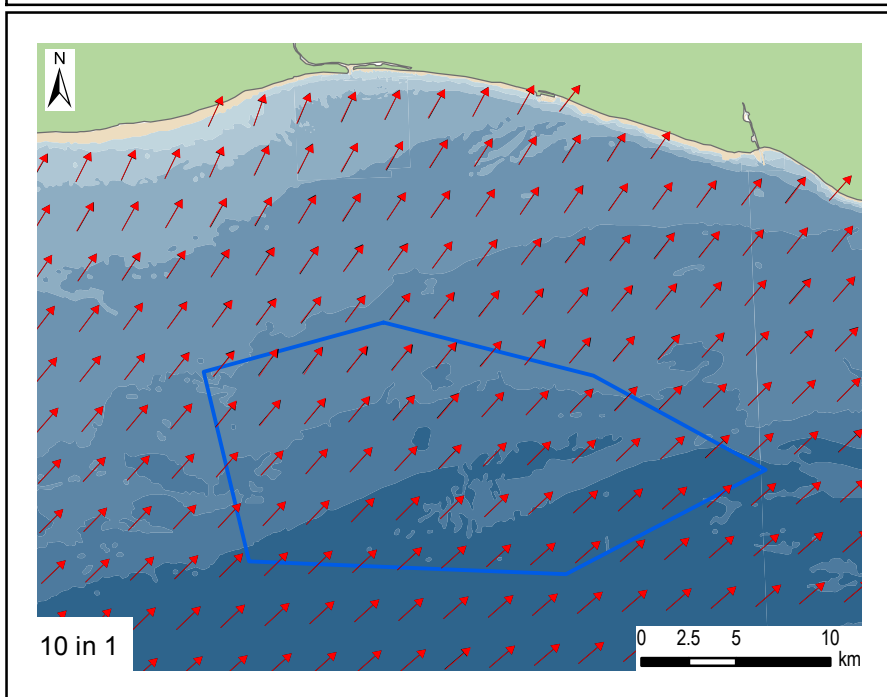
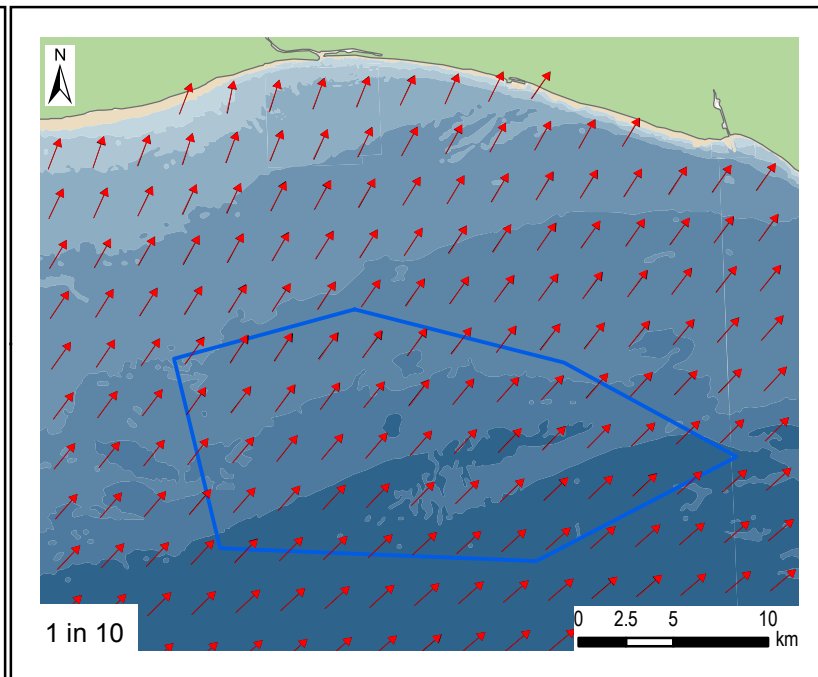
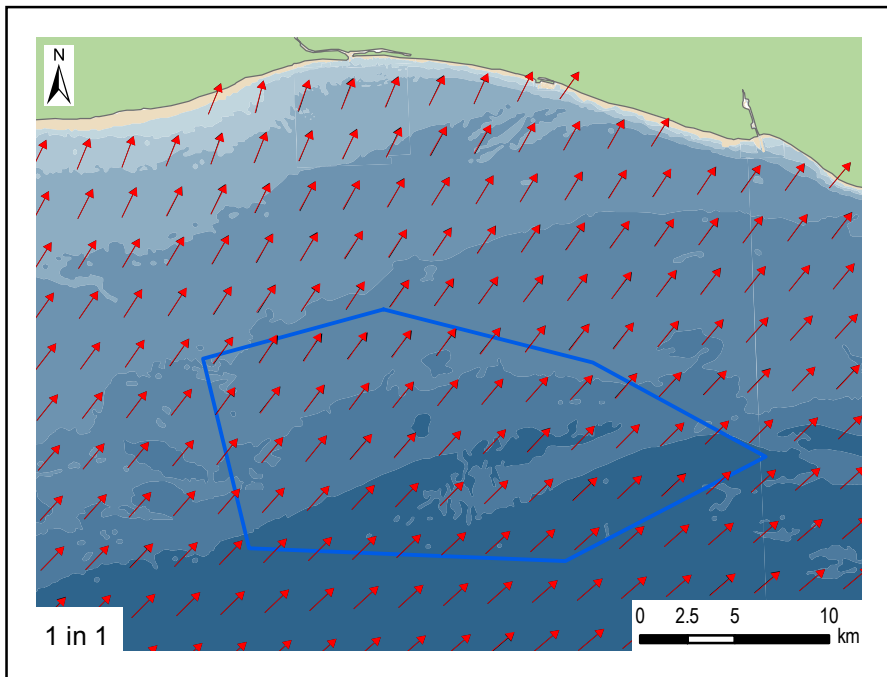
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ABP mer
marine environmental research

Potential changes to significant south west (SW) wave height

Figure 13



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 Rampion OWF application site

 Scheme

 Baseline

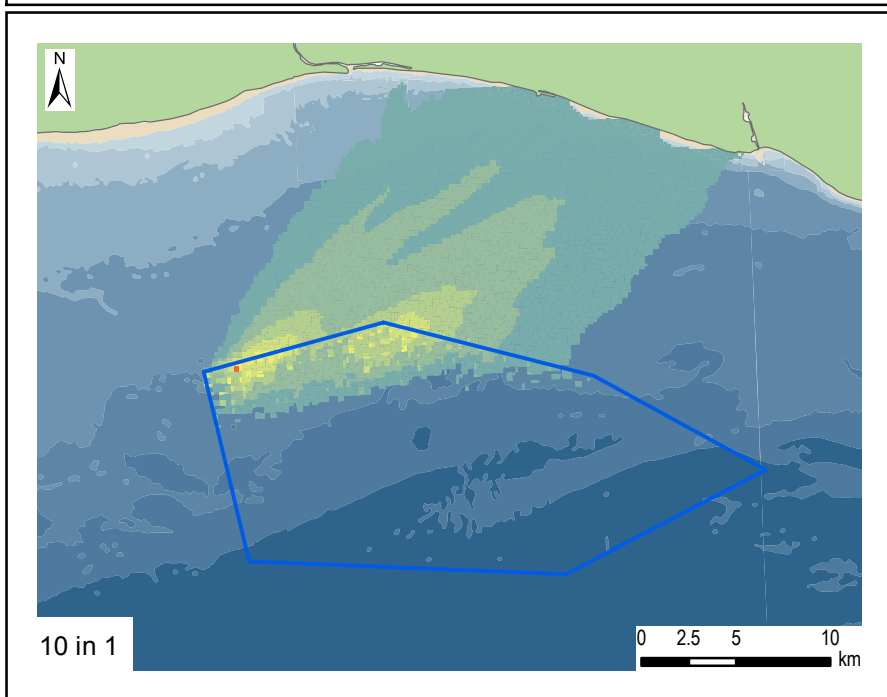
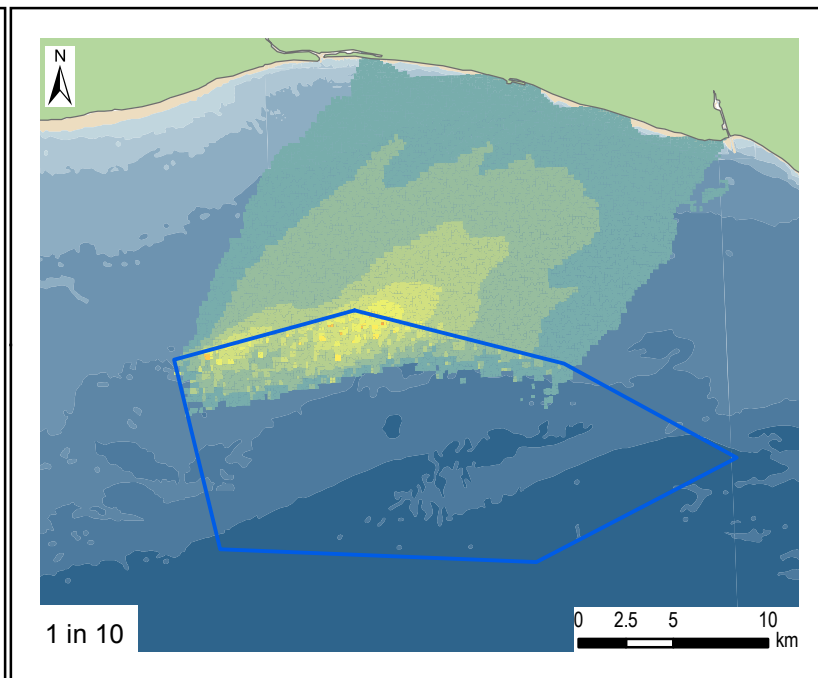
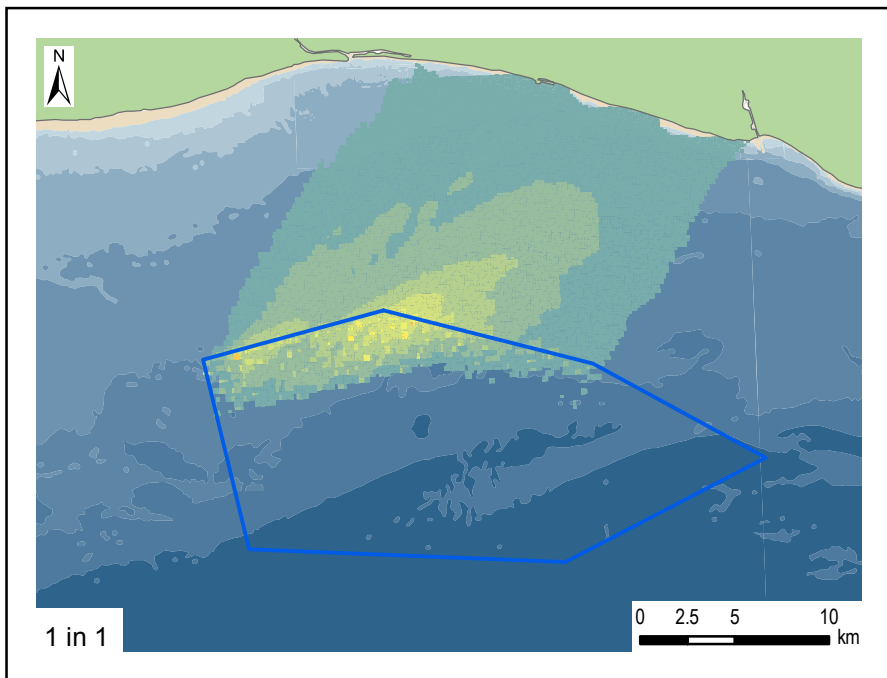
Notes: Southwest waves
At the time of High Water
Vectors scaled for wave height

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QA		FMM		
3953 - Fig14_SW_vectors				
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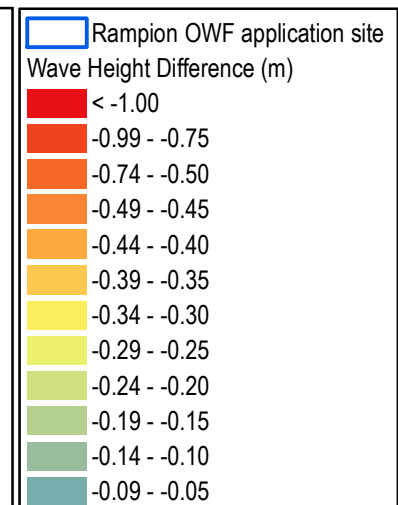


Potential changes
to wave direction

Figure 14



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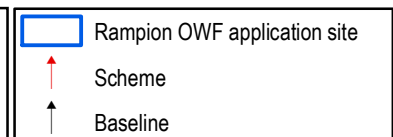
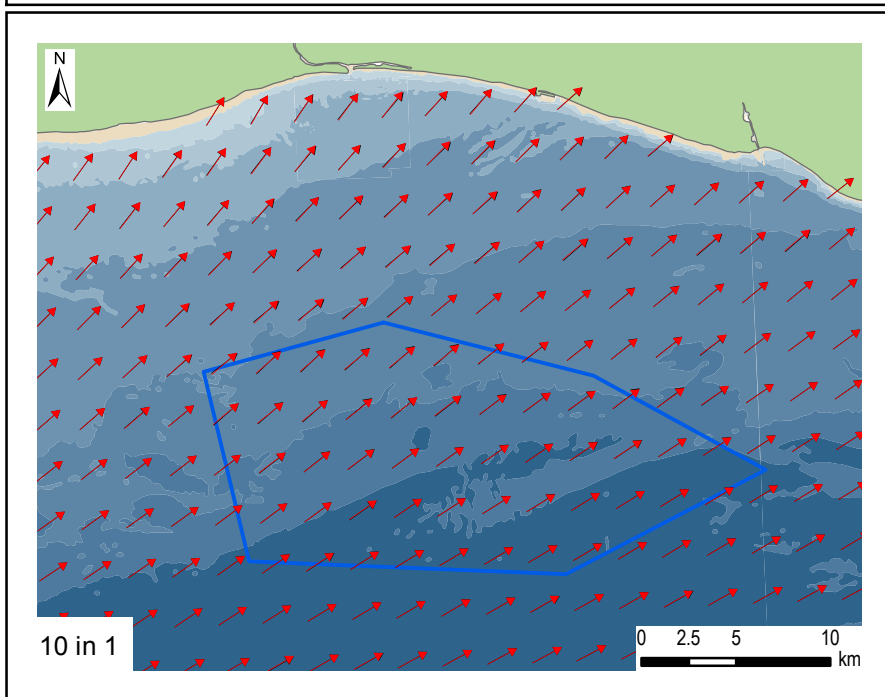
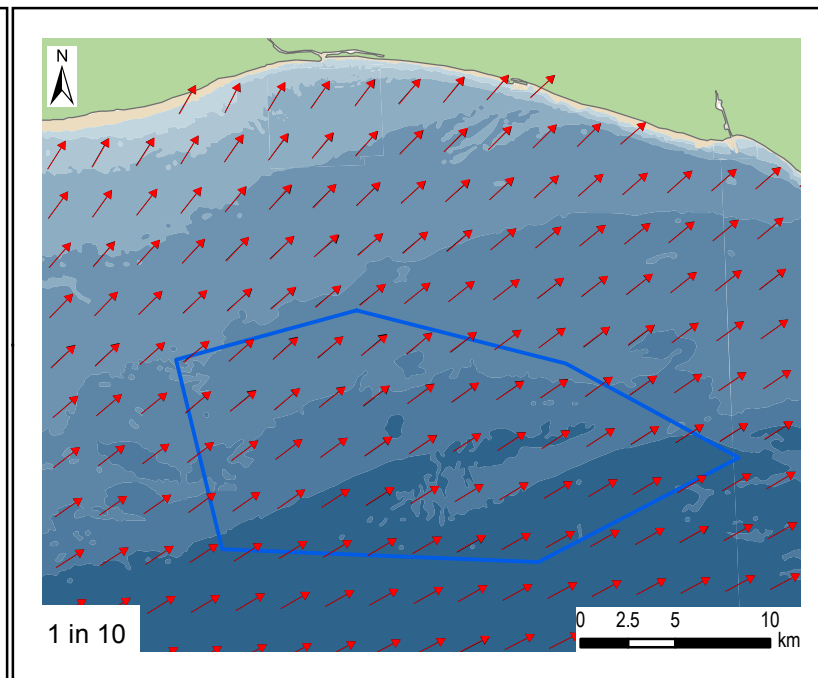
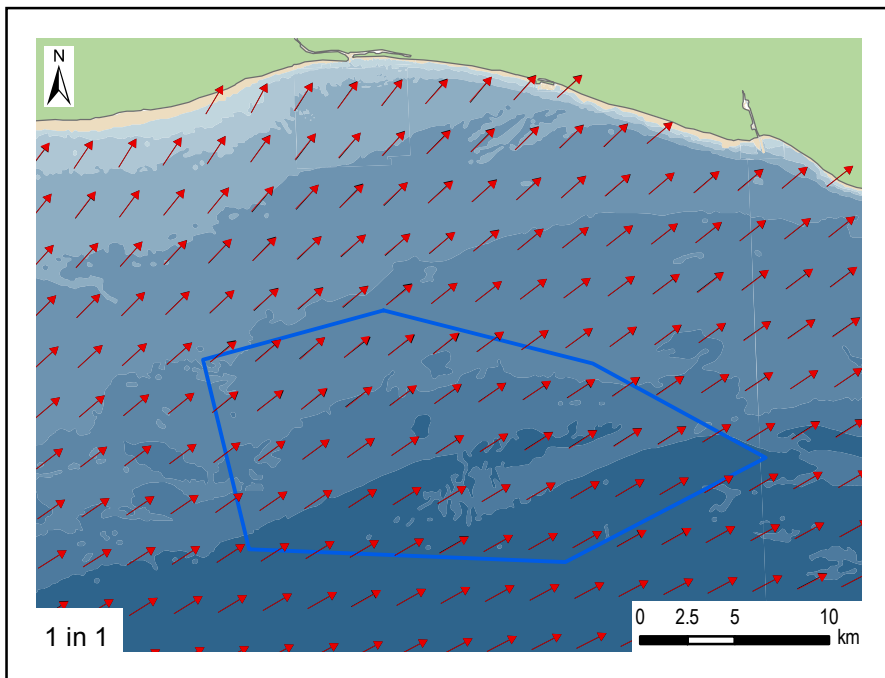
Notes: West- southwest waves
At the time of High Water

Date	By	Size	Version	
Feb 12	SRJ	A4	1	
Projection		UTM 30N		
Scale		1:400,269		
QA		FMM		
3953 - Fig15_WSW_waves				
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Potential changes to
significant West south west
(WSW) wave height

Figure 15



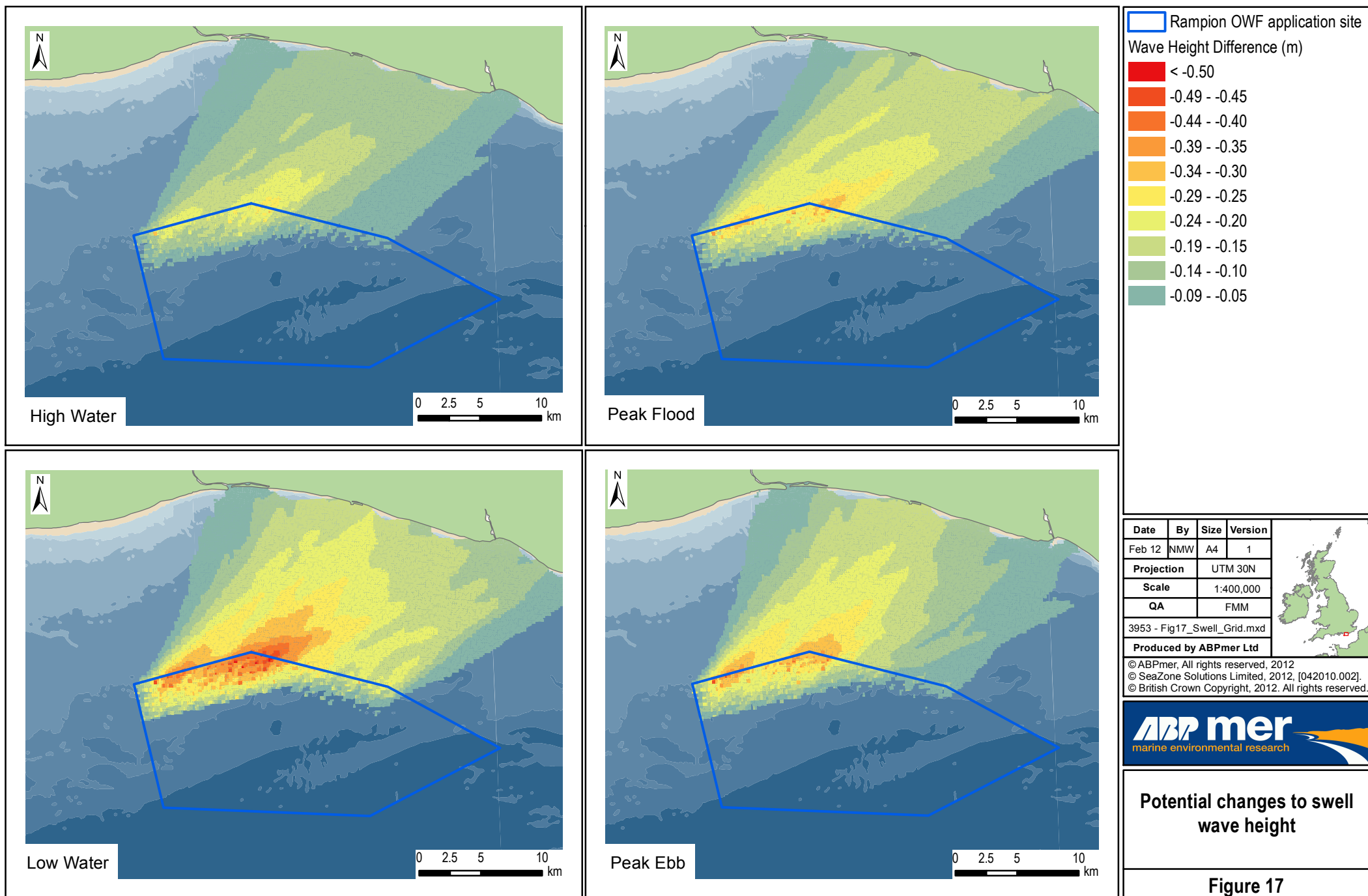
Notes: West southwest waves
At time of High Water
Vectors scaled for wave height

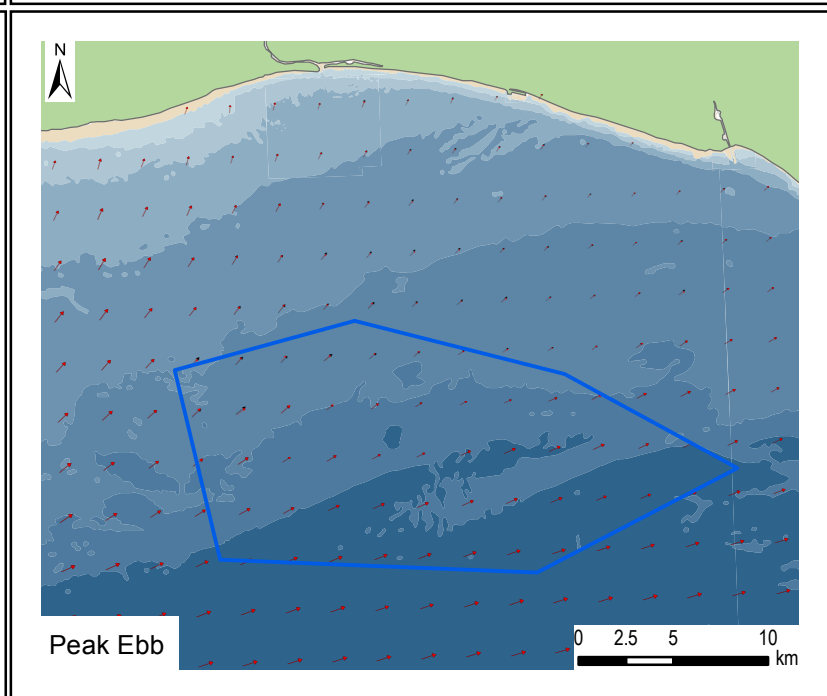
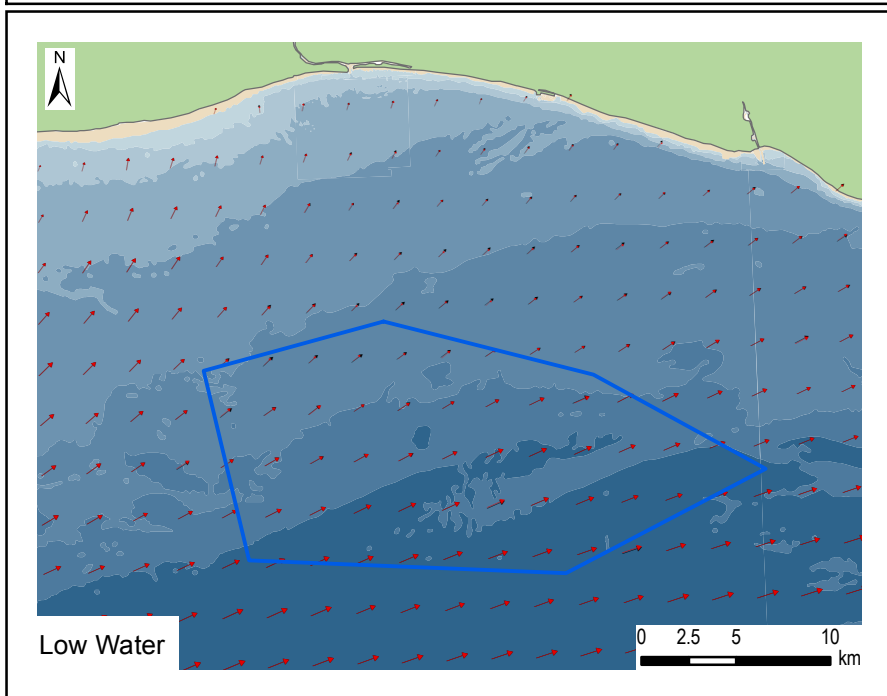
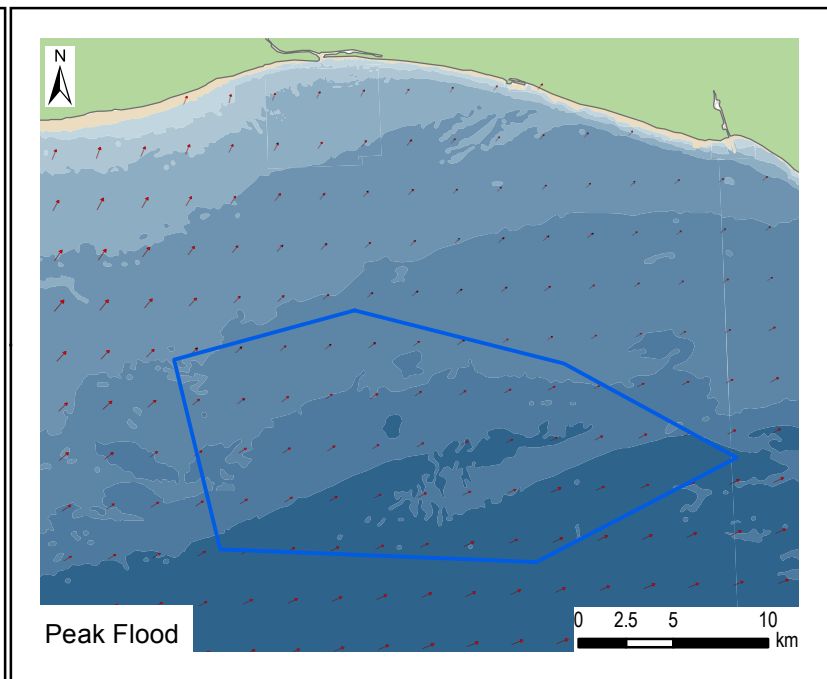
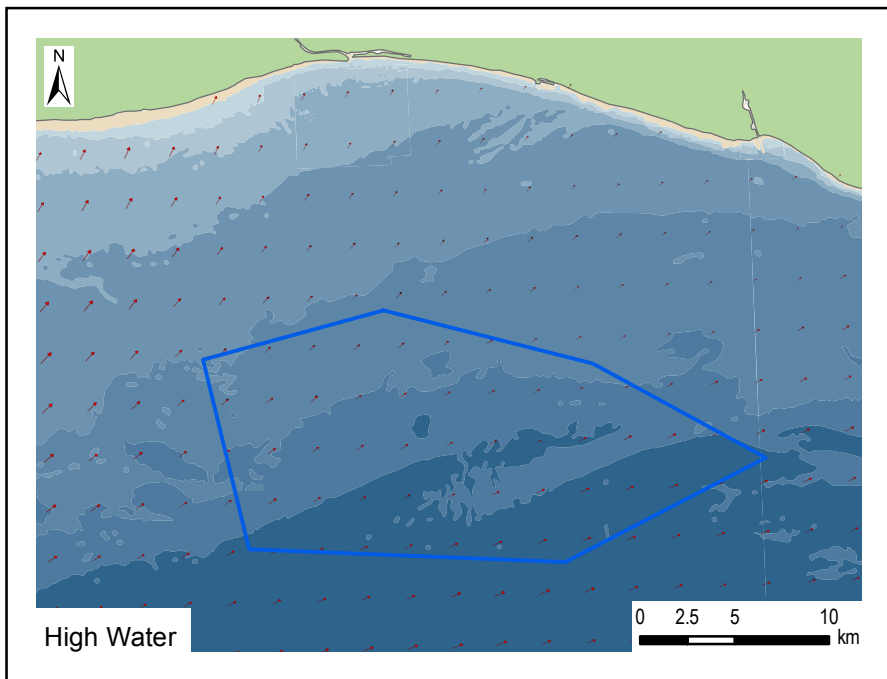
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Scale		1:400,000		
QA		FMM		
3953 - Fig16_WSW_vectors				
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Potential changes to
wave direction

