6 Physical Environment

6.1 Hydrodynamics (Wave Climate and Tidal Regime)

6.1.1.1 This chapter provides an assessment of the likely significant effects on the hydrodynamics of the three proposed wind farm sites and their regional setting. A more detailed description may be found in Technical Appendix 3.4 A (Metocean and Coastal Processes, ABPmer, 2012a).

6.1.1.2 This assessment is informed by the following baseline chapters:

- Chapter 3.1 (Bathymetry);
- Chapter 3.2 (Geology);
- Chapter 3.3 (Wind Climate);
- Chapter 3.4 (Hydrodynamics); and
- Chapter 3.5 (Sedimentary and Coastal Processes).

6.1.1.3 This impact assessment is also used to inform the following assessments:

- Chapter 6.2, 9.2 and 13.2 (Sedimentary and Coastal Processes);
- Chapter 7.1, 10.1 and 14.1 (Benthic Ecology);
- Chapter 7.2, 10.2 and 14.2 (Fish and Shellfish Ecology);
- Chapter 8.5, 11.5 and 15.5 (Archaeology and Visual Receptors); and
- Chapter 9.1 and 13.1 (Hydrodynamics: Wave Climate and Tidal Regime).

6.1.1.4 This chapter comprises the following:

- EIA Methodology;
- Primary Impact Assessment;
- Monitoring and Mitigation;
- Secondary Impact Assessment;
- Monitoring and Mitigation; and
- Residual Effects.

6.1.2 *Summary of Effects and Mitigation*

Summary of Effects

6.1.2.1 The effects on hydrodynamic receptors that were assessed for the three proposed wind farm sites include:

- Changes to the tidal regime due to the presence of the turbine foundations; and
- Changes to the wave regime due to the presence of the turbine foundations.

6.1.2.2 The following receptors are considered in this assessment:

- Smith Bank;
- Designated Coastal Habitats;
- Stratification Fronts; and
- Recreational surfing venues.

6.1.2.3 Table 6.1-1 below summarises the physical process receptors within the study area (Figure 3.1-1, Volume 6 a).

Table 6.1-1 Physical Processes Receptors Identified Within the Study Area

Receptor	Designation	Morphological Description
Smith Bank	(None)	A submerged bathymetric high in the Outer Moray Firth, covered by a veneer of sands and gravels of variable thickness and proportion.
Loch of Strathbeg	SPA and Ramsar	Marshes, reedbeds, grassland and dunes.
Troup, Pennan and Lion's Heads	SPA	Sea-cliffs, occasionally punctuated small sand or shingle beaches.
The Moray and Nairn Coast	SPA and Ramsar	Intertidal flats, saltmarsh and sand dunes.
The Inner Moray Firth	SPA and Ramsar	Extensive intertidal flats and smaller areas of saltmarsh.
Cromarty Firth	SPA and Ramsar	Extensive intertidal flats and salt marsh.
The Dornoch Firth	SPA and Ramsar	Large estuary containing extensive sand-flats and mud-flats, backed by saltmarsh and sand dunes.
The East Caithness Cliffs	SPA	Old Red Sandstone cliffs, generally between 30 to 60 m high, rising to 150 m at Berriedale.
The Inner Moray Firth	SAC	Sandbanks, intertidal mud flats and saltmarsh.
Dornoch Firth	SAC	Extensive areas of mudflats and sandflats. Sub-tidally, the Firth supports rich biogenic reefs.
Berriedale and Langwell, Oykel, Morriston and Spey	SACs	(Riverine systems emptying into the Moray Firth)
Culbin Bar	SAC	Extensive dunes, vegetated shingle and salt meadows.

Receptor	Designation	Morphological Description
Frontal Systems	(Tidal front)	Vertical stratification front
Skirza	(Surf beach)	Sand beach (with particular wave climate).
Freswick Bay	(Surf beach)	Sand beach (with particular wave climate).
Keiss	(Surf beach)	Sand / shingle beach (with particular wave climate).
Sinclair's Bay	(Surf beach)	Sand / shingle beach (with particular wave climate).
Ackergill	(Surf beach)	Sand / shingle beach (with particular wave climate).
Lossiemouth	(Surf beach)	Sand beach (with particular wave climate).
Spey Bay	(Surf beach)	Sand / shingle beach (with particular wave climate).
Cullen	(Surf beach)	Sand / shingle beach (with particular wave climate).
Sunnyside Bay	(Surf beach)	Rocky beach (with particular wave climate).
Sandend Bay	(Surf beach)	Sand beach (with particular wave climate).
Boyndie Bay	(Surf beach)	Sand / Shingle beach (with particular wave climate).
Banff Beach	(Surf beach)	Sand beach (with particular wave climate).
Pennan	(Surf beach)	Rocky beach (with particular wave climate).
Widemans	(Surf beach)	Sand / shingle beach (with particular wave climate).
Phingask	(Surf beach)	Sand / shingle beach (with particular wave climate).
West Point	(Surf beach)	Sand / shingle beach (with particular wave climate).
Fraserburgh	(Surf beach)	Sand beach (with particular wave climate).
St Combs to Inverallochy	(Surf beach)	Sand beach (with particular wave climate).

Proposed Mitigation Measures and Residual Effects

6.1.2.4 No mitigation measures are proposed.

6.1.3 Residual Impacts – Primary Impact Assessment

6.1.3.1 Table 6.1-2 below summarises the results of the primary impact assessment.

Table 6.1-2 Primary Impact Assessment Summary

Effect	Receptor	Pre–Mitigation Effect	Mitigation	Post–Mitigation Effect
Construction				
(Partial effects only)	As 'Operation'	Negligible Significance	None	Negligible Significance
Operation				
Changes to the Tidal	Smith Bank	Negligible Significance	None	Negligible Significance

Effect	Receptor	Pre–Mitigation Effect	Mitigation	Post–Mitigation Effect
Regime due to the presence of the Turbine Foundations	Designated Coastal Habitats	Negligible Significance	None	Negligible Significance
	Stratification Fronts	Negligible Significance	None	Negligible Significance
Changes to the Wave regime due to the Presence of the turbine foundations	Smith Bank	Negligible Significance	None	Negligible Significance
	Designated Coastal Habitats	Negligible Significance	None	Negligible Significance
	Recreational Surfing Venues	Negligible Significance	None	Negligible Significance
Decommissioning				
(Partial Effects Only)	As 'Operation'	Negligible Significance	None	Negligible Significance

6.1.4 Introduction

6.1.4.1 This chapter describes the likely significant effect of the Telford, Stevenson and MacColl wind farm sites on water levels, currents and waves, as physical processes in the marine environment. Consequential and other direct effects on sediment transport and geomorphology are considered in Chapter 6.2 (Sedimentary and Coastal Processes).

6.1.4.2 The baseline wave and tidal conditions are described in Chapter 3.4 of this document and Technical Appendix 3.4 A (Metocean and Coastal Processes ABPmer, 2012a).

6.1.4.3 More details regarding the design, calibration and validation of the numerical models used to inform the assessments in this chapter may be found in Technical Appendix 3.4 B (ABPmer, 2012b).

6.1.4.4 More details regarding the impact assessment methods used, results obtained and reported in this chapter may be found in Technical Appendix 3.4 C (ABPmer, 2012c).

6.1.5 Rochdale Envelope Parameters Considered in the Assessment

6.1.5.1 The range of