Figure 16





- Rampion OWF application site
- ↑ Scheme
- ↑ Baseline

Notes: Vectors scaled for wave height

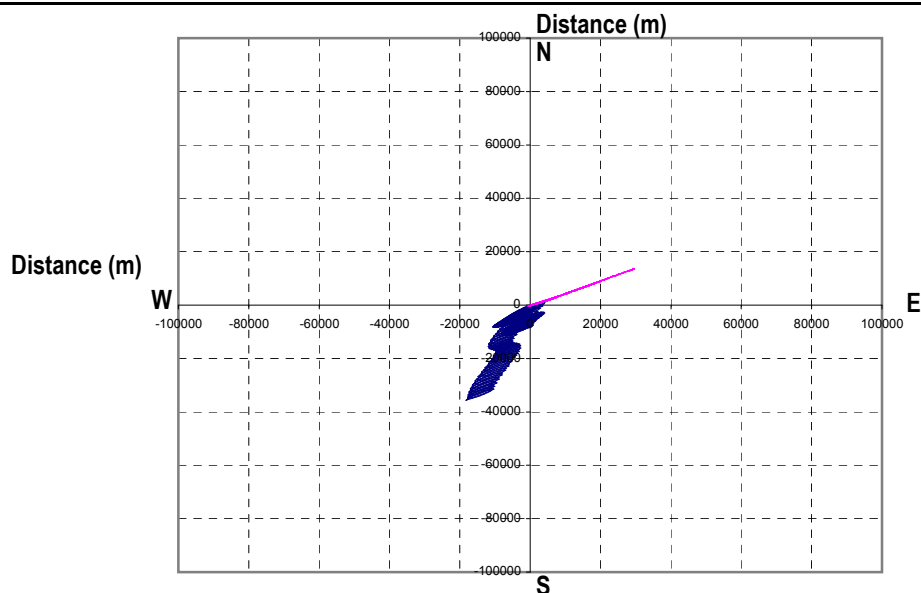
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Scale		1:400,000		
QA		FMM		
3953 - Fig18_Swell_Vectors				
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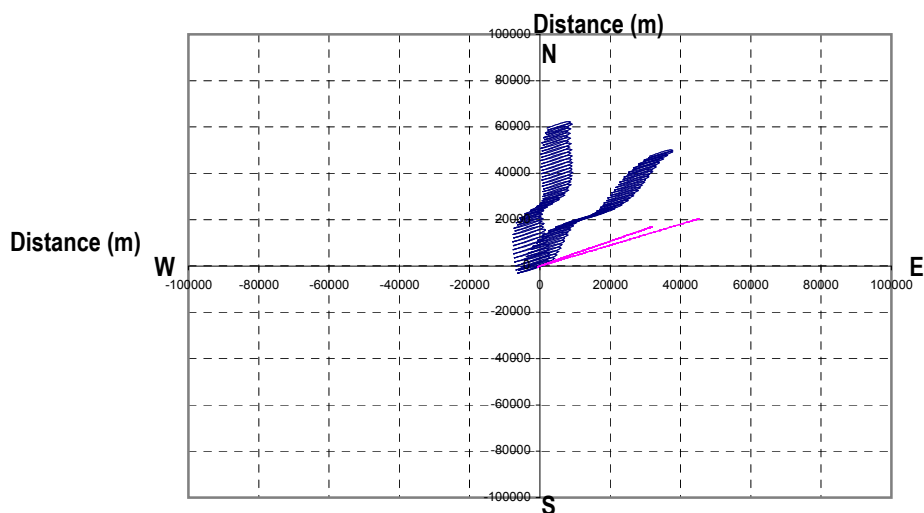
Potential change
to swell direction

Figure 18

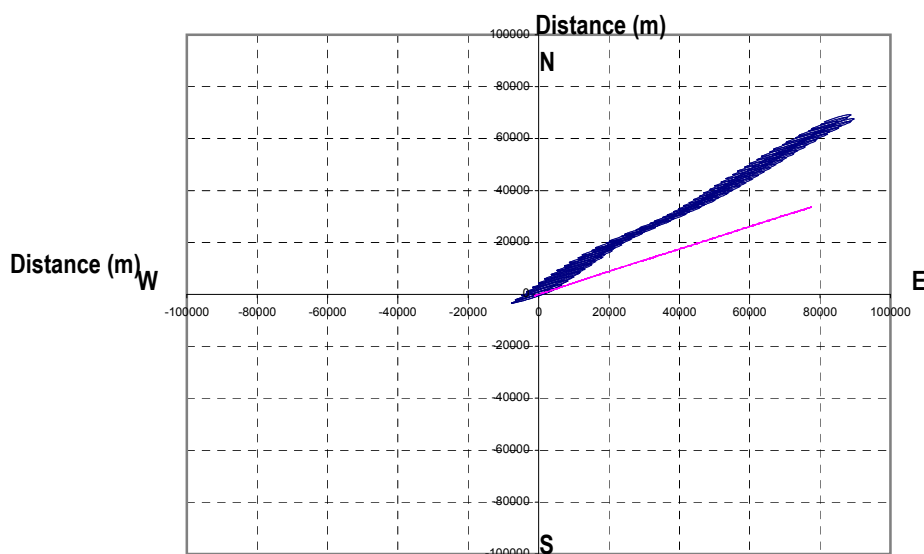
L1



L2



L3



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Scale		n/a	
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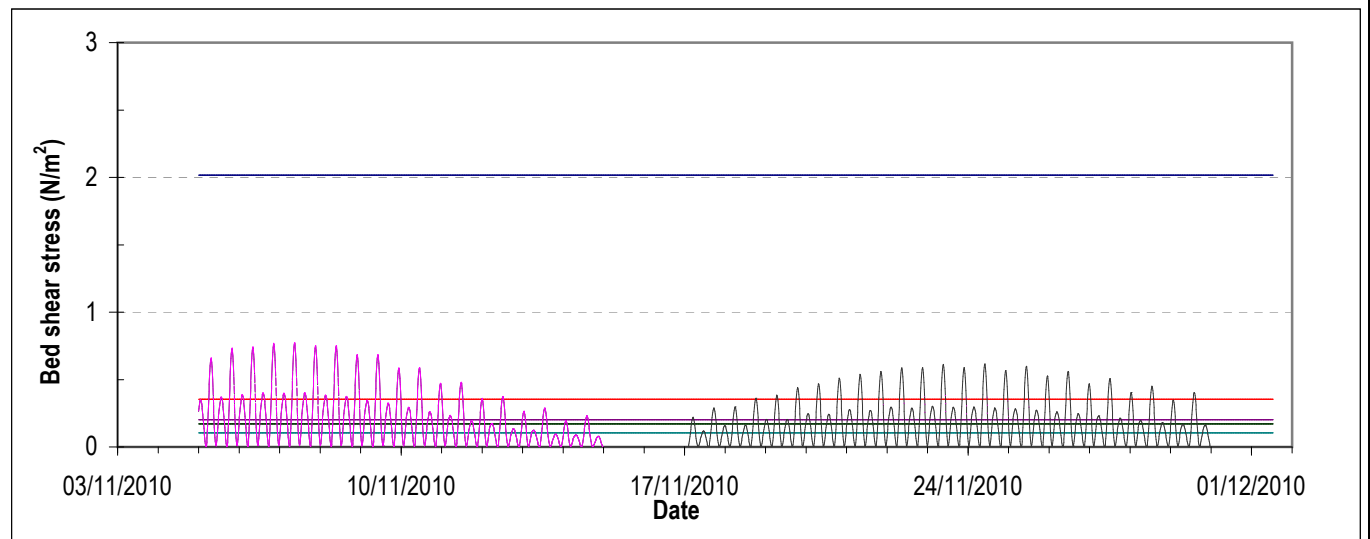
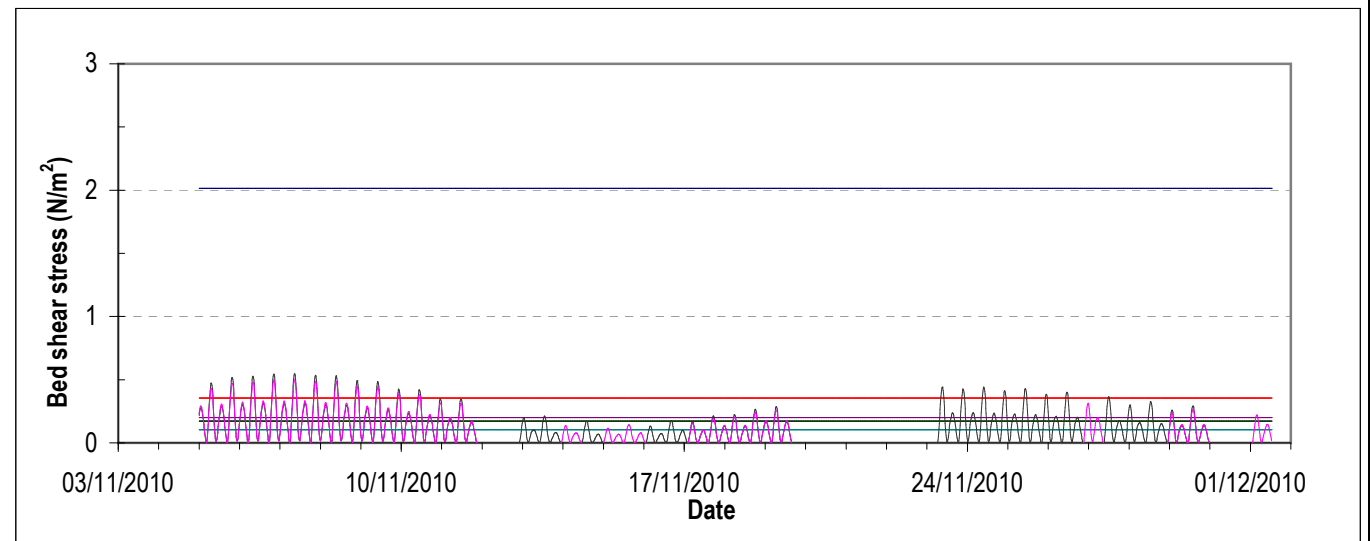
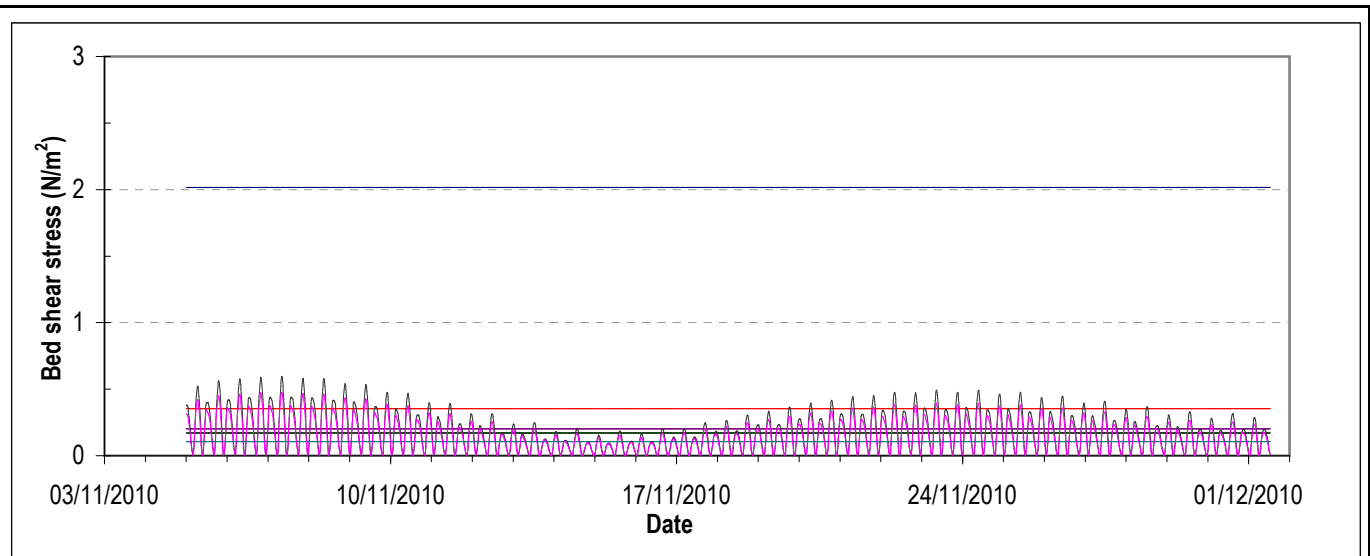
- Net Potential Advection Baseline
- Medium Sand Sediment Net Pathway Baseline
- Net Potential Advection Scheme
- Medium Sand Sediment Net Pathway Scheme

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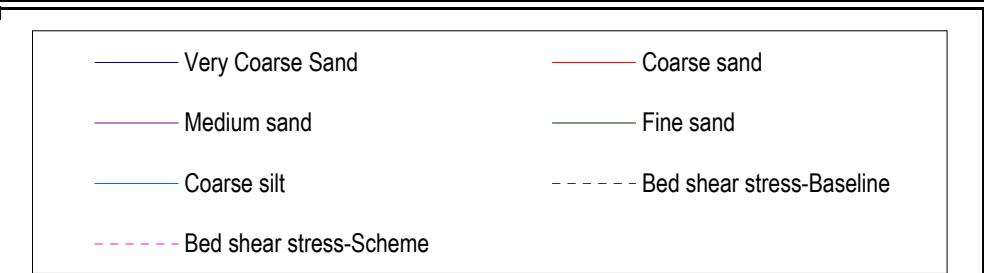
Near-field progressive vector due to currents for locations L1. L2 and L3 after 28 days

Figure 19



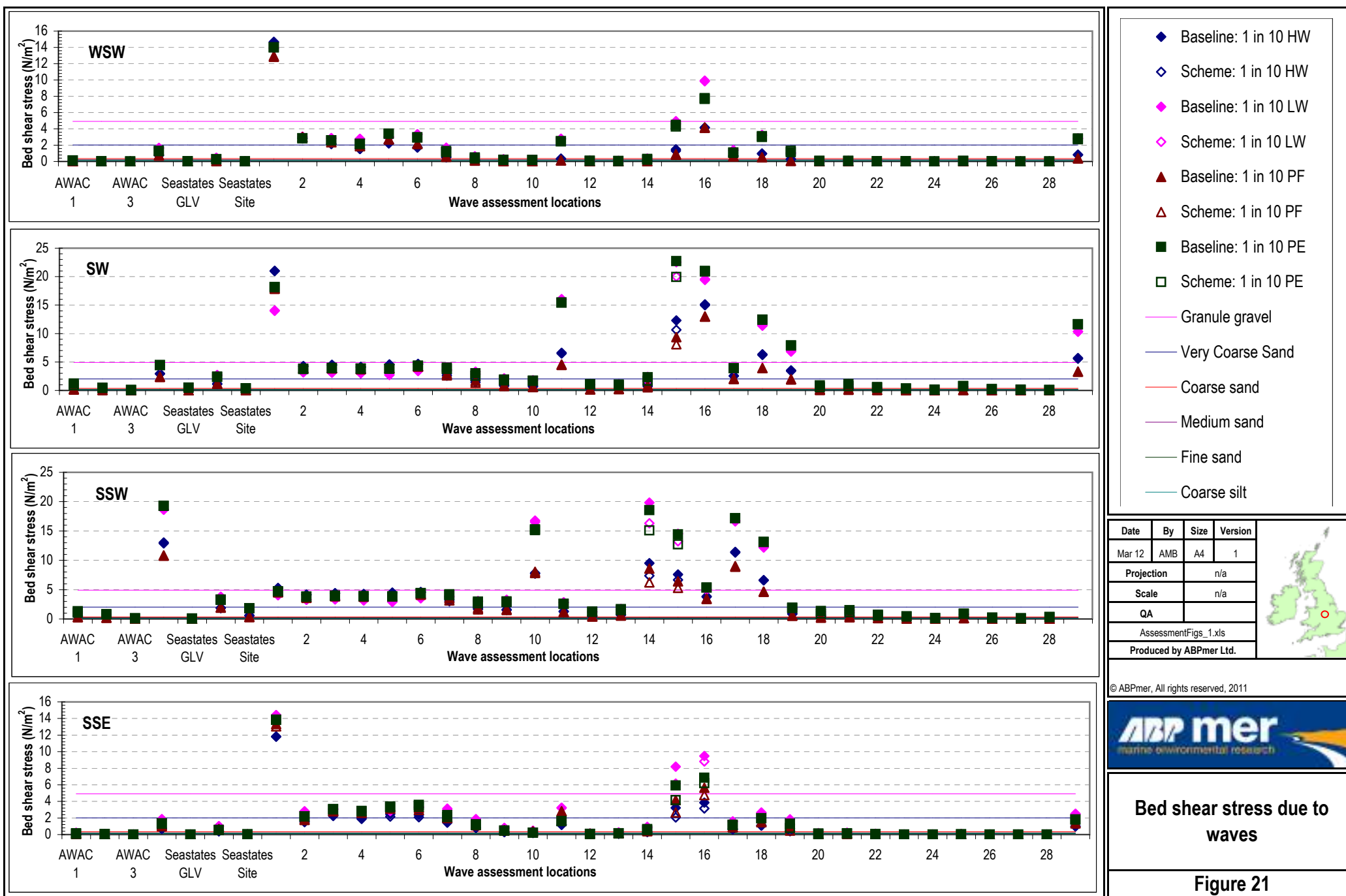
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Scale			
QA			
AssessmentFigs_1.xls			
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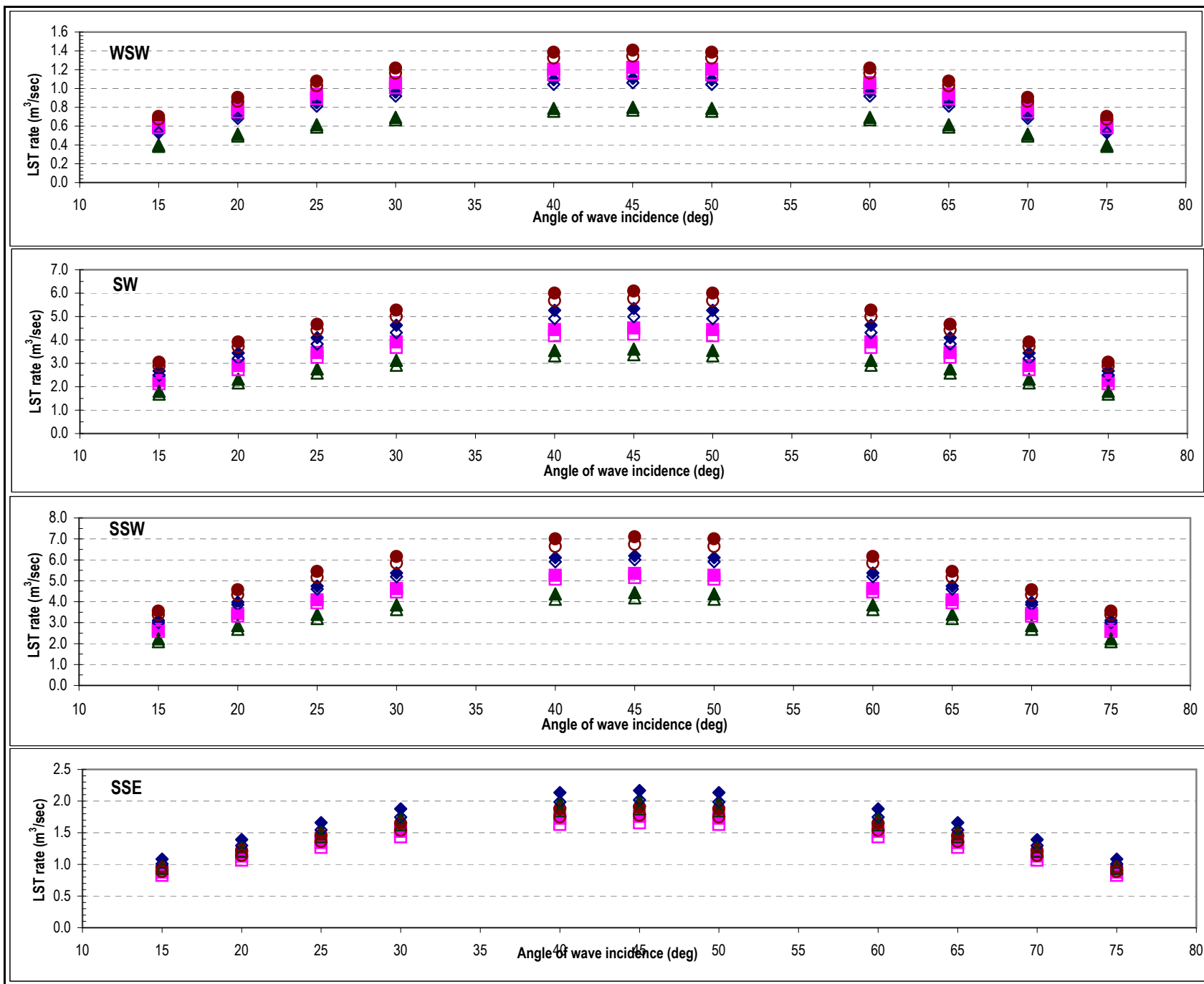
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Near-field bed shear stress due to currents only for locations L1.
L2 and L3

Figure 20





- ◆ Baseline: 1 in 10 HW
- Baseline: 1 in 10 LW
- ▲ Baseline: 1 in 10 PF
- Baseline: 1 in 10 PE
- ◇ Scheme: 1 in 10 HW
- Scheme: 1 in 10 LW
- △ Scheme: 1 in 10 PF
- Scheme: 1 in 10 PE

Date	By	Size	Version
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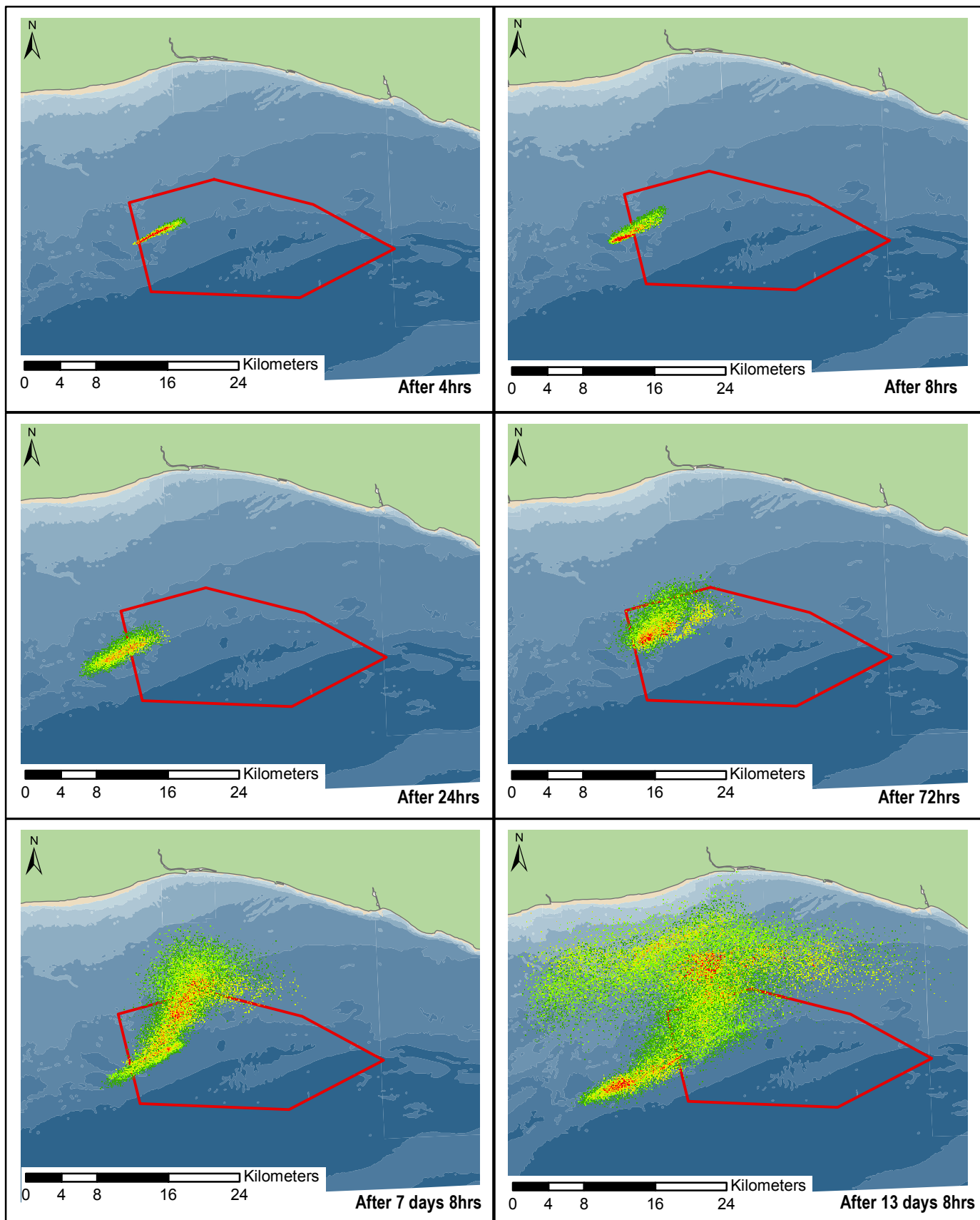


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Longshore Sediment Transport (LST) for the averaged 1 in 10 return period waves across the application site

Figure 22



	Date	By	Size	Version
	Feb 12	SRJ	A4	1
	Projection		UTM30	
	Scale		1:605,620	
	QA		FMM	
	005_Fig23_Comb1.mxd			
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>5
 5.1-10
 10.1-20
 20.1-30
 30.1-40
 >40.1 (mg/l)

Rampion OWF application site

Appendices



Appendix A

Numerical Model Calibration Report



Appendix A. Numerical Model Calibration Report

A1. Introduction

ABP Marine Environmental Research Ltd (ABPmer) has been commissioned by E.ON to undertake a hydrodynamic numerical modelling study and coastal process assessment for the development of the Rampion Wind Farm within Zone 6 (formerly The Crown Estate's (TCE) Hastings Zone). This report provides a description of the hydrodynamic model and SWAN wave model configuration, calibration and validation exercises undertaken to ensure that the model is 'fit for purpose'.

The software package Delft3D has been used in this study to determine the extent and magnitude of changes to flow and waves as a result of wind farm structures. The modelling system was developed by Delft Hydraulics for complex applications within oceanographic, coastal and estuarine environments. Delft3D–FLOW simulates the water level variation and two-dimensional flows in the area of interest. The wave module, SWAN, is a state-of-the-art third generation spectral wind-wave model, which has been applied to simulate the growth, decay and transformation of wind-generated waves and swell.

A2. Tidal Modelling

A2.1 English Channel and Southern North Sea Model

An existing Delft3D tidal model of the English Channel and Southern North Sea (ABPmer, 2008) was modified for application in this study. The model extent is from latitude 48.5°N in the south to latitude 55.0°N in the north; the western and eastern limits of the model are defined by longitude 4.5°W and 9.0°E, see Figure A1. The model grid has a resolution of approximately 1850 m in latitude and 1150 m in longitude. The model boundaries are defined by harmonic constituents derived from the water levels at those locations.

A2.2 DD Model

Delft3D software enables the model domain to be 'decomposed' into several sub-grids. This approach, referred to as Domain Decomposition (DD), provides an efficient and flexible tool which enables high resolution to be achieved in the area of interest, while lower resolution elsewhere helps minimise computational memory demands. The horizontal resolution in the English Channel and Southern North Sea model is too coarse to represent wind farm structures in the domain. Therefore, a DD approach has been applied for the present study.

The original model was de-composed into 3 sub-domains (see Figure A2). The coarse resolution is 1150 m x 1850 m in Grid 1. Towards the area of interest the resolutions are 383 m x 370 m for Grid 2 and 77 m x 74 m for Grid 3, respectively. In this way, a more accurate representation of the wind farm site has been achieved, whilst maximising the computational efficiency of the model. Figure A3 shows the project site and cable route in the arrangement of grids.

A2.3 Model Bathymetry

The model bathymetry was derived from data from the ABPmer continental shelf model. In this study, new bathymetry data from a survey at the development site has been used to improve the representation of the local morphological features. The compiled dataset was incorporated into the model domain to a common reference level, Ordnance Datum Newlyn (ODN).

A2.4 Flood and Drying

The Delft3D model uses a standard approach to the flooding and drying of intertidal areas, in which a cell is regarded as dry when the water depth in that cell becomes less than a user defined value. It remains dry, retaining a small water volume until it floods on the next rising tide. A threshold depth of 0.10 m was applied in this study.

A2.5 Bed Resistance

The Manning number accounts for the effect of bed roughness on the flow field. It is one of main model parameters used to improve model performance of calculated flow and model calibration. A constant Manning number of $0.029 \text{ m}^{-1/3}\text{s}$ has been determined from the model calibration process.

A2.6 Calibration and Validation

A2.6.1 Criteria

For quality control in the numerical model, ABPmer's internal guidelines have been used in the study. For the model to be considered fit-for-purpose the standard requires various water level and flow metrics to be compared with the following key objectives:

- Predicted High Water levels to be within 10% of spring tide ranges;
- Predicted Low Water levels to be within 15% of neap tidal ranges;
- Timing of High Water to be within ± 15 minutes;
- Tidal flows to be within ± 10 -20% of observed speed; and
- Tidal flow direction to be within $\pm 10^\circ$ of observed direction.

During the model calibration, the Manning number was varied to improve the agreement between the simulated and observed data. As an extension of the calibration process, the model validation demonstrates the ability of the model to predict field observation for periods separate to the calibration effort.

A2.6.2 Oceanographic survey data

A description of the data used during model calibration and validation are described in the following sections:

- Water level data from three tide gauges located at Newhaven, Portsmouth and Arun Platform. Contemporary data from these tide gauges were made freely available by the British

Oceanographic Data Centre (BODC) as part of the function of the National Tidal and Sea Level Facility, hosted by the Proudman Oceanographic Laboratory (POL) and funded by the Environment Agency and the Natural Environment Research Council;

- Acoustic wave and current (AWAC) data collected between 1 November 2010 to 10 May 2011 at three locations (AWAC L1, AWAC L2, and AWAC L3) within the development site; and
- Tidal current data at Site b0049879 from the BODC archive close to the development site for a period of 17 days in September 1984.

The sites of observational data records are shown in Figure A4.

A2.6.3 Calibration and validation

The hydrodynamic model was run for two 15 day spring-neap cycles to represent the range of tidal conditions most commonly encountered within the extent of the study area. The length of the model computation was sufficient to allow initial start-up instabilities to settle down prior to the start of the spring-neap cycle used in the analysis.

The model was calibrated for a spring/neap tide and validated with a second separate spring/neap tide.

A2.6.4 Water levels

Model outputs during the calibration period are presented against measured data in Figures A5 to A10. In general, model outputs are in good agreement with the measured data both in terms of phasing and the range of water levels at most sites. To provide a more quantitative assessment of the model performance, a statistical analysis based on comparing observed and modelled high water and low water levels was undertaken. These statistics were calculated over two five day periods, the first period centred on spring tides and the second centred on neaps. The results are presented in Table A1 and Table A2. The results presented are based on the difference between modelled and observed values. Positive values indicate an overestimation of the water level in the model and negative values an underestimate.

The calibration results show that water levels are well predicted by the model for both spring and neap tides, being <4 % and <8 % for spring and neap, respectively.

Phase differences at AWAC's L1 L2 and L3 are all within ± 2 minutes for both spring and neap tides; at Newhaven and Arun Platform they are within ± 11 minutes. Phase differences at Portsmouth are slightly larger; being 26-32 minutes. This is likely to be due to the low model resolution in this area and the location of the Portsmouth tide gauge within the harbour. Despite the phasing difference at Portsmouth exceeding the defined criteria in section 2.6.1, this is of no concern as the tide gauge is located well beyond the boundaries of the proposed application site. The overall consistency in the phase errors at Newhaven and Arun Platform, and particularly the three AWAC locations within the OWF site suggests that the model is producing the correct processes within the areas of interest for this study.

For the model validation, a series of graphical comparisons of the water level at all sites are demonstrated in Figures A11 to A16. The statistical descriptions of the model performance for the validation period are also detailed in Table A1 and Table A2. It can be seen that the accuracy achieved during validation is similar to that achieved during the calibration process, demonstrating that the model can accurately simulate hydrodynamics for a given period.

Table A1. Water level statistics for spring tides

Location	Period	High Water Water Level Difference in m (and as % of Range)	Low Water Water Level Difference in m (and as % of Range)	High Water Phasing Difference (Minutes)
Newhaven	Calibration	0.14 (2%)	-0.09 (-2%)	4.5
	Validation	0.13 (2%)	-0.16 (-3%)	7.8
Portsmouth	Calibration	0.18 (4%)	-0.15 (-4%)	-32.4
	Validation	0.13 (4%)	-0.22 (-6%)	-29.2
Arun Platform	Calibration	0.09 (2%)	-0.20 (-4%)	-5.6
	Validation	0.10 (2%)	-0.22 (-5%)	-5.3
AWAC L1	Calibration	0.22 (4%)	0.11 (2%)	-2.1
	Validation	0.24 (5%)	0.00 (0%)	0.1
AWAC L2	Calibration	0.06 (1%)	-0.02 (0%)	0.7
	Validation	0.10 (2%)	-0.12 (-2%)	2.2
AWAC L3	Calibration	0.07 (1%)	-0.03 (0%)	-0.9
	Validation	0.15 (3%)	-0.11 (-2%)	0.5

Table A2. Water level statistics for neap tides

Location	Period	High Water Water Level Difference in m (and as % of Range)	Low Water Water Level Difference in m (and as % of Range)	High Water Phasing Difference (Minutes)
Newhaven	Calibration	0.20 (7%)	-0.24 (-8%)	-4.0
	Validation	0.18 (4%)	-0.12 (-3%)	1.9
Portsmouth	Calibration	0.13 (7%)	-0.22 (-11%)	-26.4
	Validation	0.11 (4%)	-0.24 (-9%)	-31.3
Arun Platform	Calibration	0.10 (4%)	-0.23 (-8%)	-10.6
	Validation	0.07 (2%)	-0.24 (-6%)	-6.3
AWAC L1	Calibration	0.17 (6%)	-0.14 (-5%)	-1.7
	Validation	0.42 (11%)	0.07 (2%)	-3.5
AWAC L2	Calibration	0.08 (3%)	-0.24 (-8%)	-0.1
	Validation	0.28 (7%)	-0.08 (-2%)	-1.7
AWAC L3	Calibration	0.11 (4%)	-0.21 (-7%)	-2.2
	Validation	0.26 (7%)	-0.10 (-3%)	-3.1

A2.6.5 Currents

Modelled flows are presented against measured data in Figures A17 to A20. In general, the calibrated model predictions are found to be in good agreement with the measured data, with the direction, phasing and magnitude of the velocity curves well reproduced.

As for the water levels, a statistical analysis has been carried out on the modelled and measured flows to further assess the level of calibration achieved. This analysis quantifies the difference in peak ebb

and peak flood currents as an absolute value and as a percentage of the peak speed. The difference in flow directions has also been calculated. These statistics were calculated over two five day periods; results are presented in Tables A3 and A4. The differences are derived by subtracting observed or predicted values from model values. A positive value therefore indicates that the model is over-predicting observed values.

The modelled and observed peak current speeds agree to within 0.10 m/s, with the exception of the ebbing neap tide at BODC Site b0049879. As a percentage of peak flows the model agrees to within 10% of the observed values, and the duration of flood/ebb is similar between the model predictions and the measurements. Furthermore, a comparison of modelled and observed current directions indicates a close agreement to within 7° at all the sites for different tidal states.

Validated model velocity predictions are plotted against observations in Figures A21 to A23. To further quantify model validation, the statistical analysis results are given in Table A5 and Table A6. It is clear that the accuracy is close to what has been achieved during the calibration process.

Due to there only being 17 days worth of measured BODC time series data for location b0049879, a second spring/neap cycle was not available for model validation and it is therefore excluded from the following analyses.

Table A5. Current speed and direction statistics for spring tides

Location	Period	Speed Difference (m/s)		Direction Difference (Deg)	
		Peak Flood	Peak Ebb	Peak Flood	Peak Ebb
AWAC L1	Calibration	-0.10 (-10%)	0.01 (1%)	-2	2
	Validation	-0.07 (-8%)	0.00 (0%)	-3	1
AWAC L2	Calibration	-0.02 (-2%)	0.00 (1%)	4	3
	Validation	-0.02 (-3%)	-0.01 (-1%)	4	3
AWAC L3	Calibration	-0.04 (-4%)	-0.03 (-3%)	-2	-4
	Validation	0.00 (0%)	-0.04 (-5%)	-4	-8
BODC b0049879	Calibration	-0.07 (3%)	0.10 (-1%)	-4	-2
	Validation	N/A	N/A	N/A	N/A

Table A6. Current speed and direction statistics for neap tides

Location	Period	Speed Difference (m/s)		Direction Difference (Deg)	
		Peak Flood	Peak Ebb	Peak Flood	Peak Ebb
AWAC L1	Calibration	-0.01 (-2%)	0.01 (3%)	-3	0
	Validation	0.00 (0%)	-0.03 (-4%)	-1	1
AWAC L2	Calibration	0.00 (1%)	0.01 (4%)	4	4
	Validation	0.03 (4%)	-0.04 (-7%)	10	1
AWAC L3	Calibration	0.02 (3%)	-0.01 (-1%)	-7	-7
	Validation	0.02 (3%)	-0.05 (-8%)	-4	-9
BODC b0049879	Calibration	0.03 (2%)	0.13 (13%)	-4	-1
	Validation	N/A	N/A	N/A	N/A

A3. Wave Modelling

A3.1 Model Configuration

Nested computational grids have been configured in the SWAN model with a coarse grid for a large area and two finer grids for smaller areas. In this study the extents of three grids are the same as those in the previously described Delft3D flow model. Each grid is overlapped with each other so that the nested model boundary information is an input from the coarser model results. Due to the limitation of computer memory, the resolutions of the wave model grids were reduced from those in the Delft3D FLOW model for Grids 2 and 3, which have become 750m x 740m and 154m x 148m, respectively. Grid 1 remains the same as the flow model with a resolution of 1150m x 1850m.

As the wave model results can be affected by both water elevations and tidal currents, the coupled modelling system (SWAN and hydrodynamic model) was adjusted to take into account wave-current interaction and wave-tide interaction. The wave is fed by the tidal current and water elevation outputs from the DD hydrodynamic model as described in Section A2. The model is driven by the measured wind conditions (speed and direction) and offshore wave boundaries provided by ABPmer's Seastates model.

A3.2 Calibration and Validation

A3.2.1 Metocean survey data

The wave model was calibrated against measured wave data at AWAC L3, which is located within the proposed OWF site as shown in Figure A4. Measurements for both winds and waves were recorded for the period January 2011 to May 2011. A number of storm events were identified over this survey period; of these events two were chosen that would be suitable to calibrate and validate the model. The first event, selected for model calibration, occurred in February 2011 and had waves predominantly from the southwest (Event 1). An additional event (Event 2) in May 2011 was used for validation using the calibrated model set-up. The validation event included a range of significant wave heights from north-easterly directions.

The measured wind data at AWAC L3 provides wind speed and direction data which were applied at the model boundary to drive the model. Along with the modelled wave conditions at the offshore boundary, these wind conditions were specified in the model domain during the simulation of each event.

A3.2.2 Calibration criteria

Calibration of the wave model initially focussed on minimising the difference between predicted wave heights and measured values. There are no established industry standard calibration targets for numerical wave models. ABPmer typically aims for wave heights to be predicted within $\pm 10\%$ and wave periods within $\pm 20\%$.

The level of model calibration achieved has been quantified by analysing time-series data for the key wave parameters. This analysis involved the calculations of the mean absolute error; scatter index (SI) and correlation coefficient (R). A lower scatter index and a higher correlation coefficient are indicative of

a good level of calibration. The scatter index is the root mean square error normalised with the mean value, calculated using the equation below:

$$SI = \frac{\sqrt{\frac{1}{N} \sum_{i=1}^N (S_i - O_i)^2}}{\frac{1}{N} \sum_{i=1}^N O_i} \times 100$$

in which

N is total number of data;

O_i is the measured data; and

S_i is the simulated, or model data.

A3.2.3 Calibration and validation results

The comparison of modelled and measured time-series data for the wave height, period and direction for Event 1 are presented in Figure A24 for Site AWAC L3. The model validation was undertaken for a separate period. During this stage no further adjustment was made to the model parameters. The comparison of model and measured time-series for the standard wave parameters for Event 2 is presented in Figure A25. These figures show that the model has accurately captured the set up for both calibration and validation events.

Statistical results of wave height and period to assess the model calibration and validation are provided in Table A7 and Table A8. High correlation coefficients and low scatter index have been achieved for both wave height and period. The good degree of correlation between modelled and measured data confirms that key wave parameters are well reproduced by the model.

Table A7. Wave height statistics

Items	Model Mean	Obs. Mean	Mean Aabs. Err.	Percentage (%)	SI	R
Calibration	1.18	1.09	0.10	9	19	0.96
Validation	1.33	1.25	0.08	6	20	0.87

Table A8. Wave period statistics

Items	Model Mean	Obs. Mean	Mean Abs. Err.	Percentage (%)	SI	R
Calibration	3.70	4.55	-0.85	-19	21	0.84
Validation	3.66	4.37	-0.71	-16	18	0.89

In percentage terms the mean error of wave height presented in Table A7 are 9 % of observed values. The errors are within the suggested calibration target for ± 10 % of wave height. For wave period, the mean error is 19 % of observations, within the calibration target of ± 20 % limit. Overall the calibration of wave height and period are therefore considered to be acceptable.

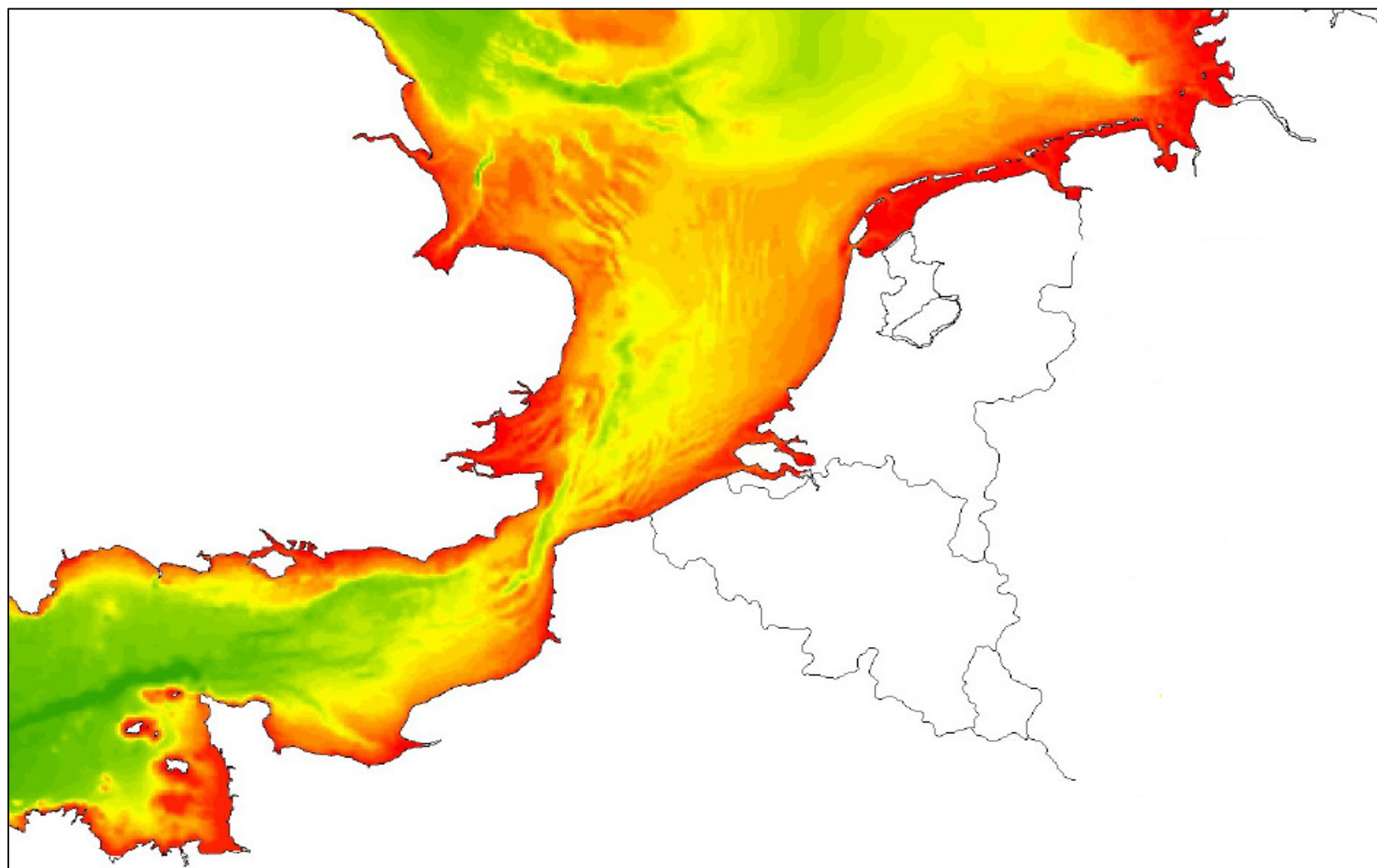
For the validation event the mean error in wave height is 6 %, and the mean error for wave period is shown to be -17 %. These results suggest that a similar accuracy in the calibration and validation stages has been achieved.

For wave direction, Figures A24 c) and A25 c) provide a direct comparison between measured and model predicted wave direction over a 3 day period. The results show that the modelled wave directions are well represented during the two storm events.

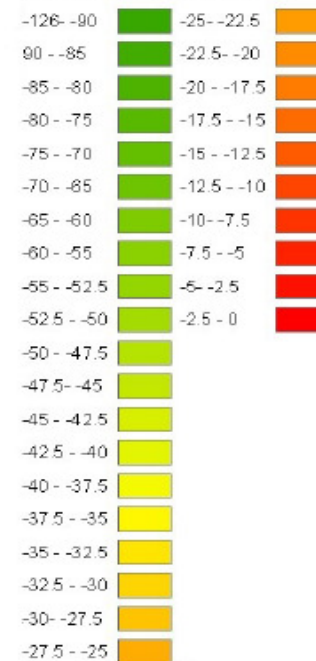
The calibration and validation exercise confirms that the SWAN model performs well for both south-westerly and north-easterly waves. The differences remain as a function of uncertainty/inaccuracies in the observed waves, wind data, and modelled boundary conditions from the Seastates model. Overall the statistical descriptions for the model calibration and validation performance are very pleasing with all the modelled and observed wave heights and periods agreeing within the defined criteria. In particular, the model accurately captures the wave peak events to a reasonable level of accuracy. It is concluded that the SWAN model provides a tool which is appropriate for the assessment of baseline conditions and wave field changes resulting from the introduction of turbine support structures.

A4. Reference

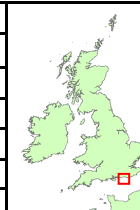
Bartlett, J.M., 1998. Quality Manual for Computational Estuarine Modelling. Environment Agency, R&D Technical Report W113, 80pp + appendix.



Bathymetry (MSL (m))



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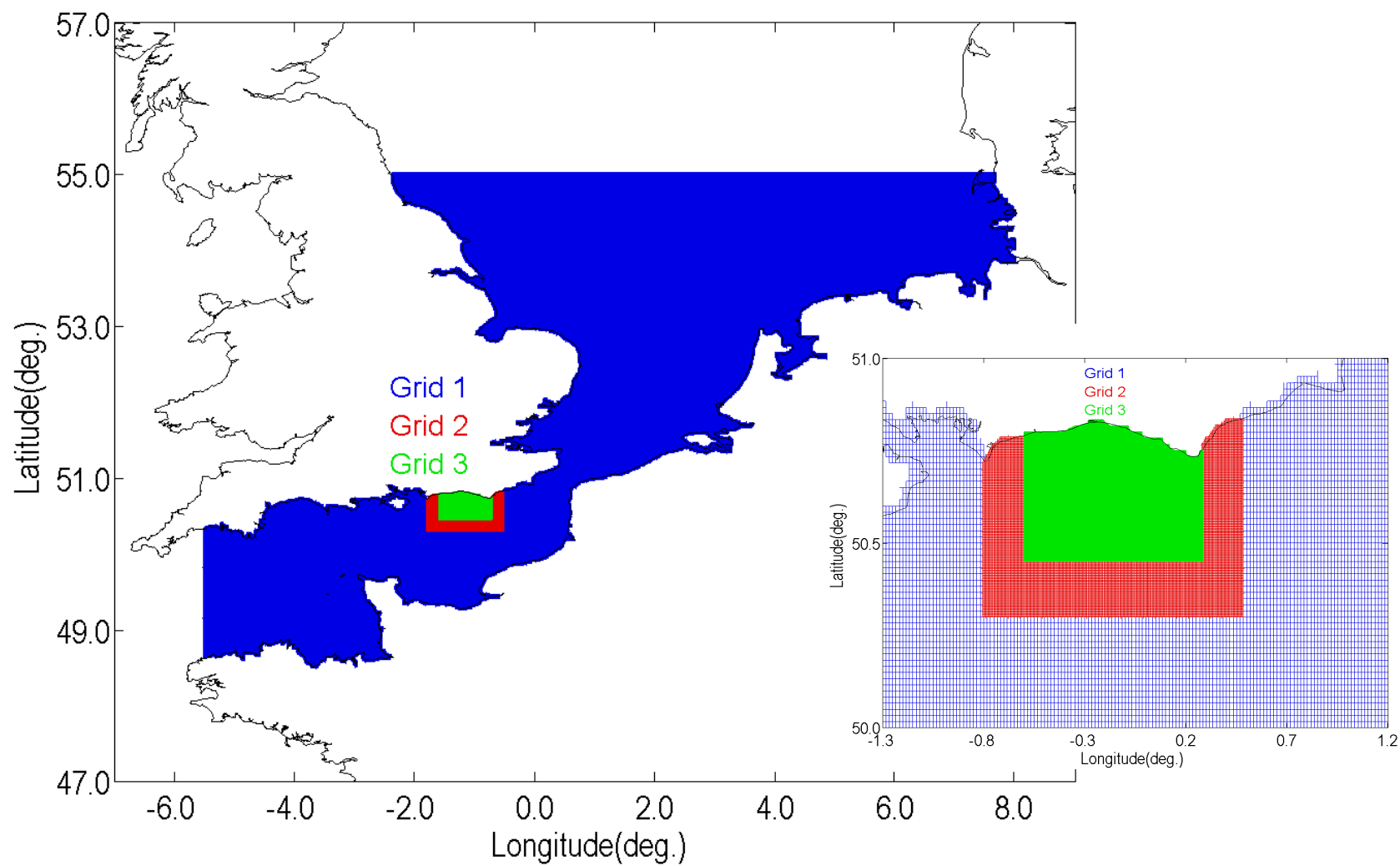


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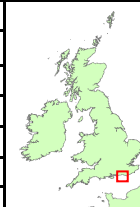


Model Domain

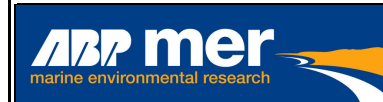
Figure A1



Date	By	Size	Version
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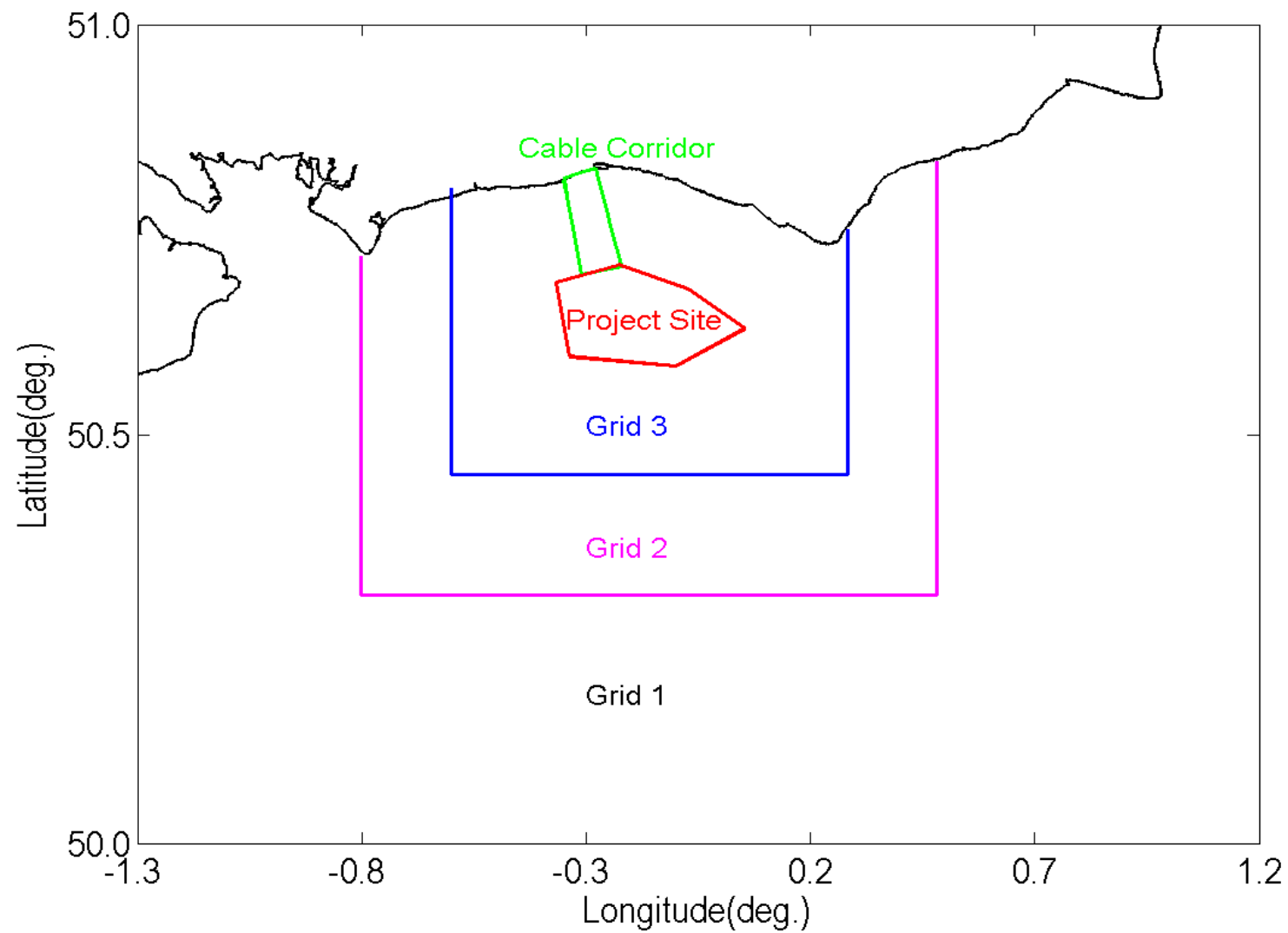
A map of the United Kingdom, including Great Britain and Ireland, is shown in light green. A small red square is located in the south of England, indicating the project area.

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DD Grids

Figure A2



Date	By	Size	Version
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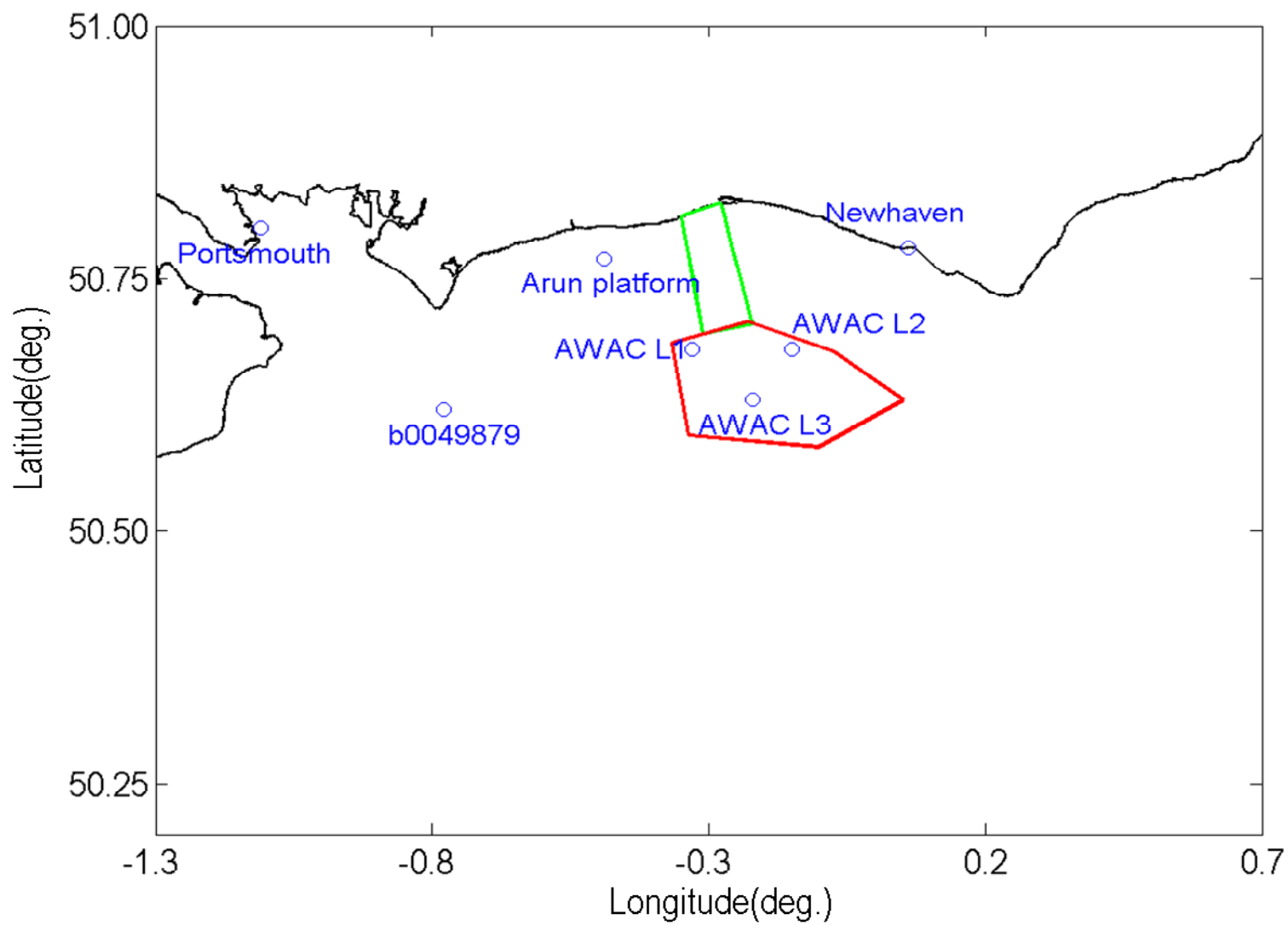
A map of the United Kingdom, including Great Britain and Ireland, is shown in light green. A small red square is located in the south of England, indicating the project location.

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Model Domain

Figure A3



Date	By	Size	Version
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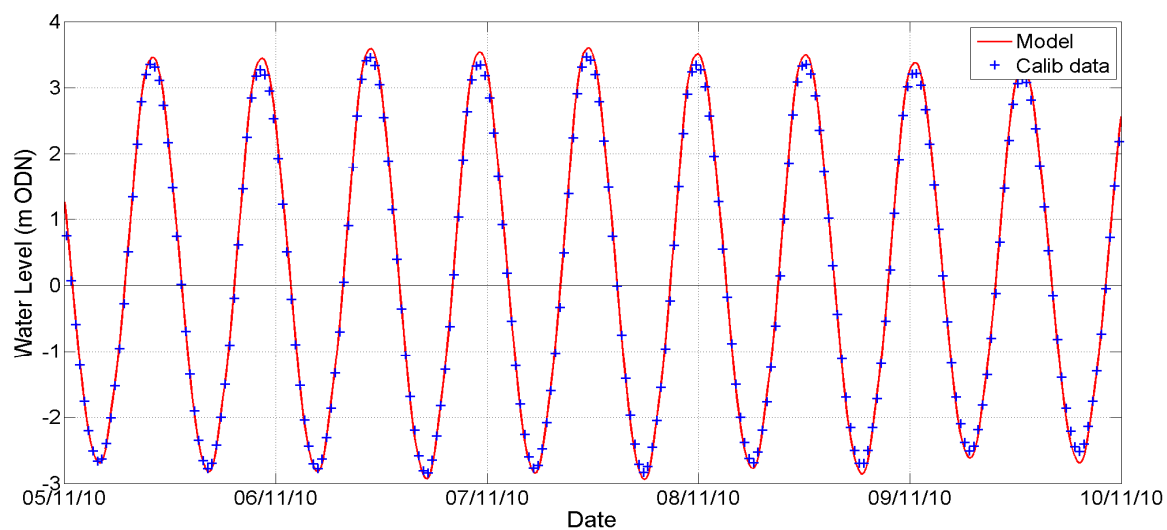
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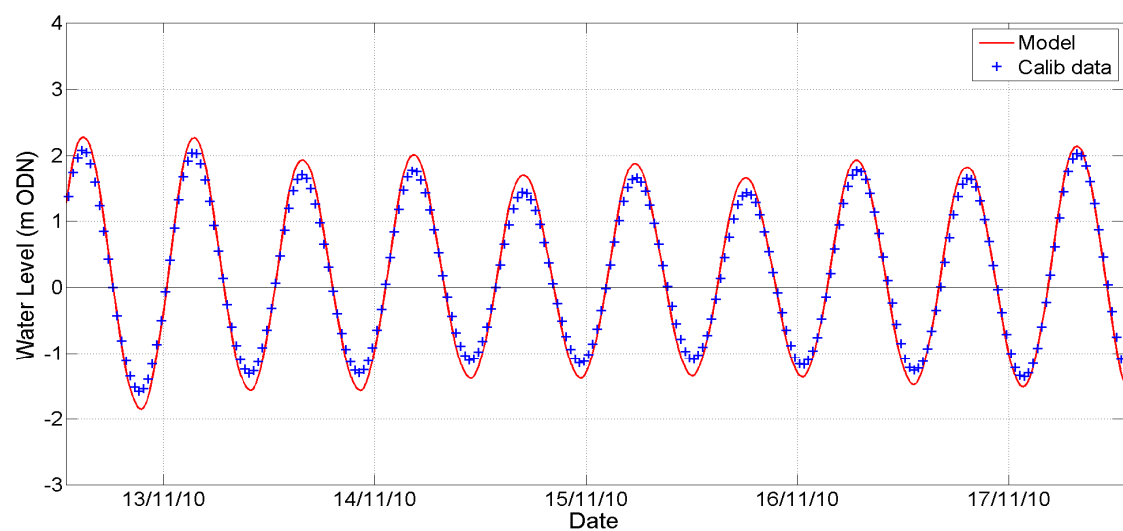
**Tidal Gauges, Current Meters
and Wave Buoys**

Figure A4

(a)



(b)



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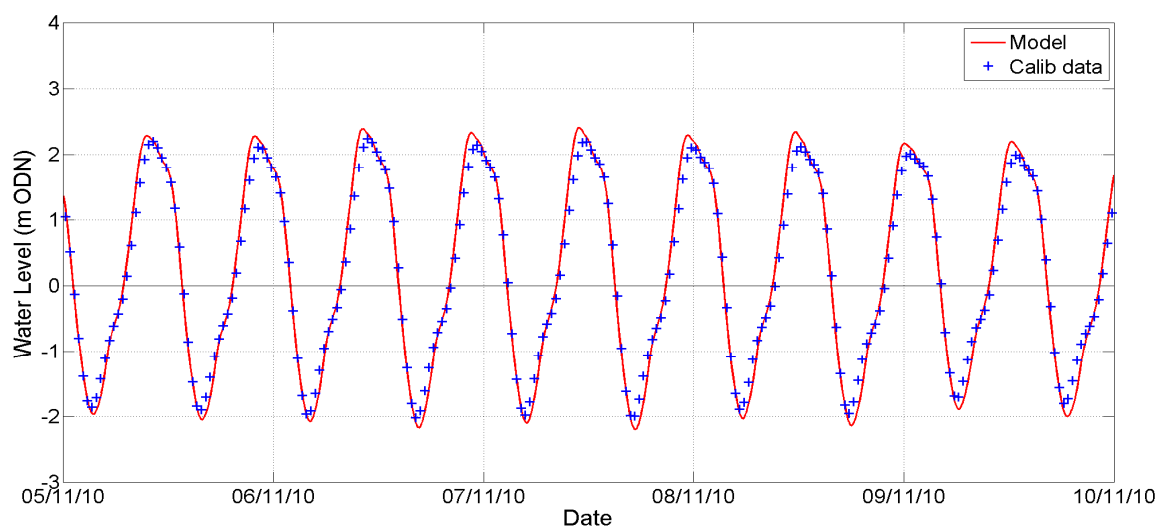
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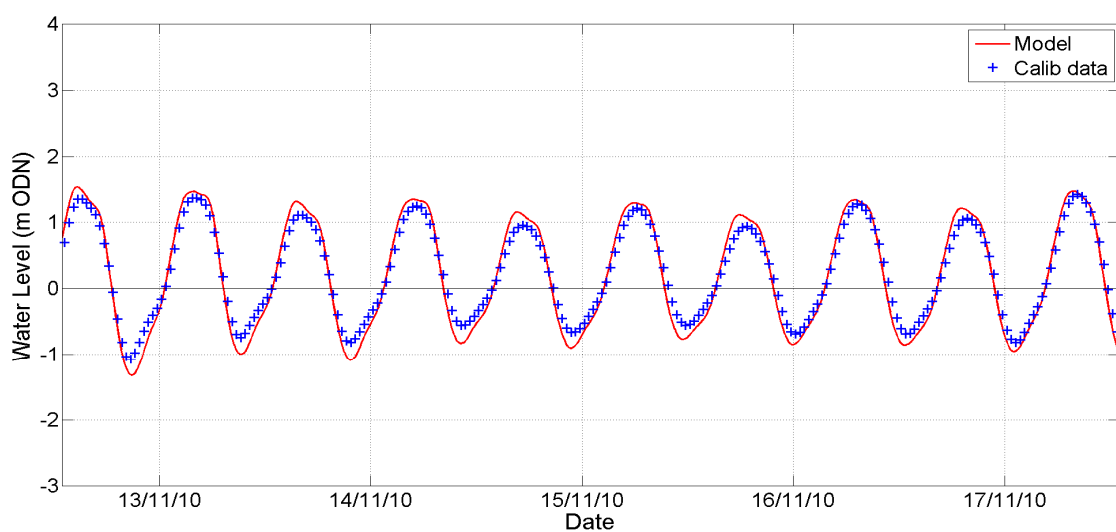
Water Level Calibration at Newhaven for (a) Spring Tide and (b) Neap Tide

Figure A5

(a)



(b)



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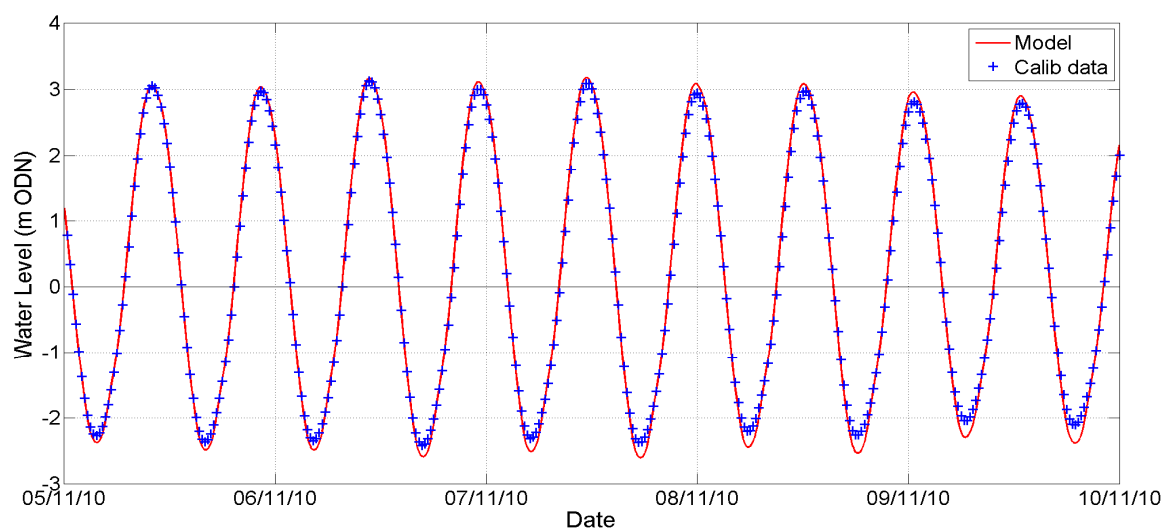
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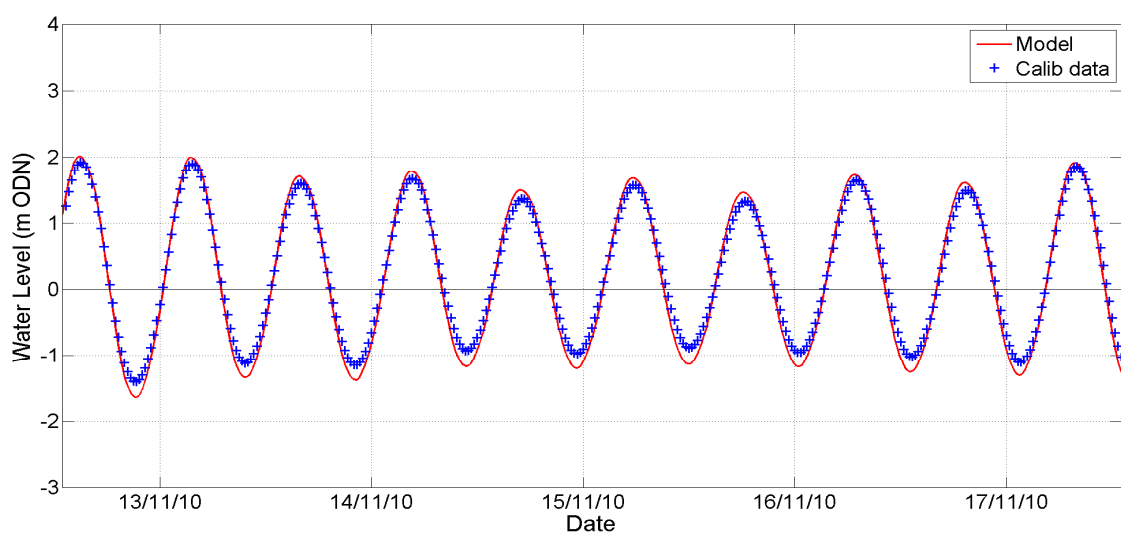
Water Level Calibration at Portsmouth for (a) Spring Tide and (b) Neap Tide

Figure A6

(a)



(b)



Date	By	Size	Version
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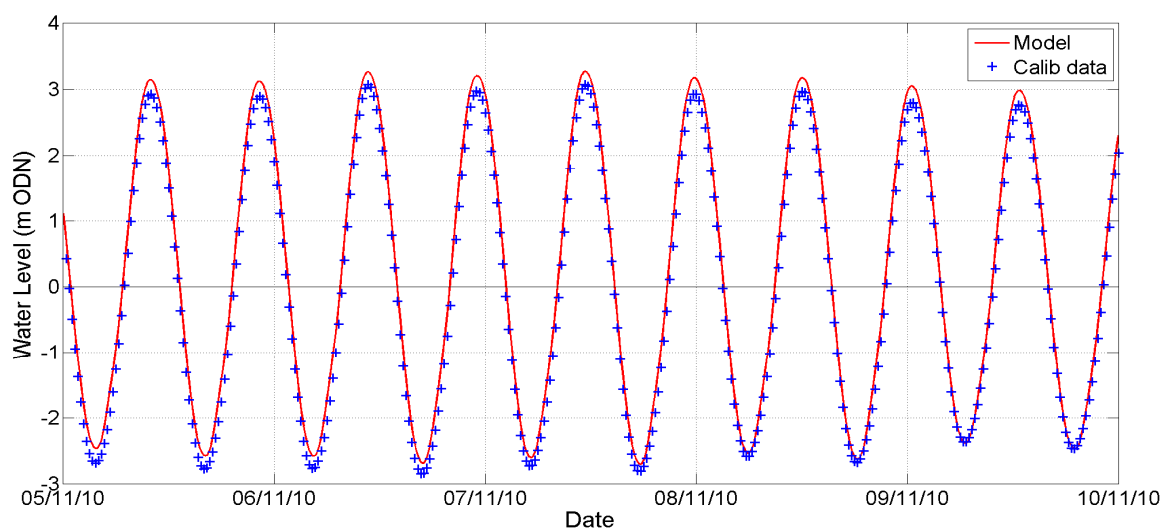
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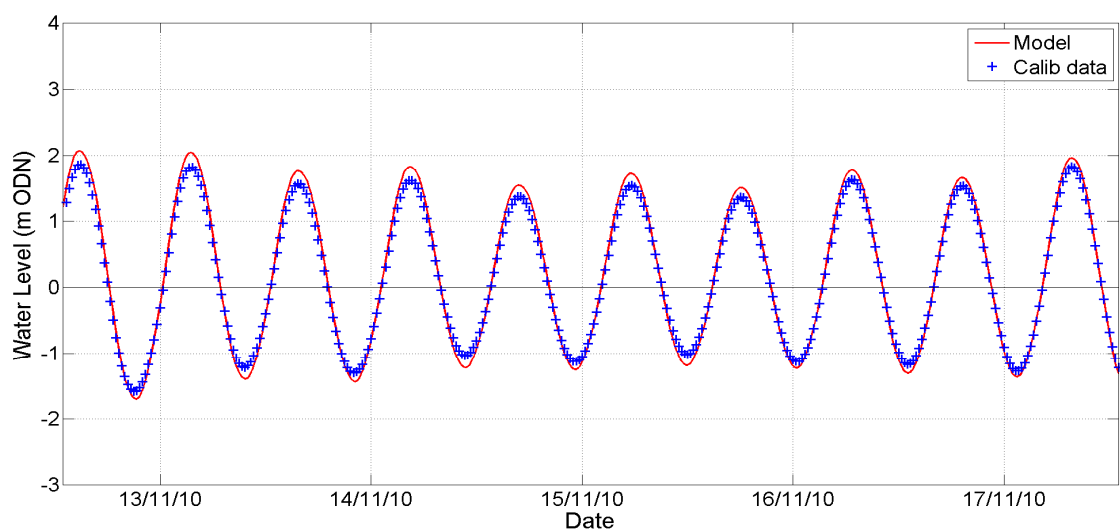
Water Level Calibration at Arun Platform for (a) Spring Tide and
(b) Neap Tide

Figure A7

(a)



(b)

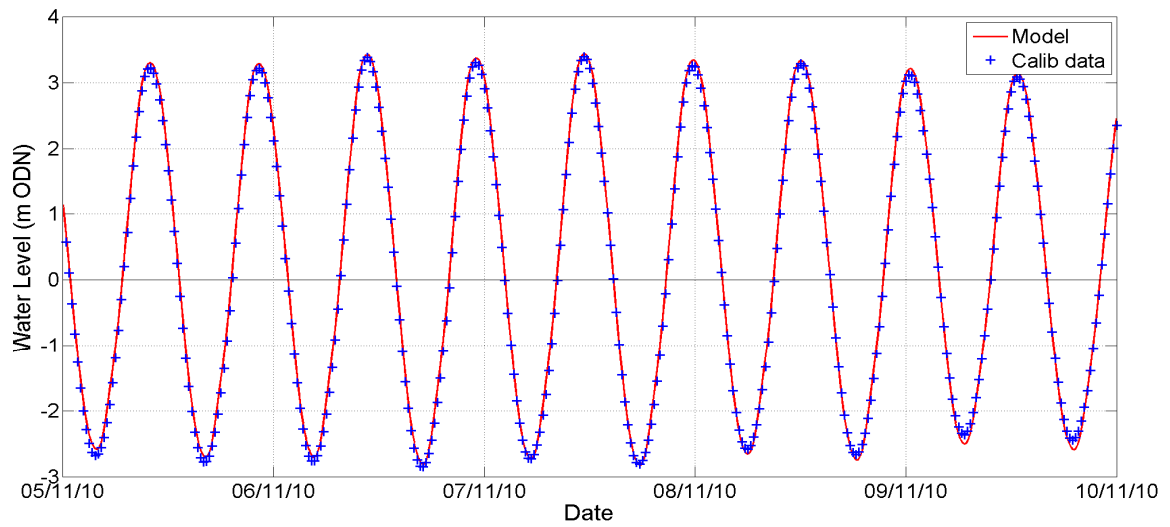


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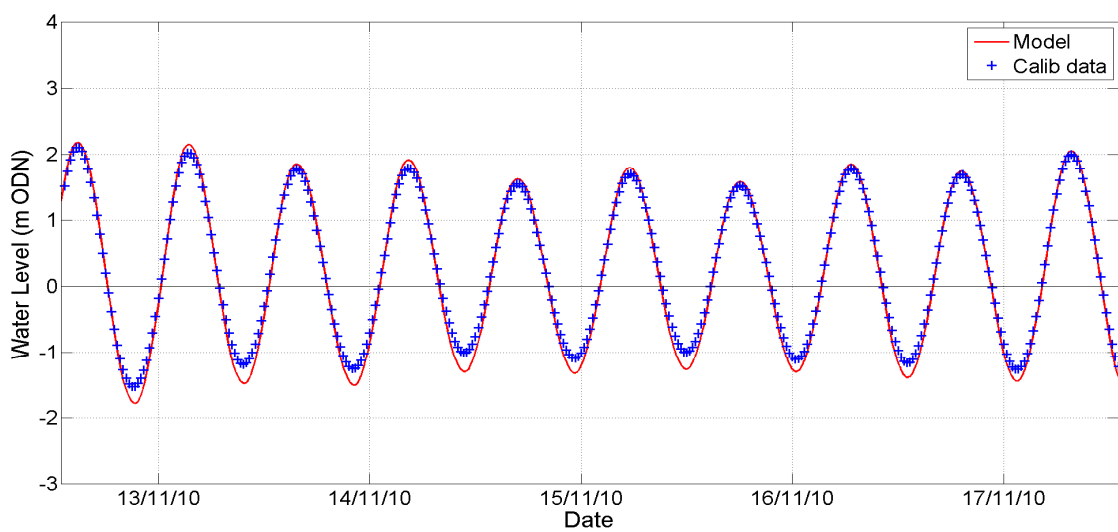
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(a)



(b)



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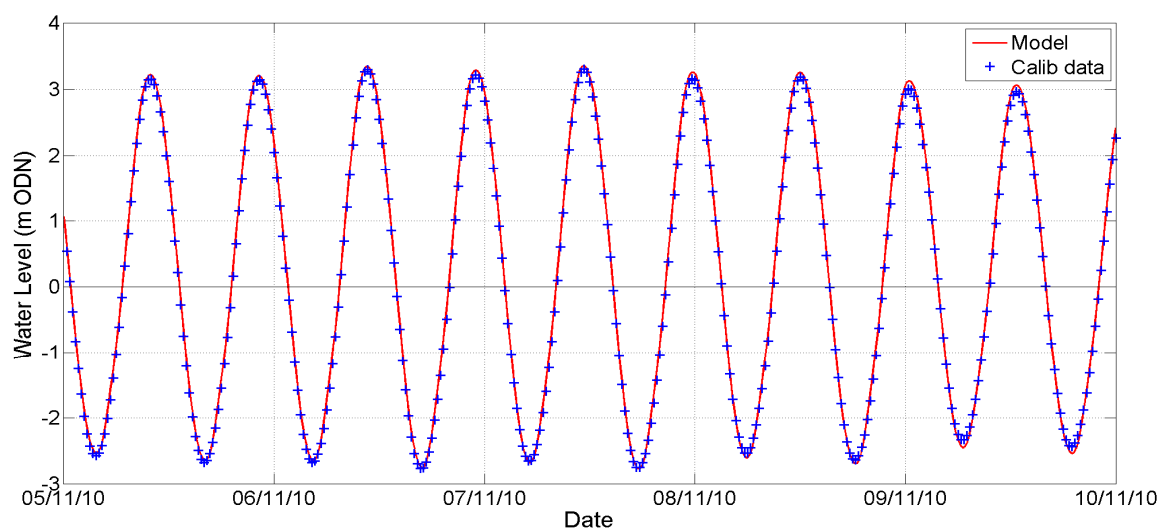
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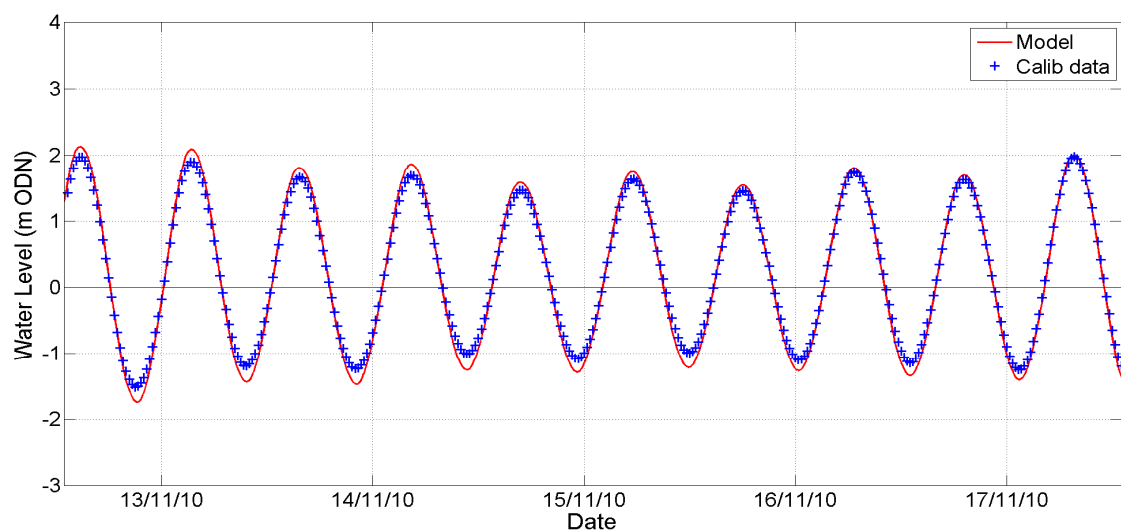
Water Level Calibration at AWAC L2 for (a) Spring Tide and (b) Neap Tide

Figure A9

(a)



(b)



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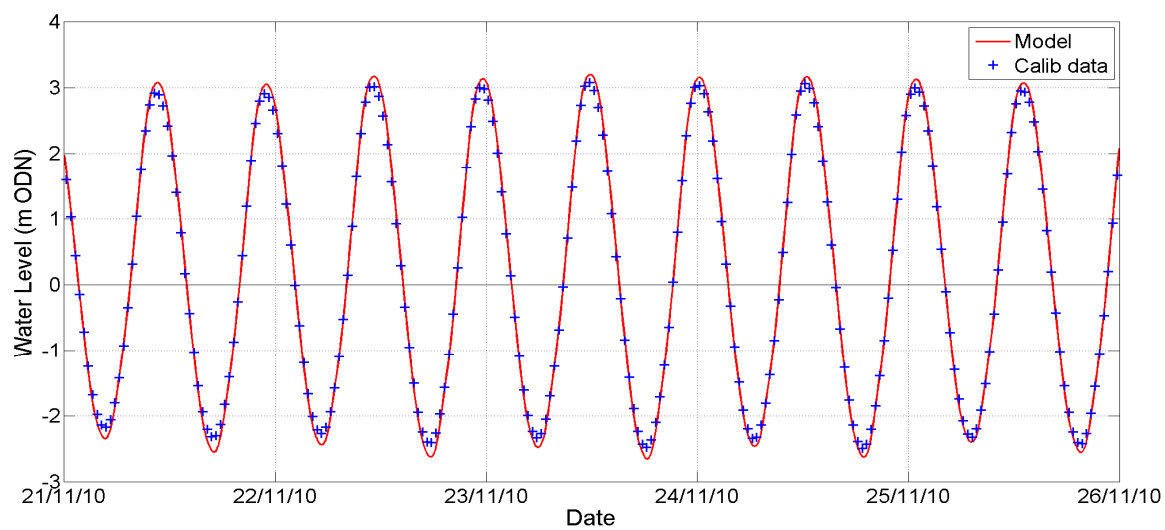
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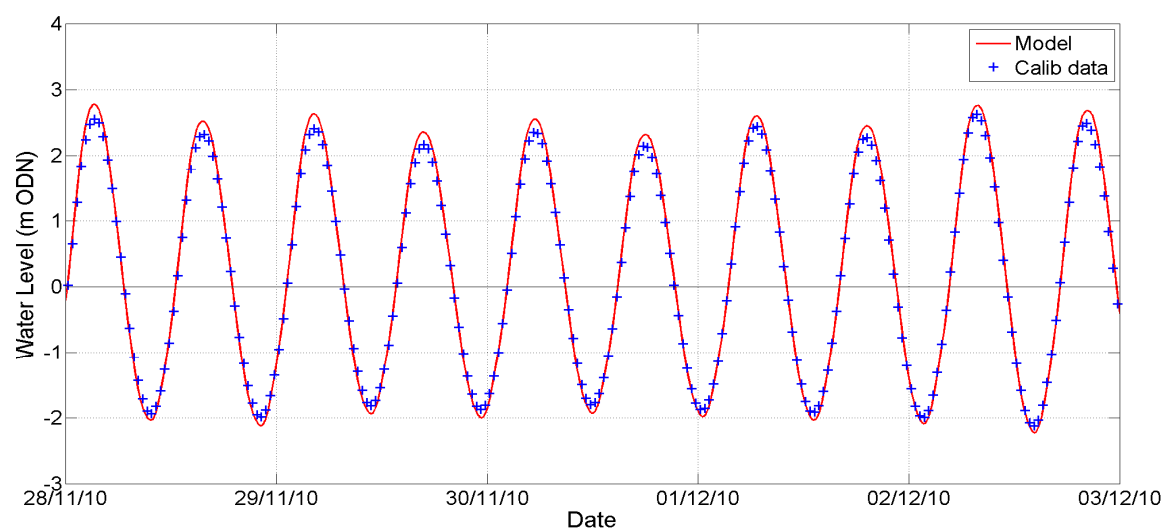
Water Level Calibration at AWAC L3 for (a) Spring Tide and (b) Neap Tide

Figure A10

(a)



(b)



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— Model
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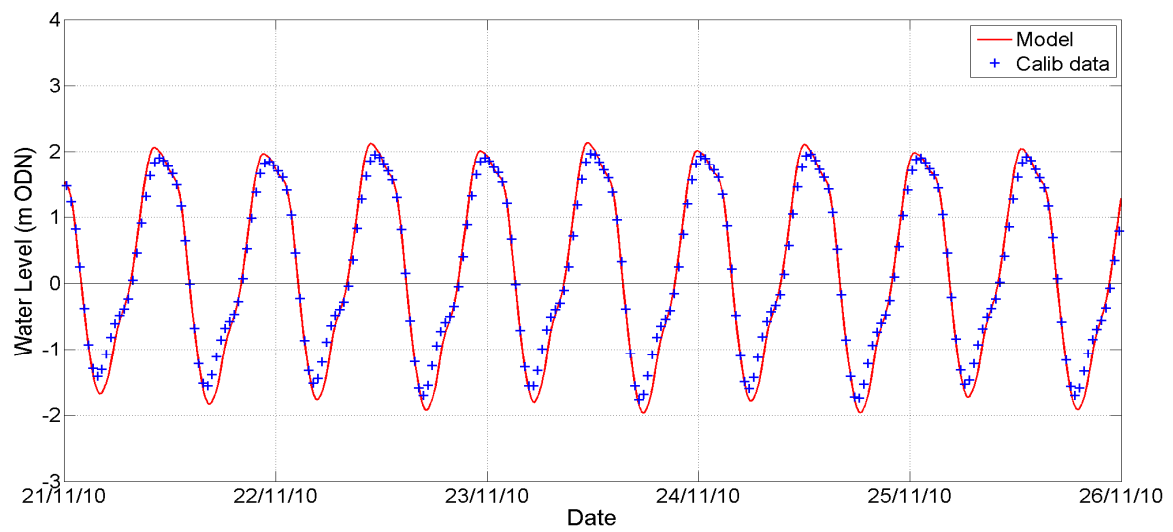
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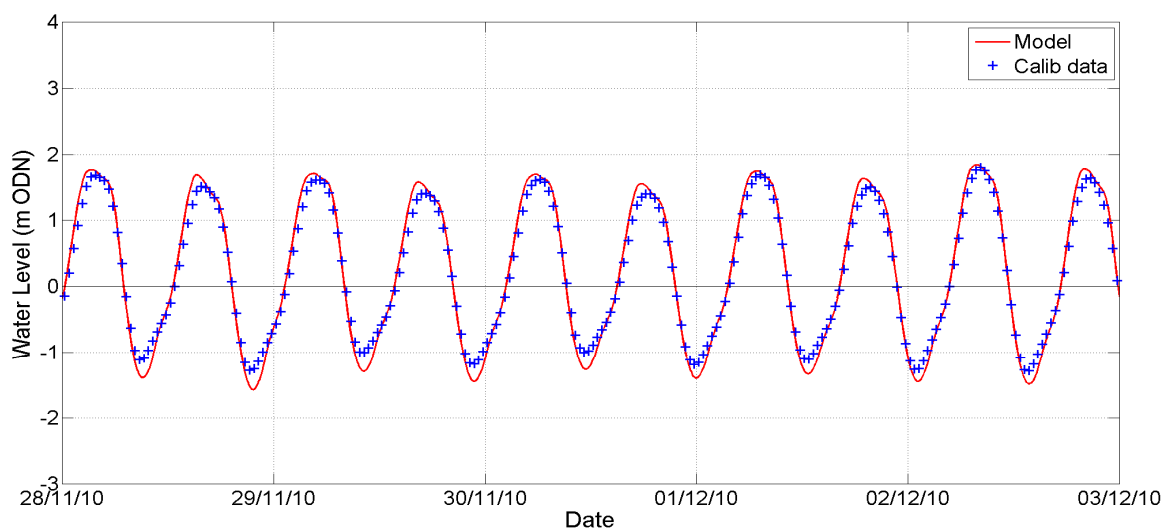
Water Level Validation at Newhaven for (a) Spring Tide and (b) Neap Tide

Figure A11

(a)



(b)



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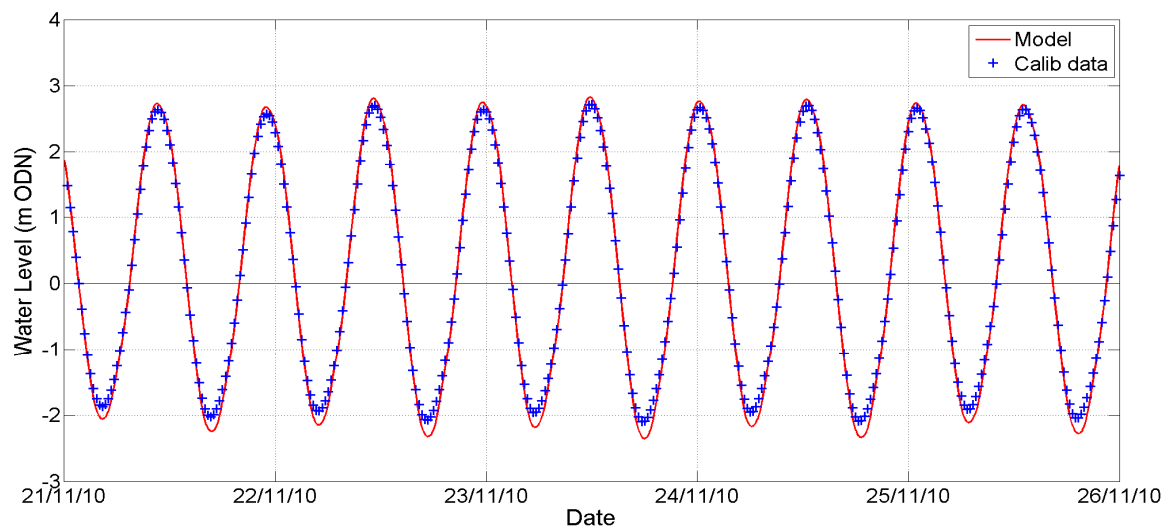
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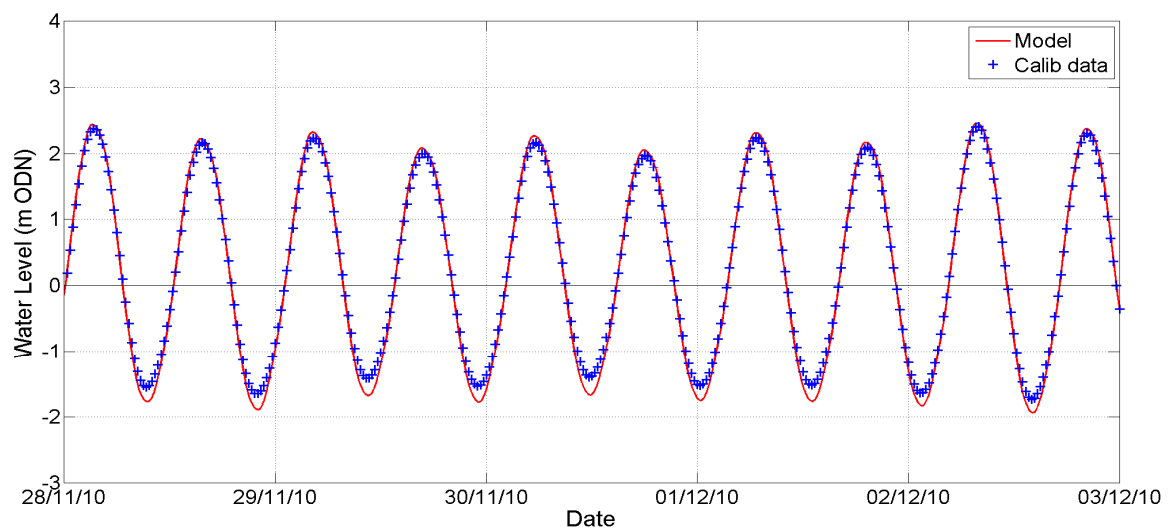
Water Level Validation at Portsmouth for (a) Spring Tide and (b) Neap Tide

Figure A12

(a)



(b)



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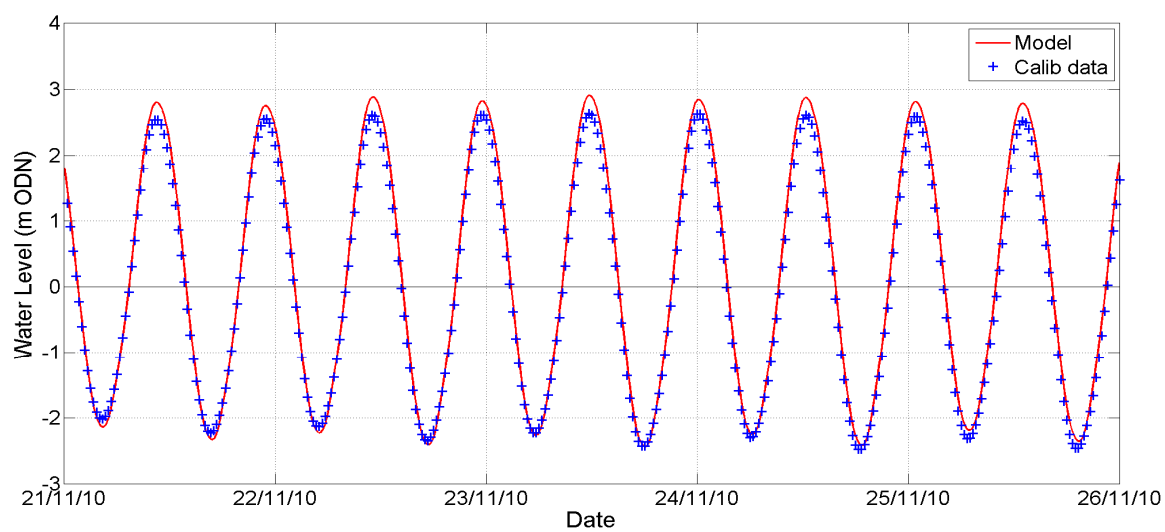
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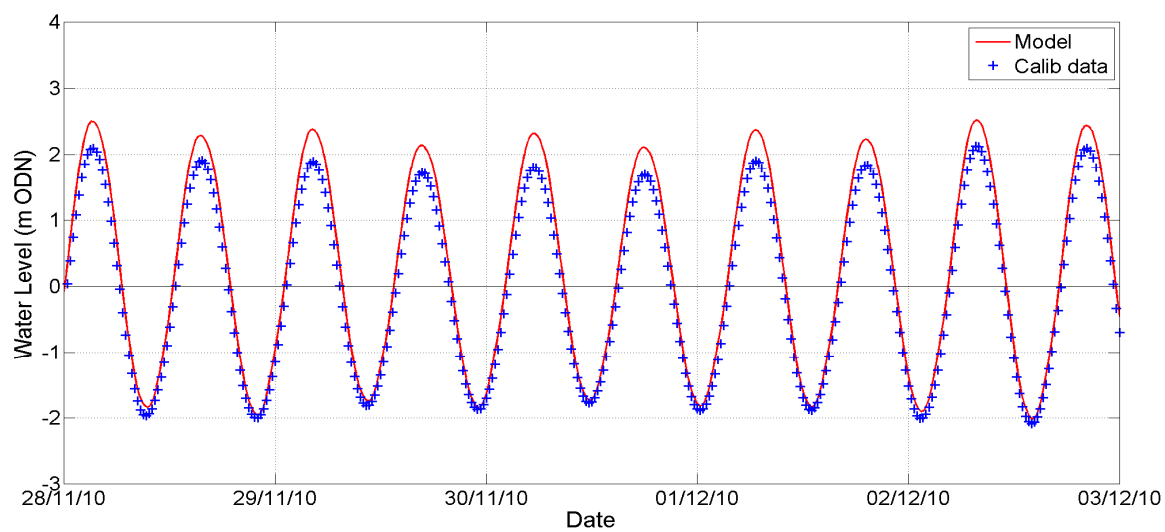
Water Level Validation at Arun Platform for (a) Spring Tide and
(b) Neap Tide

Figure A13

(a)



(b)



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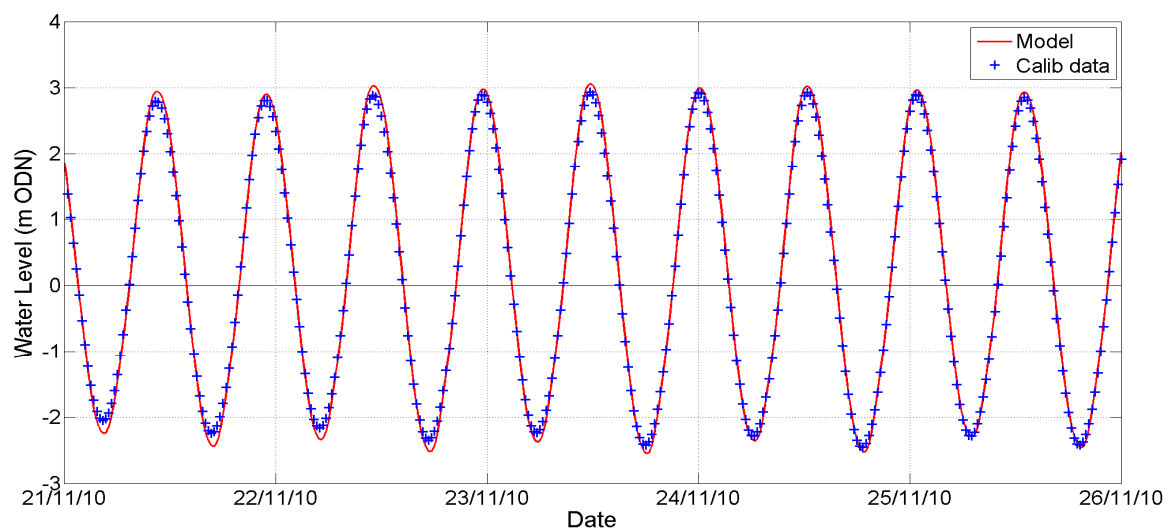
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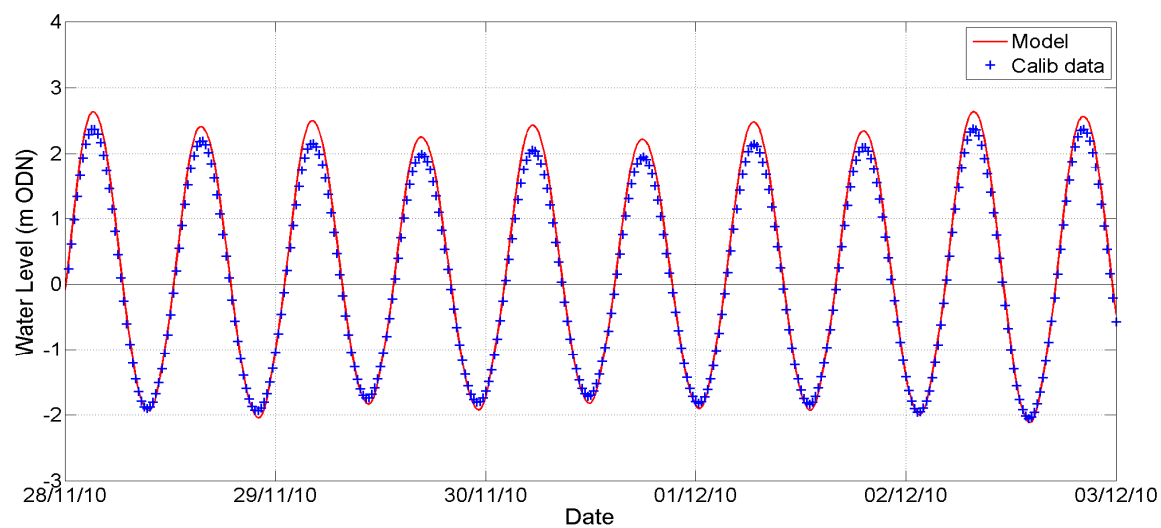
Water Level Validation at AWAC L1 for (a) Spring Tide and (b) Neap Tide

Figure A14

(a)



(b)



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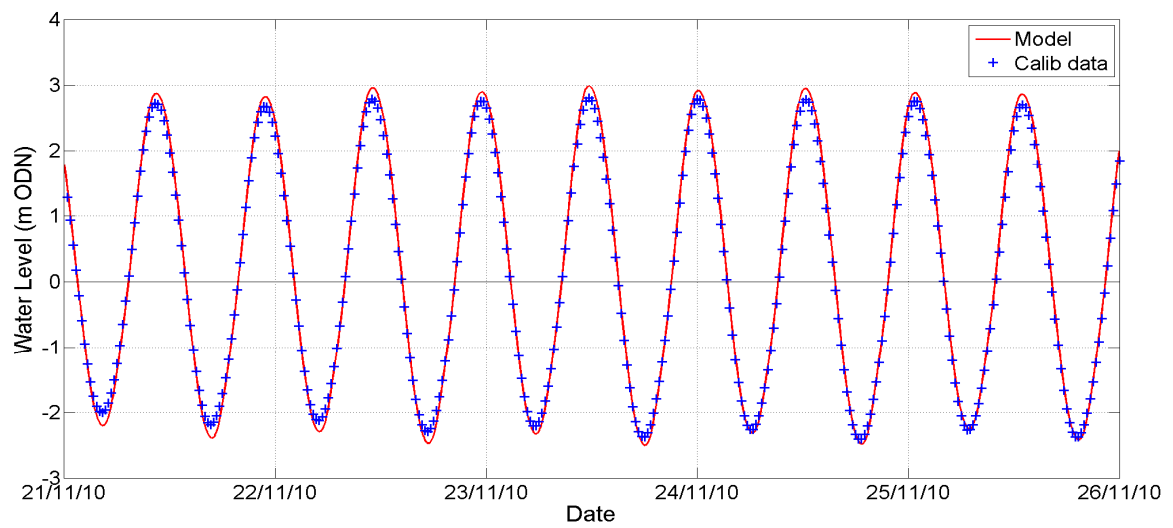
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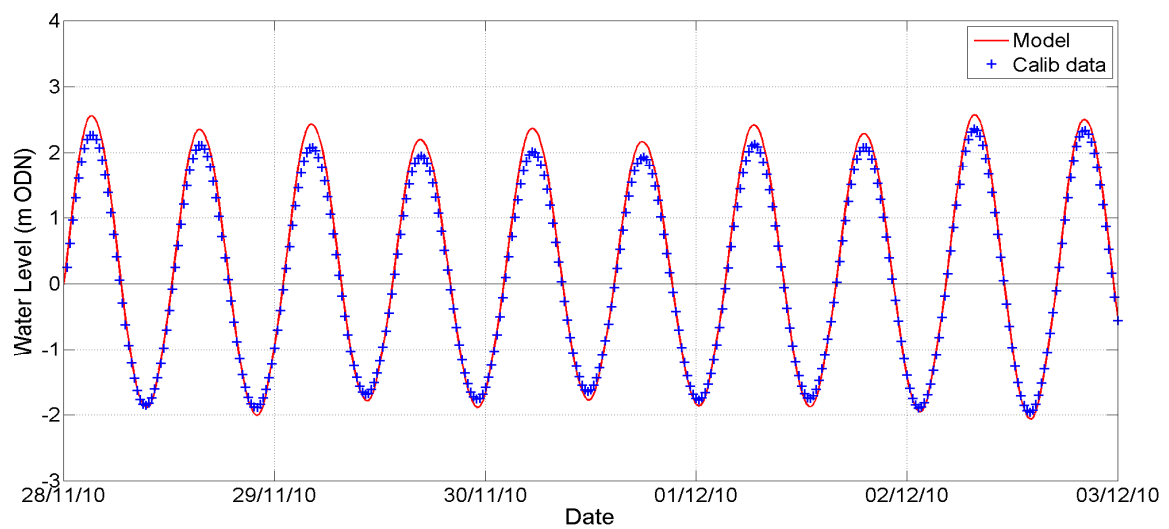
Water Level Validation at AWAC L2 for (a) Spring Tide and (b) Neap Tide

Figure A15

(a)



(b)



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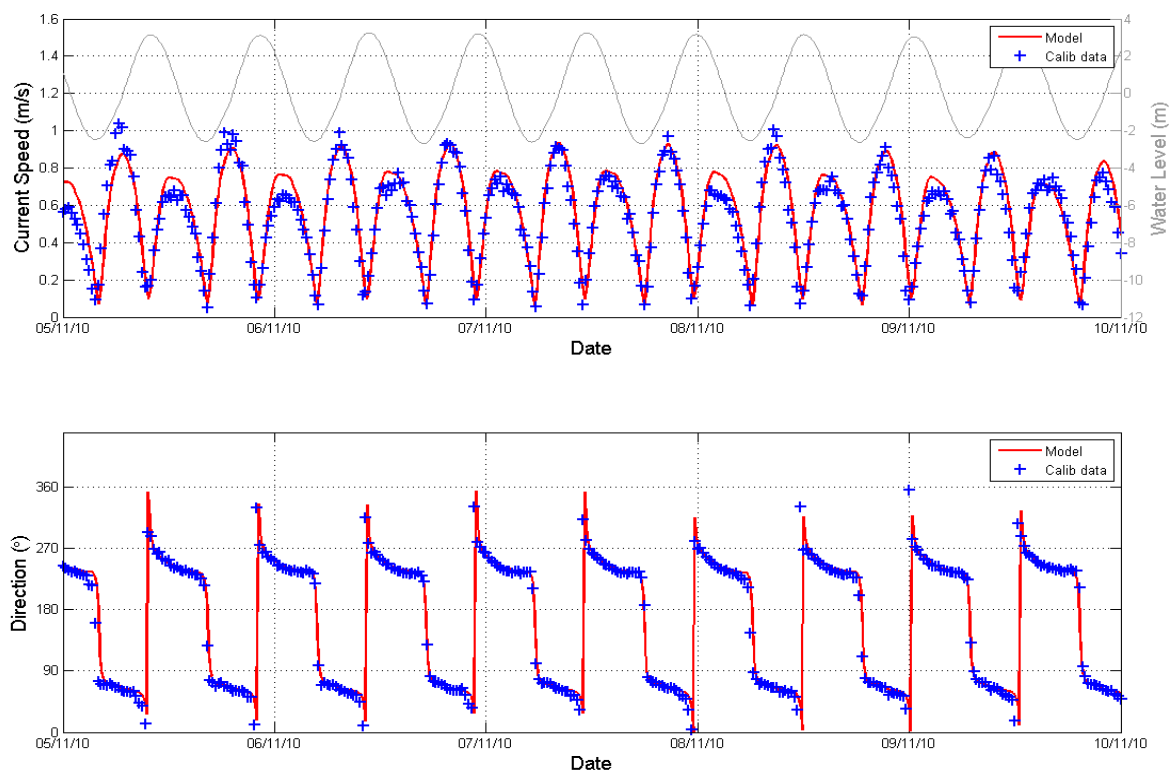
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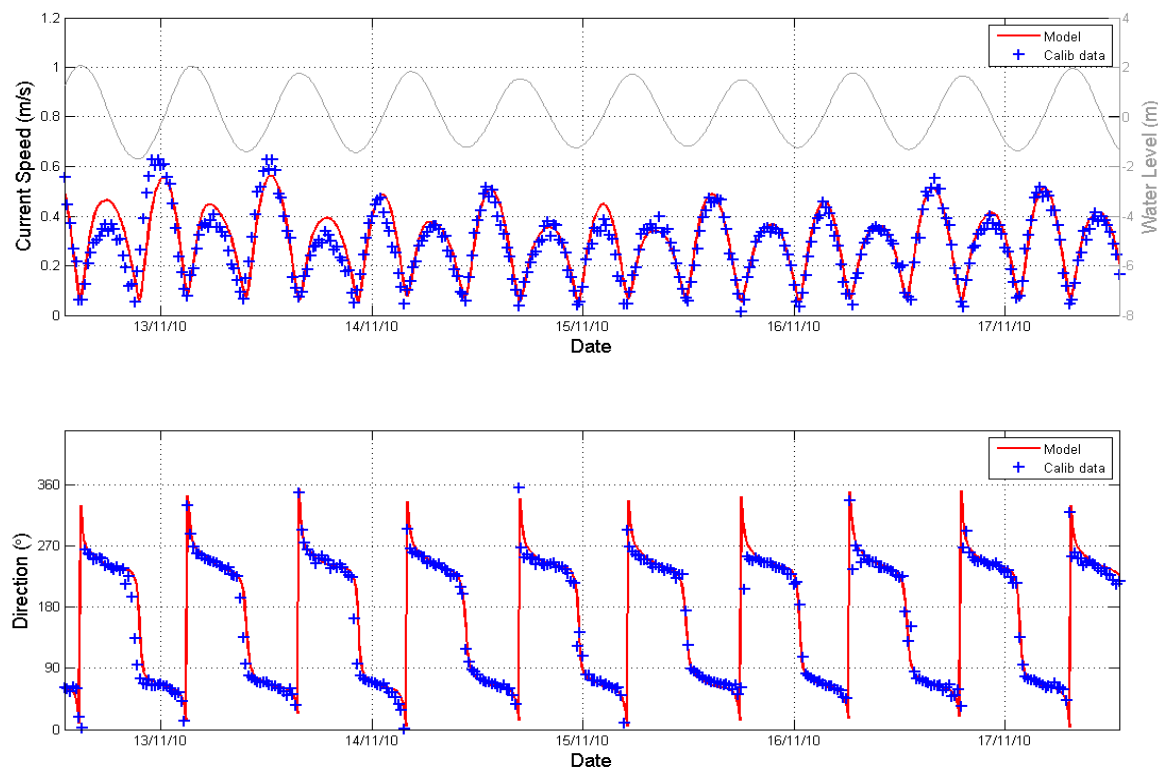
Water Level Validation at AWAC L3 for (a) Spring Tide and (b) Neap Tide

Figure A16

(a)



(b)



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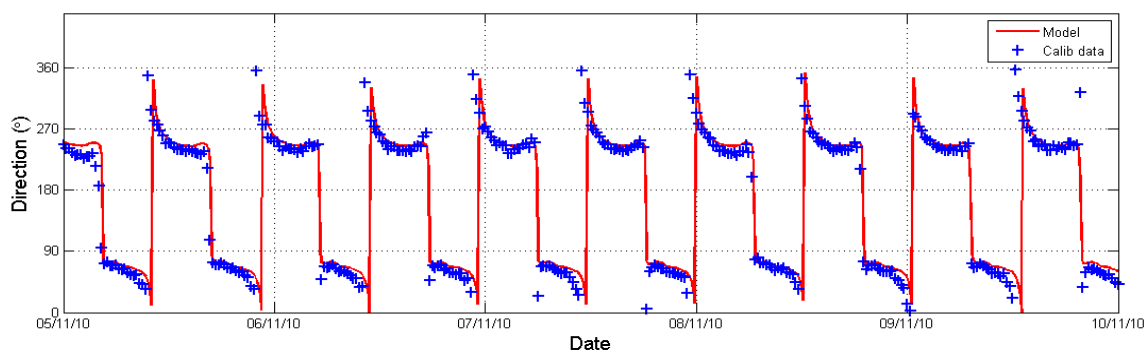
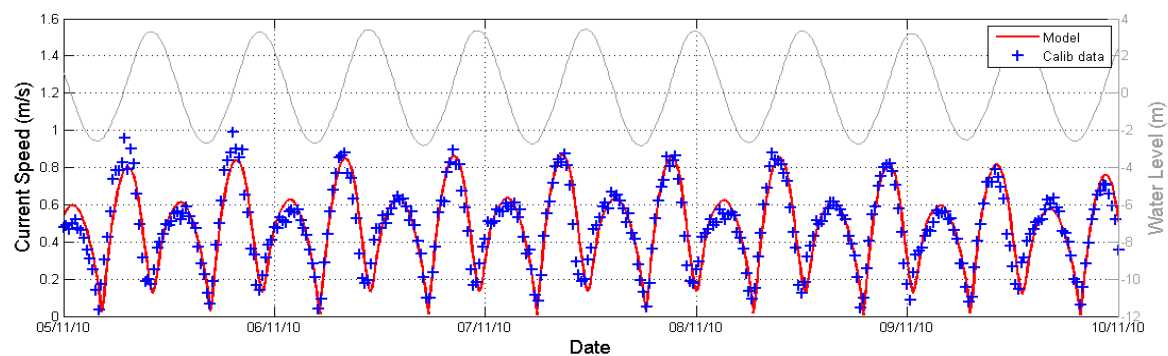
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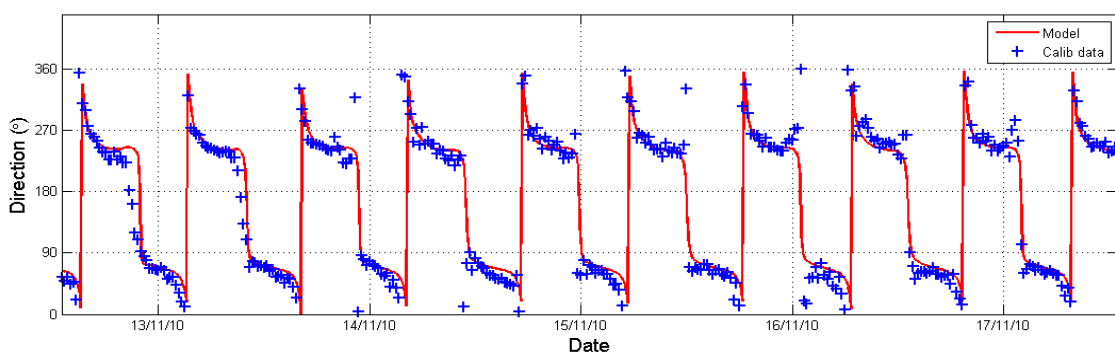
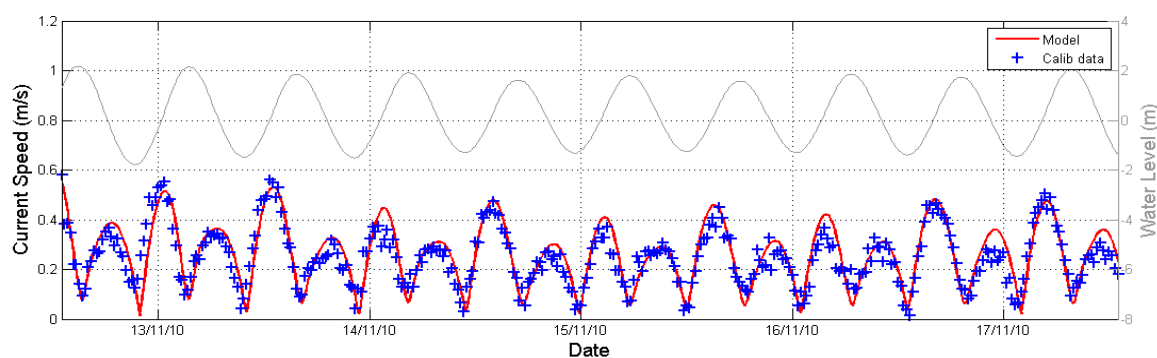
Current Speed and Direction Calibration at AWAC L1 for (a) Spring Tide and (b) Neap Tide

Figure A17

(a)



(b)



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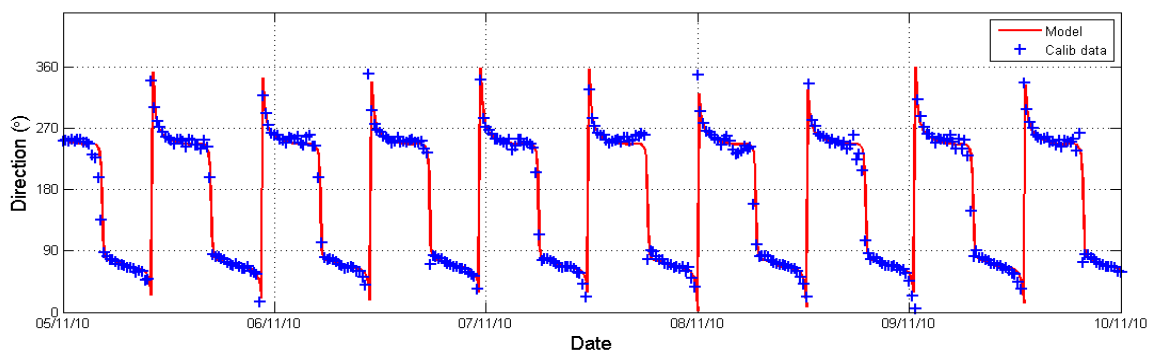
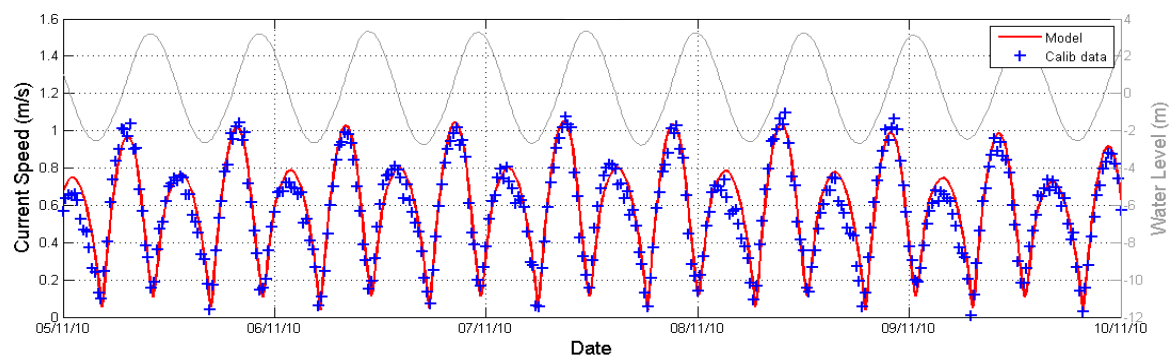
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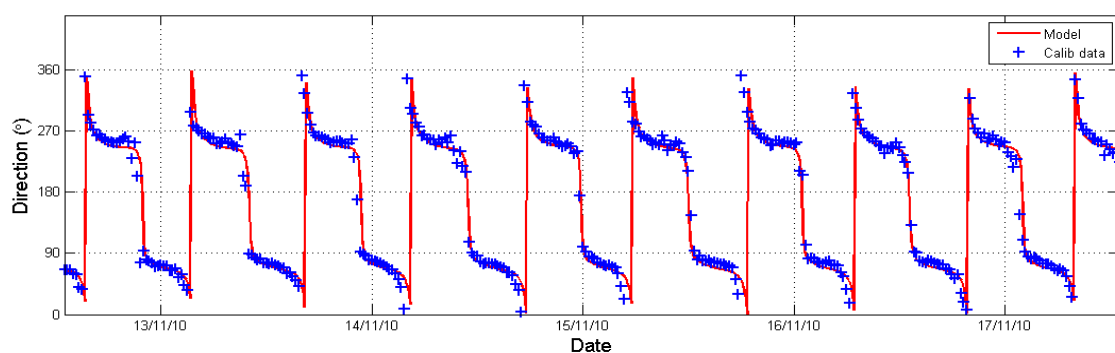
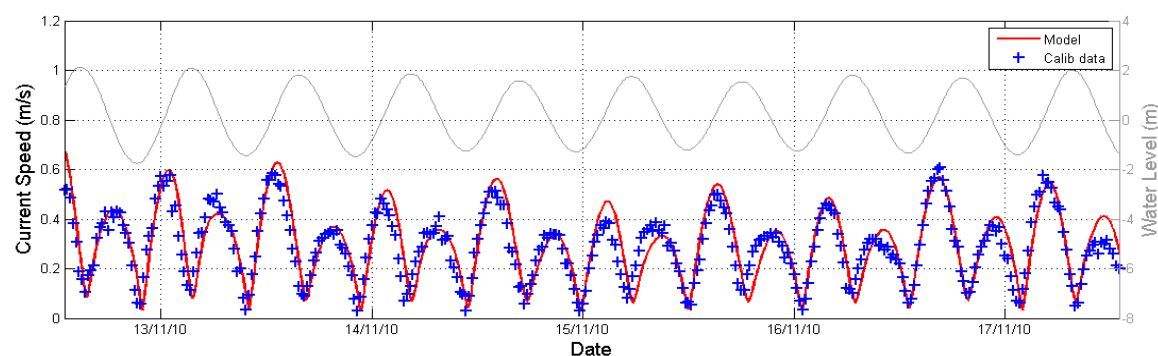
Current Speed and Direction Calibration at AWAC L2 for (a)
Spring Tide and (b) Neap Tide

Figure A18

(a)



(b)



Date	By	Size	Version
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Projection		n/a	
Scale		n/a	
QA		REW	
Calibration_Report_Figures.xls			
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— Model
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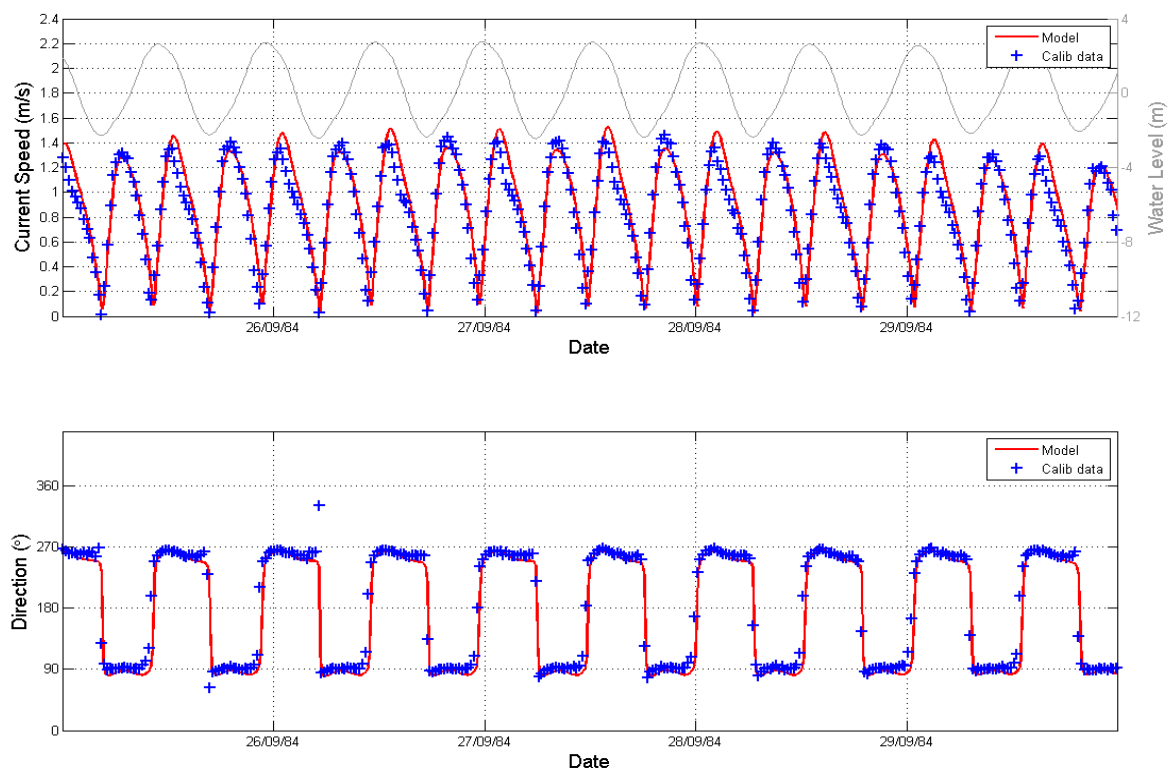
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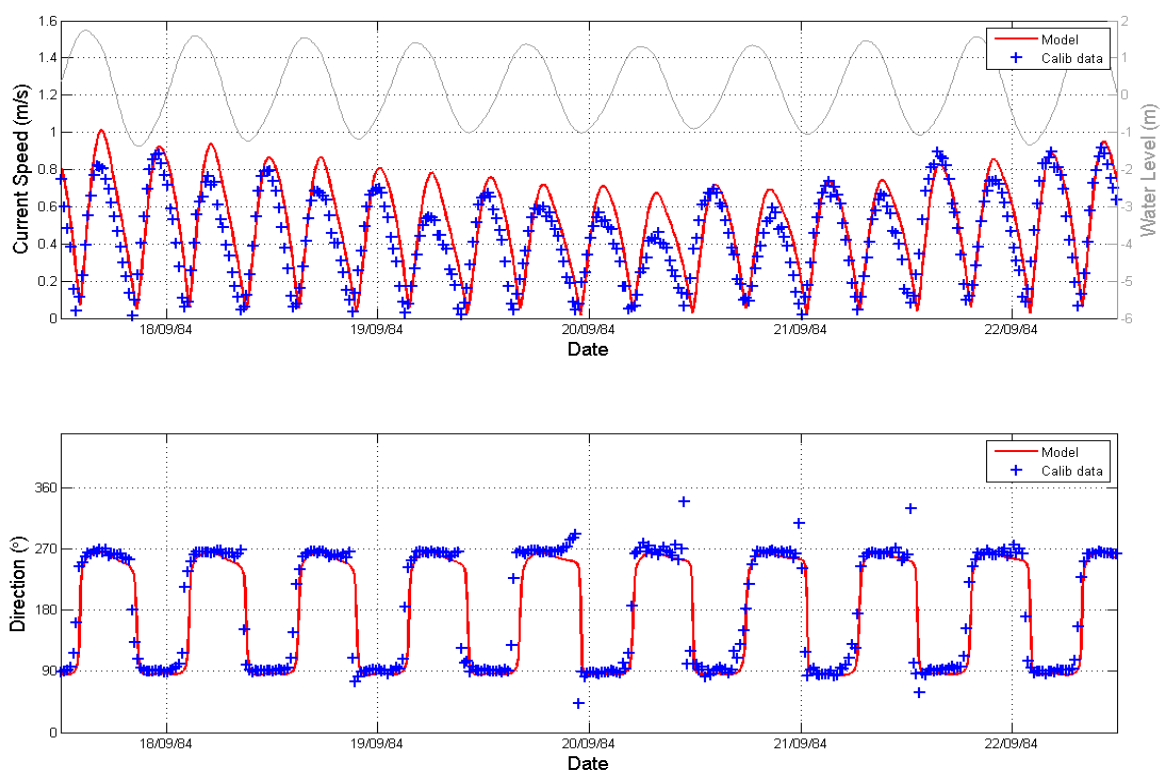
Current Speed and Direction Calibration at AWAC L3 for (a) Spring Tide and (b) Neap Tide

Figure A19

(a)



(b)

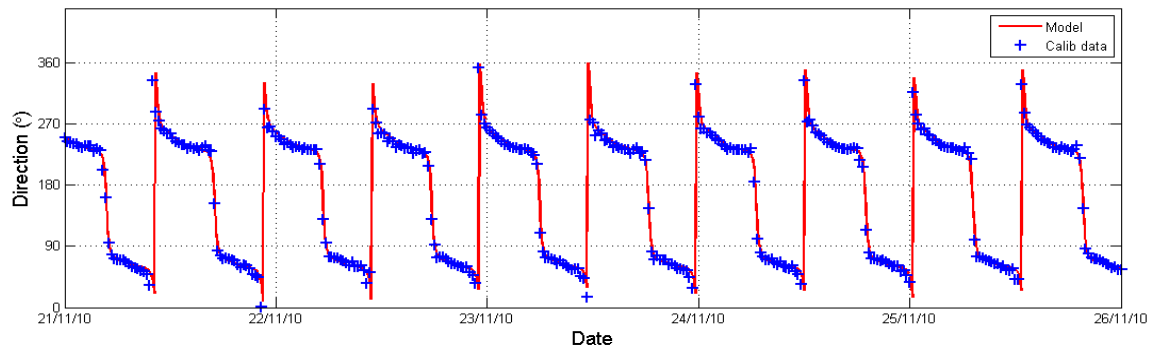
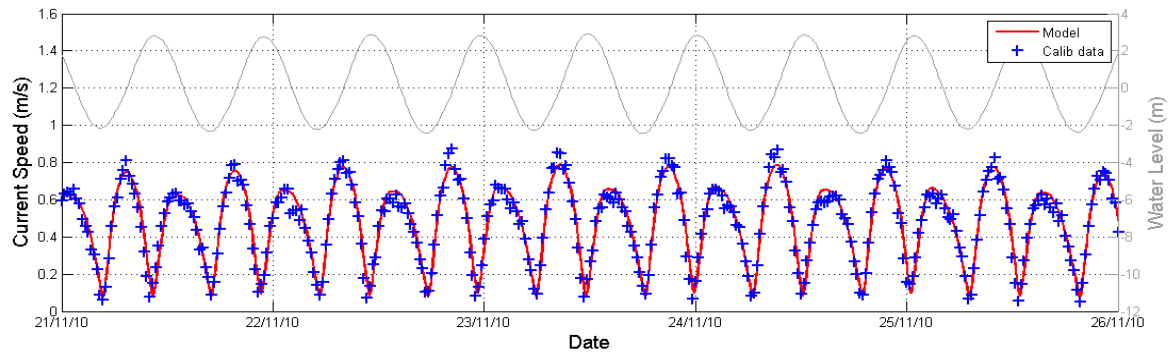


Date	By	Size	Version
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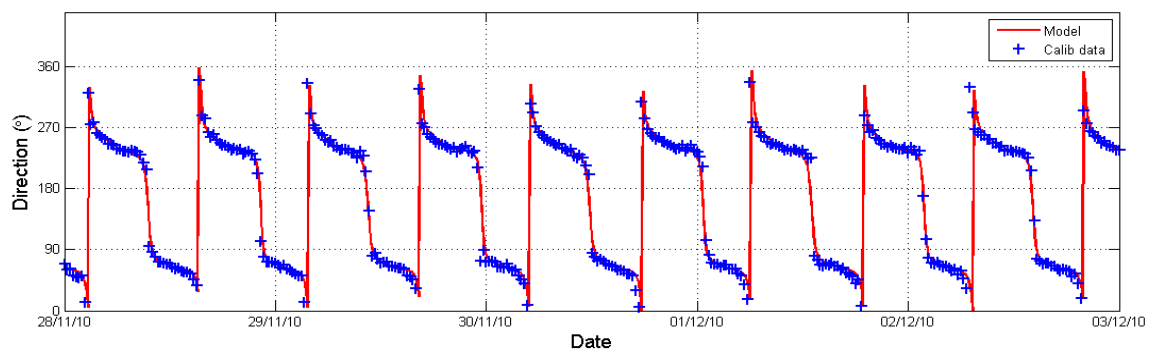
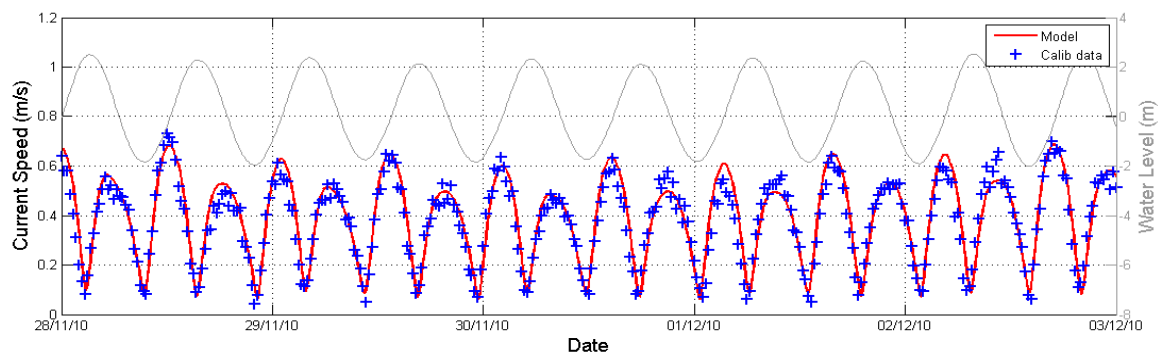
— Model
+ Calib data

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(a)



(b)



Date	By	Size	Version
Feb 12	ALB	A4	1
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Scale		n/a	
QA		REW	
Calibration_Report_Figures.xls			
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— Model
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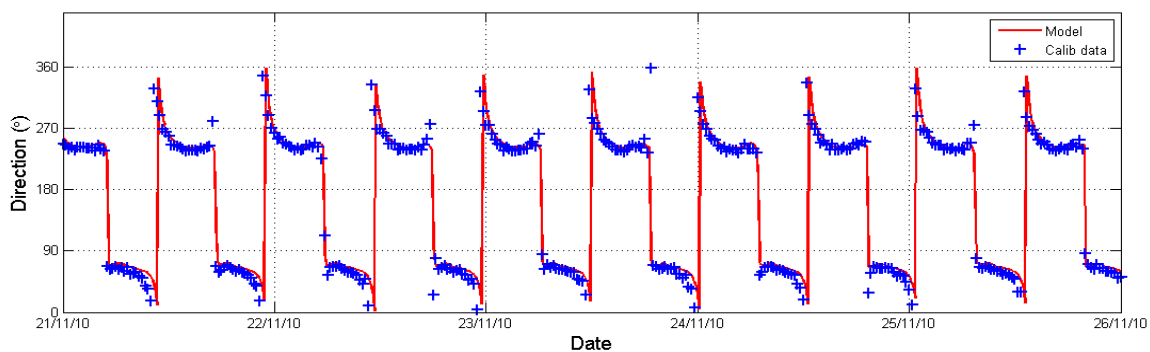
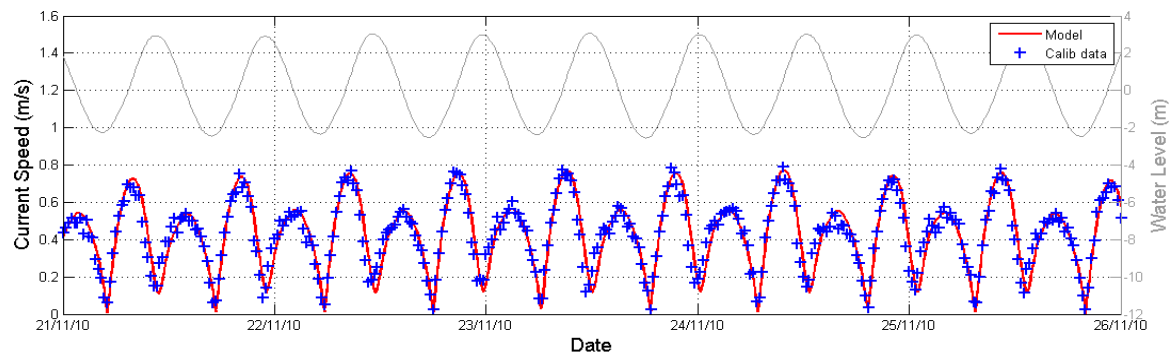
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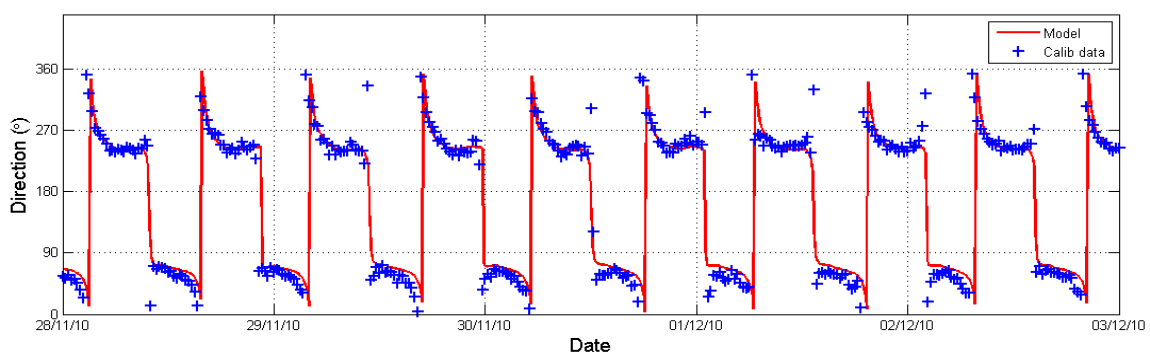
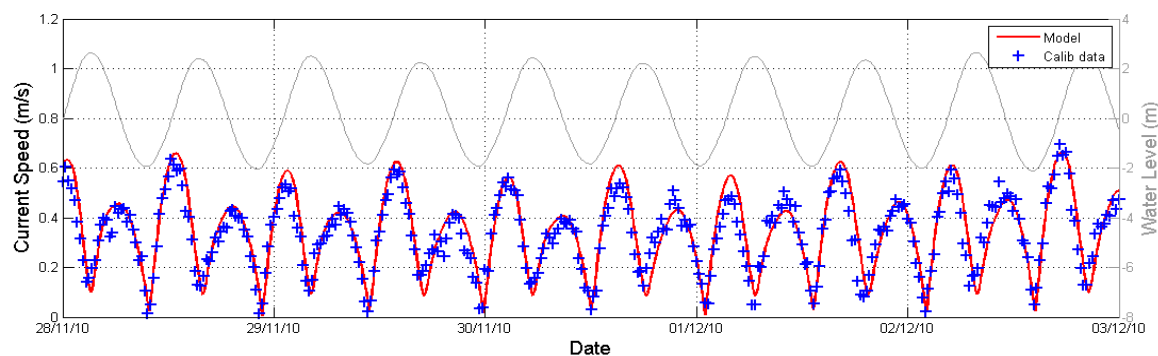
Current Speed and Direction Validation at AWAC L1 for (a) Spring Tide and (b) Neap Tide

Figure A21

(a)



(b)



Date	By	Size	Version
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Scale		n/a	
QA		REW	
Calibration_Report_Figures.xls			
Produced by ABPmer Ltd.			

— Model
+ Calib data

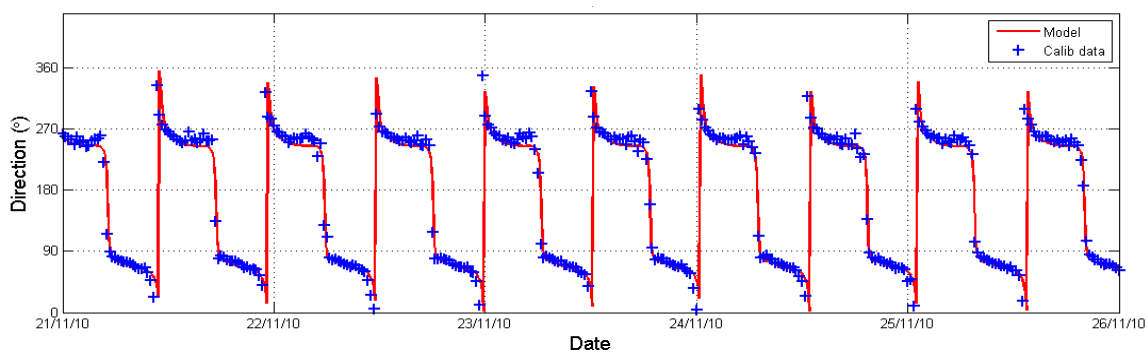
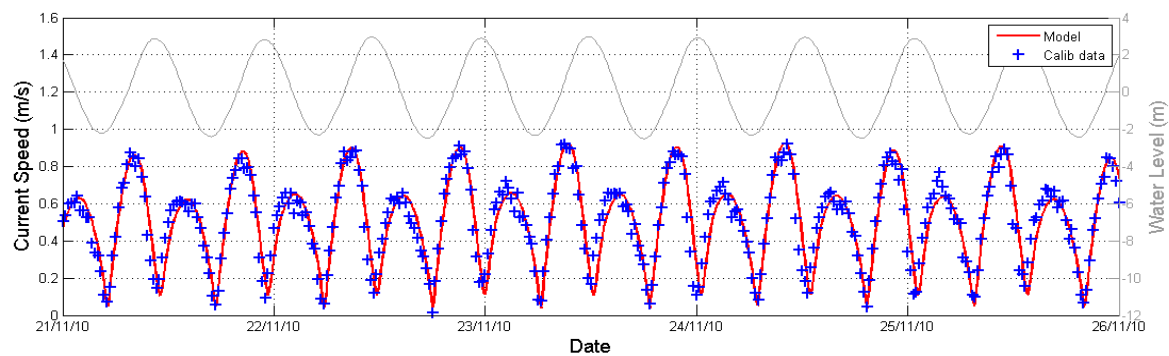
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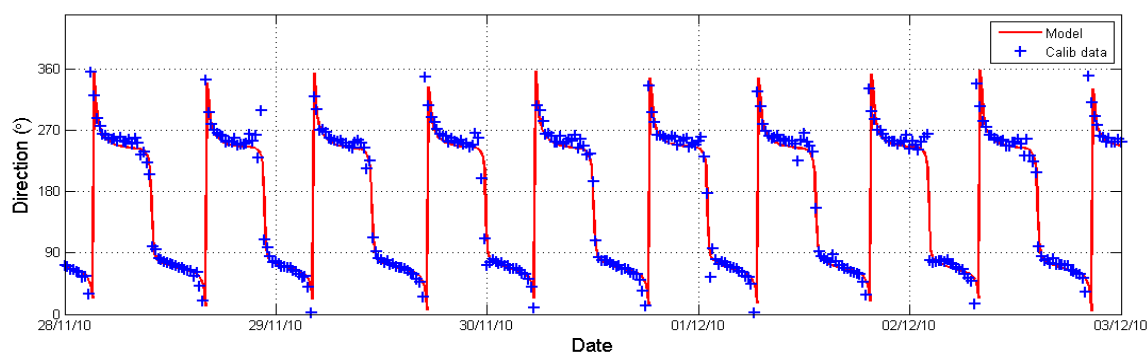
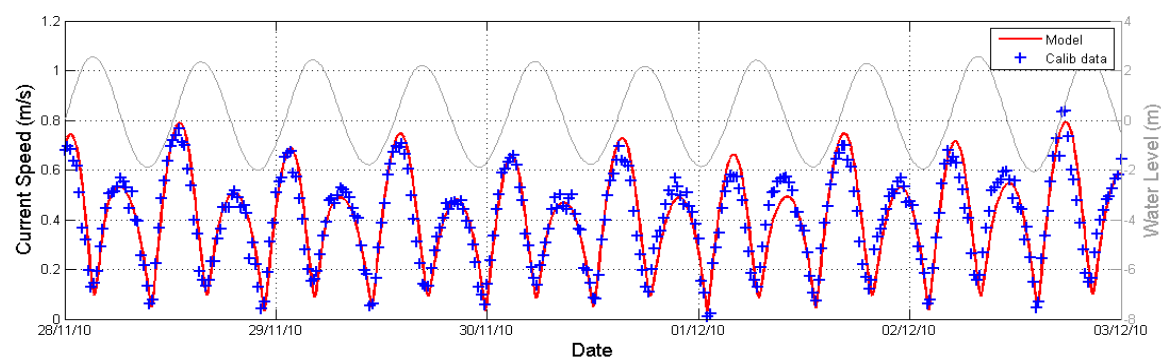
Current Speed and Direction Validation at AWAC L2 for (a) Spring Tide and (b) Neap Tide

Figure A22

(a)



(b)



Date	By	Size	Version
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Scale		n/a	
QA		REW	
Calibration_Report_Figures.xls			
Produced by ABPmer Ltd.			

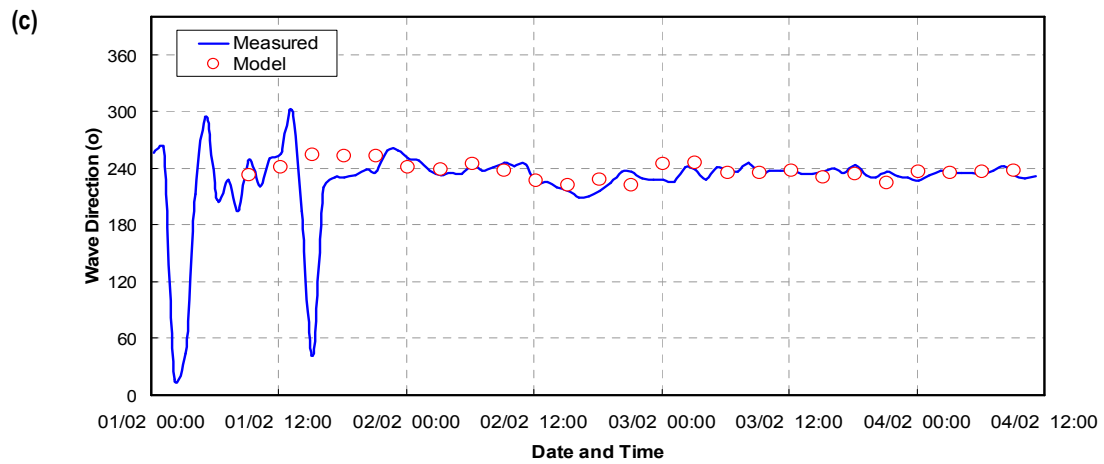
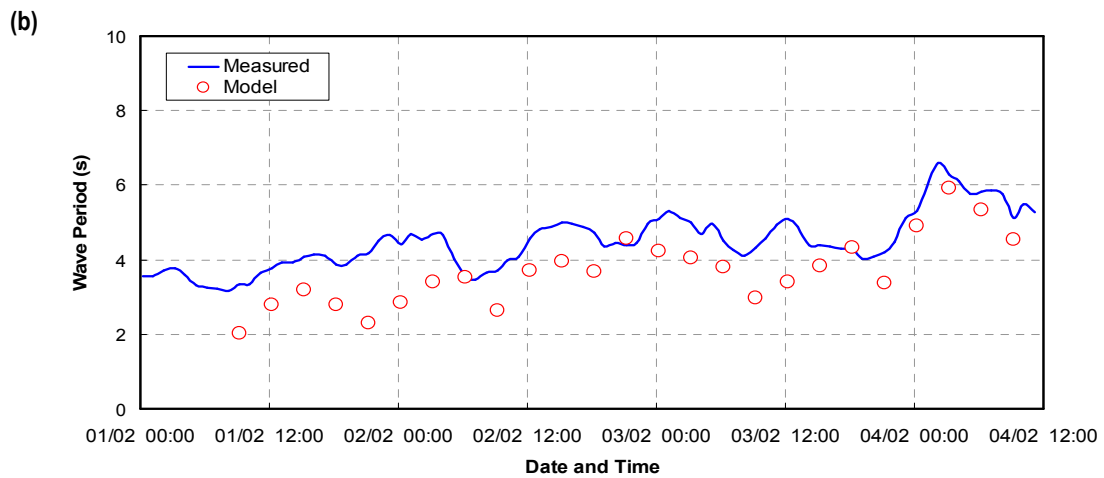
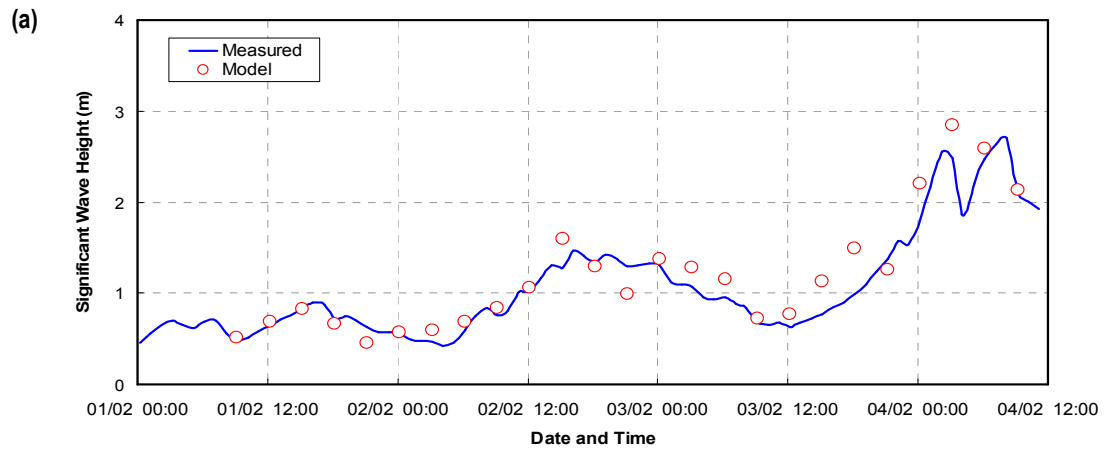
— Model
+ Calib data

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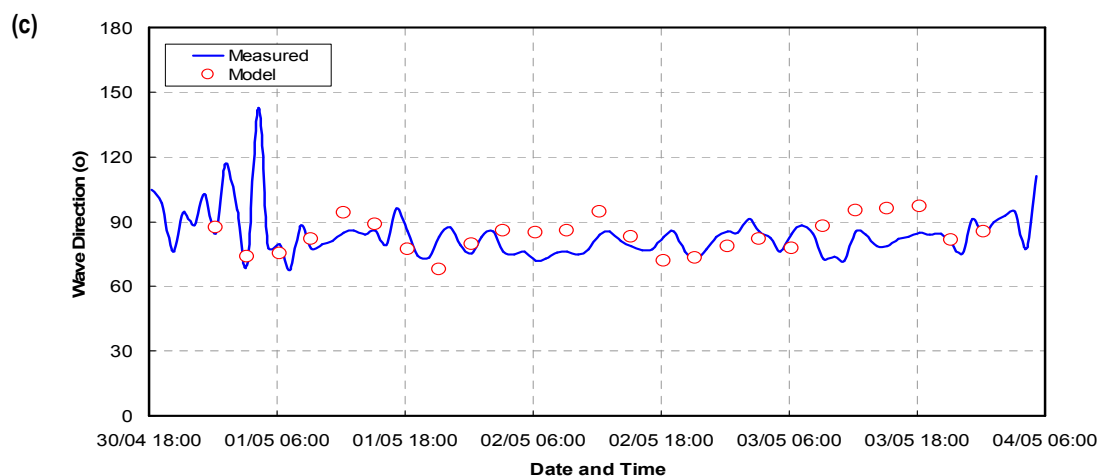
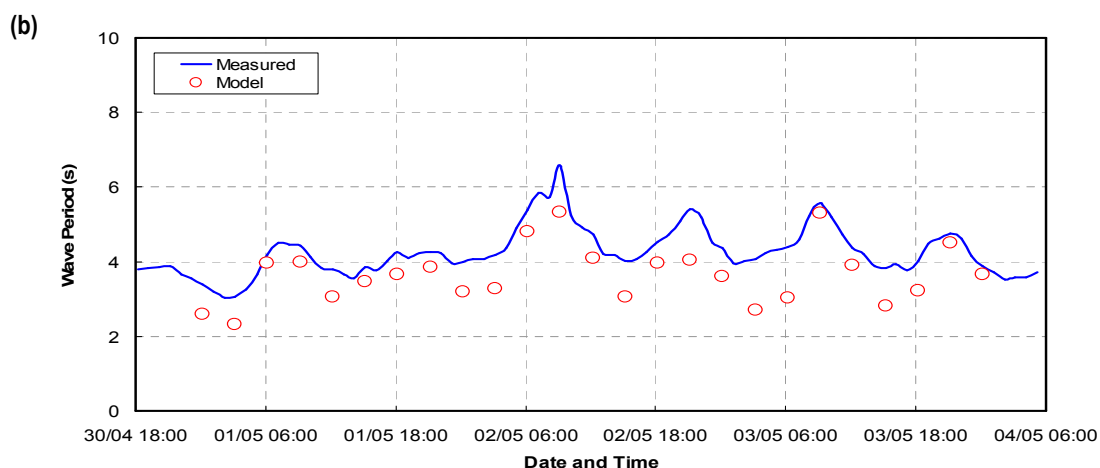
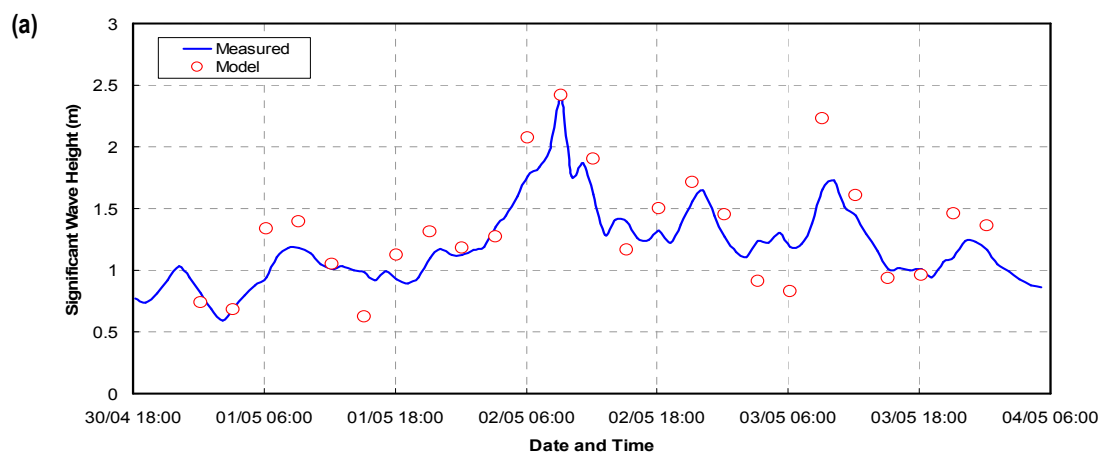
Current Speed and Direction Validation at AWAC L3 for (a) Spring Tide and (b) Neap Tide

Figure A23



	Date	By	Size	Version
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	Scale		n/a	
	QA		REW	
	Calibration_Report_Figures.xls			
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— Measured
○ Model



Date	By	Size	Version
Feb 12	ALB	A4	1
Projection		n/a	
Scale		n/a	
QA		REW	
Calibration_Report_Figures.xls			
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— Measured
○ Model

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(a) Wave Height (b) Wave Period and (c) Wave Direction
Validation at AWAC L3 - Event 2 (NE waves)

Figure A25

Appendix B

Scour Assessment Report



Appendix B. Scour Assessment Report

B1. Introduction

Water movements in the marine environment (by currents or wave action, either alone or in combination) will interact with obstacles such as wind farm turbine foundations. These interactions modify the flow, typically resulting in localised patterns of flow acceleration and/or an increase in turbulence. Such effects can lead to a corresponding (relative) increase in sediment transport potential in the affected areas, which ultimately results in the scouring (net removal) of sediments and the development of a scour pit.

The following assessment provides a conservative estimate of the dimensions of scour pits that might potentially develop around unprotected foundations of the type and dimensions proposed for the Rampion Wind Farm. The methods and assumptions used are considered suitable for the purposes of EIA (estimation of area of effect and volumes of sediment mobilised) but are not intended for use in detailed engineering design.

Where it does develop, scour will result in a morphological change (local development of seabed slopes) but will not necessarily change the sediment character in the affected area.

Should scour protection be installed, development of the local scour described in this section will be inhibited; however, the scour protection materials are more likely to represent a modification to the normally present seabed character. The area of seabed directly affected by scour protection is likely to be similar to the area potentially affected by scour and can be estimated on this basis for the purposes of EIA. Depending on the materials used, scour protection may also interact with any flows present, potentially causing 'secondary' scouring of the surrounding sediments. The depth of secondary scour is not easily predicted but is typically of a much smaller magnitude than primary scour (in proportion to the dimensions of the obstacle) and so is not considered further in this section.

B2. Impact Assessment

B2.1 Scour Depth

For the purposes of this assessment, the character sedimentary environment across the part of the site where turbines will be installed is summarised as: a thin (2 m thick or less) veneer of relatively frequently mobile sandy gravels, underlain by various types of erosion resistant bedrock and/or alluvium.

These features of the sedimentary environment lead to the following general limitations on the equilibrium maximum depth of local scour development (S_e):

- Scour is only likely to occur where the relatively less erosion resistant marine sediments (sands) are present in measurable thicknesses. Scour is therefore unlikely to occur at all in areas where the underlying erosion resistant rocks already outcrop at the surface;

- Irrespective of other contributing factors, the depth of scour development around all foundation types will be generally limited to the thickness of the marine sediment veneer locally (i.e. S_e will be 2 m or less at all turbines); and,
- Where the bed is prepared (the sediment veneer is removed) prior to installation of a foundation, the reported scour dimensions represent the maximum extent to which the bed might naturally recover with time, prior to decommissioning.

Standard relationships (e.g. those provided in Whitehouse, 1998) used to estimate S_e typically result in values greater than 2 m for the foundations being considered in the present study. In the absence of group scour (see below), S_e is directly estimated as 2 m for all sizes of monopile, GBS and suction caisson foundation types.

Group or dishpan scour (a wider extent of continuous scour, upon which local scour is superimposed) can also occur in association with the multi-member (jacket, twisted jacket and tripod) foundation types. The depth of group scour can be estimated as $0.4 D$ (Whitehouse, 1998). Group scour is accounted for as a reduction the thickness of the local sediment veneer (from the maximum value of 2 m) prior to the calculation of local scour pit dimensions. The maximum total depth of group + local scour is 2 m.

Interaction between individual members of a densely organised multi-member structure might affect the predicted depth or extent of local scour; however, the typically result is a less conservative estimate of local scour pit dimensions (Whitehouse, 1998) and so this factor is not considered further here.

In practice, the presence of a significant proportion of gravel in the seabed sediments will also tend to produce an erosion resistant, gravel lag layer at the seabed surface as finer sediments are winnowed away during the scouring process. This could potentially limit the maximum depth of scour to less than 2 m. This is a less conservative assumption and so is not considered further here.

B2.2 Scour Extent, Area and Volume

The flow modifications causing scour are typically greatest in magnitude immediately adjacent to the obstacle, decreasing rapidly with horizontal distance to ambient conditions within approximately 0.5 times the obstacle diameter (D) (Whitehouse, 1998).

The scour extent (S_{extent}) is defined as the radial distance from the point of maximum scour depth to the edge of the scour pit (where the bed level is again equal to the mean ambient or original seabed level). The horizontal extent of the resulting scour pit in uniformly erodible sediments is greater than the area directly affected by flow modification, as sediment surrounding the pit is destabilized until it is eroded to maintain a stable slope angle between the base of the scour pit and the surrounding bed level (approximately 32° from horizontal for sandy sediments (Soulsby, 1997)).

In a situation such as the Rampion site where the maximum equilibrium scour depth is limited by the underlying geology, the extent of the resulting scour pit will be limited also. For the purposes of providing a realistic yet conservative estimate of scour extent, it is assumed that all sediment will be eroded to the maximum depth (2 m) in the area of modified flow (up to $0.5 D$ from the edge of the structure) and that a stable slope is developed from the edge of this area to the ambient bed level. S_{extent} is therefore estimated as follows:

$$S_{\text{extent}} = 0.5D + \frac{S_e}{\tan 32^\circ} \approx 0.5D + (S_e \times 1.6) \quad (\text{Eq. B1})$$

For the maximum predicted value of S_e at the site (2 m), the associated value of S_{extent} is therefore 0.5 D + 3.2 m. The resulting values of S_{extent} are summarised in Table B1.

The extent of group scour from the outer perimeter of the foundation is estimated (on the basis of schematic images in Whitehouse, 1998) to be approximately half the structure base length scale.

The scour footprint ($S_{\text{footprint}}$) is defined as the area of seabed affected by scour, but excluding the footprint of the foundation, i.e.:

$$S_{\text{footprint}} = \pi \left(\frac{S_{\text{extent}}}{2} \right)^2 - \pi \left(\frac{D}{2} \right)^2 \quad (\text{Eq. B2})$$

Where D is the diameter of a circular foundation (or member). The value of $S_{\text{footprint}}$ for a multi-member foundation (e.g. jacket, twisted jacket and tripod) is calculated for each individual member at the seabed and summated to estimate the total area for the foundation in Table #.

The scour pit volume is calculated as that of an inverted truncated cone described by Equations 1 and 2 above, accounting for the presence of the foundation but excluding its volume.

The total cumulative area of seabed affected by scour from all foundations in an array is also shown in Table B2. Values are also conservatively presented as a proportion of the area of seabed in the part of the site where turbines are planned to be deployed (167 km²). It should be noted that this is less than the total area of the whole wind farm license (271 km²), for which the equivalent values would be approximately 40% smaller.

B3. Summary

Scour depth at each turbine is likely to be inherently limited to the thickness of the locally present marine sands (up to 2 m) by the presence of relatively erosion resistant underlying soils. This assumption also leads to a corresponding limitation on the likely extent, area and volume of seabed affected by scour pits.

Individual scour pits will be generally characterised as a local modification to bathymetry (typically a depression) around the foundation base with associated sloping sides. The texture of the seabed surface in the pit will likely be a mixture of exposed bedrock and/or sediment with a greater proportion of coarser material than previously present. The actual nature and proportion of each will depend on the thickness and particle size distribution of the marine sediments present locally. Scour pit dimensions might be smaller than predicted in those parts of the site where a significant proportion of gravel is present in the marine sediments, due to the development of a gravel lag layer which may armour the pit surface as finer sediment is winnowed away.

Tables B1 and B2 show that the dimensions of individual scour pit features are predicted to be relatively smaller than the scale of the associated foundations. As such, individual scour pits are

considered unlikely to coalesce between foundations and possibly even also between individual members of some larger multi-member foundations. Long scour tails extending from any local scour pits have been observed at Scroby Sands wind farm, created by tidal asymmetry and associated with very rectilinear tidal current patterns. Because tidal currents rotate (around 30 °) during each half tidal cycle at the Rampion Wind Farm site, there is considered to be very little likelihood of this occurring in this location.

Cumulatively, scour pits will affect only a small proportion of the seabed area in the vicinity of the turbine array (typically <0.15% for slender member foundation types and <0.3% for GBS and suction caisson foundations).

Table B1. Estimated scour pit dimensions at the Rampion Wind Farm

Parameter	Structure											
	Monopile		Jacket		Twisted Jacket		Tripod		Gravity Base		Suction Caisson	
	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest
Equilibrium Scour Depth (m)												
Local	2.0	2.0	1.1	1.1	1.4	1.2	0.8	0.8	2.0	2.0	2.0	2.0
Group			0.9	0.9	0.9	1.1	1.2	1.2				
Scour extent from footprint** (m)	5.5	6.2	2.9	2.9	3.0	2.9	2.8	2.8	15.2	20.0	15.7	20.7
Scour footprint** (m ²)												
Local (exec. structure)	170	238	187	187	172	183	151	151	1,872	3,350	2,008	3,622
Group (exec. structure)	-	-	573	1,190	1,005	2,028	595	595	-	-	-	-
Structure alone	15.9	28.3	16.6	16.6	8.7	14.3	21.2	21.2	452.4	881.4	490.9	962.1
Scour volume** (m ³)												
Local (exec. structure)	218	322	128	723	132	183	86	86	3,229	5,994	3,480	6,509
Group (exec. structure)	-	-	527	622	591	2,028	713	713	-	-	-	-
Total (exec. structure)	218	322	655	1,345	723	2,211	799	799	3,229	5,994	3,480	6,509
Bed prep. volume (m ³)	668	1,470	565	622	622	1,247	657	848	905	1,763	2,945	6,735
* Bed prep volume negligible if corner piles are inserted without drilling. ** Based upon the local scour for steady currents. Footprint and volume values per foundation.												

Table B2. Total estimated foundation and scour pit footprint at the Rampion Wind Farm

Parameter	Structure											
	Monopile		Jacket		Twisted Jacket		Tripod		Gravity Base		Suction Caisson	
	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest	Smallest	Largest
Number of foundations	175	100	175	100	175	100	175	100	175	100	175	100
Seabed footprint of all foundations (m ²)	2,783	2,827	2,908	1,662	1,518	1,433	3,711	2,121	79,168	88,141	85,903	96,211
Proportion of total site area (%)	0.002	0.002	0.002	0.001	0.001	0.001	0.002	0.001	0.047	0.053	0.051	0.058
Seabed footprint of local scour (m ²)	29,819	23,767	32,778	18,730	30,086	18,272	26,506	15,146	327,600	335,012	351,324	362,239
Proportion of total site area (%)	0.018	0.014	0.020	0.011	0.018	0.011	0.011	0.009	0.196	0.201	0.210	0.217
Seabed footprint of group scour (m ²)	-	-	100,280	119,026	175,855	202,800	104,046	59,455	-	-	-	-
Proportion of total site area (%)			0.060	0.071	0.105	0.121	0.062	0.036				
Seabed footprint of all foundations and scour (m ²)	32,602	26,594	103,188	120,687	177,372	204,233	107,757	61,575	406,768	423,153	437,227	458,450
Proportion of total site area (%)	0.020	0.016	0.062	0.072	0.106	0.122	0.065	0.037	0.244	0.253	0.262	0.275

Appendix C

Quantification of Potential Changes to the Wave Regime



Appendix C. Quantification of Potential Changes to the Wave Regime

Table C1. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario A (SSE), High Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field (array)							
15	10 in 1	1.20	146	3.7	-0.05 (-4%)	2 (2%)	-0.1 (-2%)
	1 in 1	2.47	149	5.0	-0.06 (-2%)	1 (1%)	0.0 (-1%)
	1 in 10	3.26	150	5.7	-0.06 (-2%)	1 (1%)	0.0 (-1%)
16	10 in 1	1.18	146	3.6	-0.06 (-5%)	1 (0%)	-0.1 (-2%)
	1 in 1	2.43	149	4.9	-0.06 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	3.20	150	5.6	-0.07 (-2%)	1 (0%)	-0.1 (-1%)
18	10 in 1	1.22	146	3.7	-0.02 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	2.47	149	5.0	-0.04 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	3.25	150	5.7	-0.06 (-2%)	0 (0%)	0.0 (-1%)
Mid-field (between array and coast)							
12	10 in 1	1.19	148	3.6	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	2.40	151	4.9	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	3.12	153	5.5	-0.02 (-1%)	0 (0%)	0.0 (0%)
13	10 in 1	1.16	147	3.6	-0.02 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	2.35	150	4.9	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.05	151	5.5	-0.03 (-1%)	0 (0%)	0.0 (-1%)
14	10 in 1	1.18	149	3.6	-0.02 (-2%)	1 (1%)	0.0 (-1%)
	1 in 1	2.35	151	4.9	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.05	152	5.5	-0.02 (-1%)	1 (0%)	0.0 (0%)
Far-field (coastal)							
3	10 in 1	1.18	157	3.4	-0.01 (-1%)	1 (0%)	0.0 (0%)
	1 in 1	2.20	158	4.7	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.78	158	5.4	-0.01 (0%)	0 (0%)	0.0 (0%)
4	10 in 1	1.09	153	3.4	-0.01 (-1%)	1 (0%)	0.0 (-1%)
	1 in 1	2.10	157	4.7	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	2.72	159	5.4	-0.02 (-1%)	0 (0%)	0.0 (0%)
6	10 in 1	1.09	151	3.4	-0.01 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	2.08	152	4.7	-0.01 (0%)	0 (0%)	0.0 (-1%)
	1 in 10	2.66	153	5.4	-0.02 (-1%)	0 (0%)	0.0 (-1%)
7	10 in 1	1.13	149	3.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	2.19	153	4.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.82	155	5.4	-0.01 (0%)	0 (0%)	0.0 (0%)
Hs	Significant Wave Height						
Dir	Mean Wave Direction						
Tm	Mean Absolute Wave Period						
*	The location of the observations points within this table are displayed on Figure 3.						

Table C2. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario A (SSE), Low Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field (array)							
15	10 in 1	1.24	157	3.7	-0.05 (-4%)	2 (1%)	-0.1 (-3%)
	1 in 1	2.43	156	5.0	-0.04 (-2%)	1 (1%)	0.0 (0%)
	1 in 10	3.18	156	5.6	-0.04 (-1%)	1 (0%)	0.0 (0%)
16	10 in 1	1.24	158	3.7	-0.06 (-5%)	0 (0%)	-0.1 (-3%)
	1 in 1	2.44	157	5.0	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	3.17	157	5.6	-0.07 (-2%)	0 (0%)	0.0 (-1%)
18	10 in 1	1.20	159	3.6	-0.03 (-2%)	-1 (0%)	-0.1 (-2%)
	1 in 1	2.40	158	4.9	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.15	158	5.5	-0.05 (-2%)	0 (0%)	0.0 (-1%)
Mid-field (between array and coast)							
12	10 in 1	1.20	160	3.6	-0.02 (-1%)	-2 (-1%)	-0.1 (-2%)
	1 in 1	2.32	160	4.9	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	2.97	161	5.5	-0.03 (-1%)	0 (0%)	0.0 (-1%)
13	10 in 1	1.22	157	3.6	-0.03 (-2%)	0 (0%)	-0.1 (-2%)
	1 in 1	2.30	157	4.9	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	2.93	157	5.5	-0.02 (-1%)	0 (0%)	0.0 (-1%)
14	10 in 1	1.19	156	3.6	-0.02 (-2%)	0 (0%)	-0.1 (-2%)
	1 in 1	2.24	157	4.9	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.89	158	5.6	-0.01 (0%)	0 (0%)	0.0 (0%)
Far-field (coastal)							
3	10 in 1	0.98	156	3.2	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	1.59	161	4.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	1.66	162	5.1	0.00 (0%)	0 (0%)	0.0 (0%)
4	10 in 1	0.91	165	3.2	0.00 (1%)	0 (0%)	0.0 (-1%)
	1 in 1	1.52	171	4.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	1.62	172	4.9	0.00 (0%)	0 (0%)	0.0 (0%)
6	10 in 1	0.97	155	3.3	0.01 (1%)	0 (0%)	0.0 (0%)
	1 in 1	1.39	157	4.8	0.00 (0%)	0 (0%)	0.0 (-1%)
	1 in 10	1.43	157	5.3	0.00 (0%)	0 (0%)	0.0 (0%)
7	10 in 1	1.05	161	3.4	-0.01 (-1%)	-1 (-1%)	-0.1 (-2%)
	1 in 1	1.85	163	4.6	-0.01 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	2.23	165	5.3	-0.01 (0%)	0 (0%)	0.0 (-1%)
Hs	Significant Wave Height						
Dir	Mean Wave Direction						
Tm	Mean Absolute Wave Period						
*	The location of the observations points within this table are displayed on Figure 3.						

Table C3. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario B (SSW), High Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.24	199	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.26	198	6.5	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.81	196	7.0	-0.01 (0%)	0 (0%)	0.0 (0%)
16	10 in 1	3.15	198	5.6	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.15	197	6.3	-0.06 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.67	195	6.8	-0.06 (-1%)	0 (0%)	0.0 (0%)
17	10 in 1	3.16	201	5.6	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.19	199	6.3	-0.08 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	4.73	198	6.8	-0.09 (-2%)	0 (0%)	0.0 (-1%)
18	10 in 1	3.18	202	5.6	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	4.26	202	6.4	-0.11 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.85	201	6.9	-0.12 (-2%)	0 (0%)	0.0 (-1%)
Mid-field (between array and coast)							
11	10 in 1	3.19	201	5.6	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	4.23	200	6.3	-0.05 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.76	198	6.8	-0.05 (-1%)	0 (0%)	0.0 (-1%)
12	10 in 1	3.07	199	5.5	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.99	197	6.2	-0.05 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.47	195	6.7	-0.05 (-1%)	0 (0%)	0.0 (-1%)
13	10 in 1	3.12	197	5.7	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	4.04	195	6.4	-0.02 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.49	193	6.9	-0.02 (0%)	0 (0%)	0.0 (0%)
Far-field							
5	10 in 1	2.93	195	6.0	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.38	191	6.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.46	188	7.2	0.00 (0%)	0 (0%)	0.0 (0%)
6	10 in 1	2.79	191	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.44	188	6.6	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.62	185	7.0	0.00 (0%)	0 (0%)	0.0 (0%)
8	10 in 1	2.93	196	5.5	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.80	194	6.2	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.20	192	6.7	-0.04 (-1%)	0 (0%)	0.0 (-1%)
9	10 in 1	3.08	199	5.6	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	4.03	197	6.3	-0.03 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.49	195	6.7	-0.04 (-1%)	0 (0%)	0.0 (0%)
Hs	Significant Wave Height						
Dir	Mean Wave Direction						
Tm	Mean Absolute Wave Period						
*	The location of the observations points within this table are displayed on Figure 3.						

Table C4. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario B (SSW), Low Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.29	201	5.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.33	199	6.6	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.93	198	7.1	0.06 (1%)	0 (0%)	0.0 (0%)
16	10 in 1	3.27	199	5.8	-0.06 (-2%)	0 (0%)	0.0 (0%)
	1 in 1	4.27	197	6.5	-0.06 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.83	196	7.0	0.00 (0%)	0 (0%)	0.0 (0%)
17	10 in 1	3.34	202	5.9	-0.06 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.37	200	6.6	-0.09 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.96	199	7.1	-0.02 (0%)	0 (0%)	-0.1 (-1%)
18	10 in 1	3.38	204	5.9	-0.09 (-3%)	-1 (0%)	-0.1 (-1%)
	1 in 1	4.42	203	6.6	-0.12 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	5.02	203	7.1	-0.05 (-1%)	0 (0%)	-0.1 (-1%)
Mid-field (between array and coast)							
11	10 in 1	3.30	202	5.8	-0.05 (-1%)	-1 (0%)	-0.1 (-1%)
	1 in 1	4.31	201	6.6	-0.06 (-1%)	-1 (0%)	-0.1 (-1%)
	1 in 10	4.87	200	7.0	0.01 (0%)	0 (0%)	-0.1 (-1%)
12	10 in 1	3.09	198	5.7	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.98	197	6.4	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.49	195	6.9	0.01 (0%)	0 (0%)	-0.1 (-1%)
13	10 in 1	3.10	195	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.99	193	6.6	-0.02 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.47	191	7.0	0.06 (1%)	0 (0%)	0.0 (0%)
Far-field							
5	10 in 1	1.28	175	4.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	1.30	169	4.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	1.31	167	4.9	0.00 (0%)	1 (0%)	0.0 (0%)
6	10 in 1	1.45	173	5.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	1.47	169	5.7	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	1.49	168	5.8	-0.01 (-1%)	1 (0%)	0.0 (0%)
8	10 in 1	2.74	194	5.6	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.42	193	6.4	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.65	192	6.8	0.01 (0%)	0 (0%)	0.0 (-1%)
9	10 in 1	3.10	197	5.8	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.97	195	6.5	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.44	194	6.9	0.05 (1%)	0 (0%)	0.0 (-1%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.							

Table C5. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario C (SW), High Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.23	218	5.9	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.15	216	6.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.57	215	6.8	0.00 (0%)	0 (0%)	0.0 (0%)
16	10 in 1	3.04	216	5.6	-0.05 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	3.94	213	6.2	-0.05 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.32	212	6.5	-0.05 (-1%)	0 (0%)	0.0 (0%)
17	10 in 1	3.10	219	5.6	-0.05 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	4.01	217	6.2	-0.07 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	4.39	216	6.5	-0.08 (-2%)	0 (0%)	0.0 (-1%)
18	10 in 1	3.02	221	5.5	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	3.92	218	6.1	-0.09 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.30	218	6.3	-0.11 (-3%)	0 (0%)	-0.1 (-1%)
Mid-field (between array and coast)							
13	10 in 1	3.01	219	5.5	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.89	216	6.1	-0.05 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.26	215	6.4	-0.06 (-1%)	0 (0%)	-0.1 (-1%)
14	10 in 1	2.94	215	5.5	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.77	212	6.1	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.13	212	6.4	-0.04 (-1%)	0 (0%)	0.0 (0%)
15	10 in 1	3.07	212	5.8	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.95	209	6.5	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.34	208	6.9	-0.01 (0%)	0 (0%)	0.0 (0%)
Far-field							
5	10 in 1	2.97	205	6.3	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.39	201	7.3	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.46	200	7.6	0.00 (0%)	0 (0%)	0.0 (0%)
6	10 in 1	2.82	202	6.1	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.44	197	6.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	3.60	195	7.3	0.00 (0%)	0 (0%)	0.0 (0%)
8	10 in 1	2.72	211	5.4	-0.02 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	3.46	208	6.0	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.77	207	6.3	-0.03 (-1%)	0 (0%)	0.0 (0%)
9	10 in 1	2.90	214	5.5	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.71	211	6.1	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.06	210	6.3	-0.03 (-1%)	0 (0%)	0.0 (-1%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.							

Table C6. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario C (SW), Low Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	3.20	217	5.7	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	4.15	214	6.5	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.59	213	6.9	0.00 (0%)	0 (0%)	0.0 (0%)
16	10 in 1	3.12	214	5.6	-0.06 (-2%)	0 (0%)	0.0 (0%)
	1 in 1	4.02	211	6.4	-0.05 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	4.41	209	6.7	-0.05 (-1%)	0 (0%)	0.0 (0%)
17	10 in 1	3.19	217	5.8	-0.05 (-2%)	0 (0%)	0.0 (-1%)
	1 in 1	4.14	214	6.5	-0.07 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	4.55	213	6.8	-0.08 (-2%)	0 (0%)	-0.1 (-1%)
18	10 in 1	3.25	221	5.8	-0.10 (-3%)	-1 (0%)	-0.1 (-1%)
	1 in 1	4.10	218	6.4	-0.13 (-3%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.49	217	6.6	-0.13 (-3%)	0 (0%)	-0.1 (-1%)
Mid-field (between array and coast)							
13	10 in 1	3.11	217	5.7	-0.05 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 1	3.97	215	6.3	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.32	213	6.6	-0.07 (-2%)	0 (0%)	-0.1 (-1%)
14	10 in 1	2.90	212	5.5	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.69	209	6.2	-0.04 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	4.04	208	6.5	-0.04 (-1%)	0 (0%)	0.0 (-1%)
15	10 in 1	2.95	207	5.6	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 1	3.84	204	6.5	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	4.24	202	6.9	-0.02 (0%)	0 (0%)	0.0 (0%)
Far-field							
5	10 in 1	1.28	185	4.2	0.00 (0%)	1 (0%)	0.1 (2%)
	1 in 1	1.29	179	4.1	0.00 (0%)	1 (1%)	0.1 (2%)
	1 in 10	1.29	177	4.1	0.00 (0%)	1 (1%)	0.1 (2%)
6	10 in 1	1.44	180	4.9	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	1.47	176	5.1	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	1.48	174	5.1	0.00 (0%)	0 (0%)	0.0 (0%)
8	10 in 1	2.48	206	5.2	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.14	202	6.0	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	3.40	201	6.3	-0.02 (-1%)	0 (0%)	-0.1 (-1%)
9	10 in 1	2.88	209	5.5	-0.03 (-1%)	0 (0%)	0.0 (-1%)
	1 in 1	3.68	206	6.2	-0.05 (-1%)	0 (0%)	-0.1 (-1%)
	1 in 10	4.01	204	6.5	-0.05 (-1%)	0 (0%)	-0.1 (-1%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.							

Table C7. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario D (WSW), High Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	1.59	229	4.6	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	2.08	230	5.0	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.32	229	5.3	0.00 (0%)	0 (0%)	0.0 (0%)
17	10 in 1	1.44	232	4.2	-0.04 (-3%)	1 (0%)	-0.1 (-1%)
	1 in 1	1.90	232	4.7	-0.04 (-2%)	1 (0%)	0.0 (-1%)
	1 in 10	2.13	231	4.9	-0.04 (-2%)	1 (0%)	0.0 (-1%)
Mid-field (between array and coast)							
12	10 in 1	1.38	228	4.1	-0.03 (-2%)	1 (0%)	0.0 (-1%)
	1 in 1	1.82	228	4.6	-0.03 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	2.03	227	4.8	-0.03 (-1%)	1 (0%)	0.0 (-1%)
13	10 in 1	1.50	223	4.5	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	1.96	223	5.0	-0.01 (0%)	0 (0%)	0.0 (0%)
	1 in 10	2.17	222	5.2	-0.01 (0%)	0 (0%)	0.0 (0%)
Far-field							
7	10 in 1	1.25	216	4.1	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 1	1.62	215	4.6	-0.01 (-1%)	0 (0%)	0.0 (0%)
	1 in 10	1.79	213	4.8	-0.01 (-1%)	0 (0%)	0.0 (0%)
8	10 in 1	1.28	223	4.0	-0.02 (-2%)	1 (0%)	0.0 (-1%)
	1 in 1	1.67	223	4.4	-0.02 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	1.85	222	4.7	-0.02 (-1%)	0 (0%)	0.0 (-1%)
9	10 in 1	1.32	228	4.0	-0.03 (-2%)	0 (0%)	-0.1 (-2%)
	1 in 1	1.73	228	4.4	-0.03 (-2%)	0 (0%)	0.0 (-1%)
	1 in 10	1.93	227	4.6	-0.02 (-1%)	0 (0%)	0.0 (-1%)
Hs	Significant Wave Height						
Dir	Mean Wave Direction						
Tm	Mean Absolute Wave Period						
*	The location of the observations points within this table are displayed on Figure 3.						

Table C8. Quantification of potential changes to the wave climate due to the Rampion Wind Farm: Scenario D (WSW), Low Water

Observation Point*	Return Period (yrs)	Baseline			Actual Difference Due to Scheme (and as %)		
		Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
Near-field							
15	10 in 1	1.78	227	4.8	0.00 (0%)	0 (0%)	0.0 (0%)
	1 in 1	2.21	227	5.1	0.00 (0%)	0 (0%)	0.0 (1%)
	1 in 10	2.44	226	5.4	-0.01 (-1%)	0 (0%)	0.1 (1%)
17	10 in 1	1.65	230	4.6	-0.04 (-2%)	0 (0%)	-0.1 (-3%)
	1 in 1	2.10	229	4.9	-0.05 (-2%)	1 (0%)	0.0 (-1%)
	1 in 10	2.34	228	5.2	-0.05 (-2%)	1 (0%)	0.0 (-1%)
Mid-field (between array and coast)							
12	10 in 1	1.49	222	4.3	-0.01 (-1%)	0 (0%)	-0.1 (-3%)
	1 in 1	1.90	222	4.6	-0.03 (-2%)	1 (0%)	0.0 (-1%)
	1 in 10	2.11	221	4.9	-0.03 (-2%)	1 (0%)	0.0 (-1%)
13	10 in 1	1.57	215	4.6	0.00 (0%)	0 (0%)	0.0 (-1%)
	1 in 1	1.96	215	5.0	-0.01 (-1%)	1 (0%)	0.0 (0%)
	1 in 10	2.19	213	5.3	-0.02 (-1%)	1 (0%)	0.0 (0%)
Far-field							
7	10 in 1	1.14	201	4.0	0.01 (1%)	0 (0%)	-0.1 (-3%)
	1 in 1	1.42	202	4.4	-0.01 (-1%)	0 (0%)	0.0 (-1%)
	1 in 10	1.58	200	4.7	-0.02 (-1%)	0 (0%)	0.0 (0%)
8	10 in 1	1.23	216	3.9	0.01 (0%)	1 (0%)	-0.1 (-3%)
	1 in 1	1.57	216	4.3	-0.02 (-1%)	0 (0%)	-0.1 (-1%)
	1 in 10	1.74	215	4.5	-0.03 (-1%)	0 (0%)	-0.1 (-1%)
9	10 in 1	1.40	223	4.1	-0.02 (-1%)	0 (0%)	-0.1 (-3%)
	1 in 1	1.81	223	4.5	-0.03 (-2%)	0 (0%)	-0.1 (-2%)
	1 in 10	2.00	221	4.7	-0.05 (-2%)	0 (0%)	-0.1 (-2%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.							

Table C9. Quantification of potential changes to the swell regime due to the Rampion Wind Farm, High Water

Observation Point*	Baseline			Actual Difference Due to Scheme (and as %)		
	Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
1	1.80	217	10.6	0.00 (0%)	0 (0%)	0.0 (0%)
2	1.72	199	10.5	0.00 (0%)	0 (0%)	0.0 (0%)
3	1.27	204	10.0	0.00 (0%)	0 (0%)	0.0 (0%)
4	1.06	205	10.1	0.00 (0%)	0 (0%)	0.0 (0%)
5	1.29	203	10.1	0.00 (0%)	0 (0%)	0.0 (0%)
6	1.07	200	9.7	0.00 (0%)	0 (0%)	0.0 (0%)
7	0.73	205	9.4	0.00 (0%)	0 (0%)	0.0 (0%)
8	0.63	216	9.0	-0.01 (-1%)	0 (0%)	0.0 (0%)
9	0.59	222	8.5	-0.02 (-4%)	0 (0%)	0.0 (0%)
10	0.46	227	8.9	0.00 (-1%)	0 (0%)	0.0 (0%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.						

Table C10. Quantification of potential changes to the swell regime due to the Rampion Wind Farm, Low Water

Observation Point*	Baseline			Actual Difference Due to Scheme (and as %)		
	Hs (m)	Dir (°N)	Tm (s)	Hs (m)	Dir (°N)	Tm (s)
1	1.43	213	9.0	-0.01 (0%)	0 (0%)	0.0 (0%)
2	1.03	183	9.9	0.00 (0%)	0 (0%)	0.0 (0%)
3	0.88	196	9.7	0.00 (0%)	0 (0%)	0.0 (0%)
4	0.86	201	9.9	0.00 (0%)	0 (0%)	0.0 (0%)
5	1.21	189	10.4	0.00 (0%)	0 (0%)	0.0 (0%)
6	1.12	186	9.7	0.00 (0%)	0 (0%)	0.0 (0%)
7	0.89	199	9.5	0.00 (0%)	0 (0%)	0.0 (0%)
8	0.83	214	8.9	-0.01 (-1%)	0 (0%)	0.0 (0%)
9	0.96	220	8.3	-0.05 (-5%)	1 (0%)	-0.1 (-1%)
10	1.22	232	8.0	-0.04 (-3%)	0 (0%)	0.0 (0%)
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period * The location of the observations points within this table are displayed on Figure 3.						

Table C11. Quantification of potential changes (as percent) to the four specified surf scenarios due to the Rampion Wind Farm (High Water)

Surfing Location	Scenario 1 (S1)			Scenario 2 (S2)			Scenario 3 (S3)			Scenario 4 (S4)		
	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm
1 (Worthing)	0	0	0	1	0	-1	-1	0	1	0	0	-2
2 (Lancing Green)	0	0	0	0	0	-1	0	0	0	1	0	-1
3 (Shoreham Harbour)	0	0	0	0	0	-1	0	0	0	1	0	0
4 (Hot Pipe)	0	0	0	-1	0	-1	0	0	0	1	0	-1
5 (West Pier)	0	0	0	-2	0	-1	0	0	0	1	0	-2
6 (Brighton Pier)	0	0	0	-1	0	-1	0	0	0	1	0	-3
7 (Brighton Marina)	0	0	0	-2	0	-1	-1	0	0	0	0	-4
8 (Rottingdean)	-1	0	0	-2	0	-1	-1	0	0	0	0	-4
9 (Telscombe Cliffs)	-4	0	0	-1	0	-2	-1	0	0	0	0	-4
10 (Tide Mills, Seaford)	-1	0	0	-2	0	-2	-2	0	-1	0	0	-4
11 (Birling Gap)	0	0	0	-1	0	-2	-1	0	0	1	0	-3
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period												

Table C12. Quantification of potential changes (as percent) to the four specified surf scenarios due to the Rampion Wind Farm (Low Water)

Surfing Location	Scenario 1 (S1)			Scenario 2 (S2)			Scenario 3 (S3)			Scenario 4 (S4)		
	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm	Hs	Dir	Tm
1 (Worthing)	0	0	0	-1	0	0	-1	0	1	-1	1	5
2 (Lancing Green)	0	0	0	0	0	0	0	0	0	0	0	7
3 (Shoreham Harbour)	0	0	0	0	0	0	0	0	0	-2	0	2
4 (Hot Pipe)	0	0	0	-1	0	0	0	0	0	-1	0	1
5 (West Pier)	0	0	0	-1	0	-1	-1	0	0	-2	0	2
6 (Brighton Pier)	0	0	0	-1	0	-1	0	0	0	-3	0	2
7 (Brighton Marina)	0	0	0	0	0	-1	-1	0	-1	-3	0	1
8 (Rottingdean)	-1	0	0	-1	0	-1	-1	0	-1	-3	0	0
9 (Telscombe Cliffs)	-5	0	-1	-1	0	-1	-1	0	-1	-3	0	-1
10 (Tide Mills, Seaford)	-3	0	0	-2	0	-1	-2	0	-2	-3	0	0
11 (Birling Gap)	0	0	0	-1	0	-1	0	0	0	-1	0	2
Hs Significant Wave Height Dir Mean Wave Direction Tm Mean Absolute Wave Period												



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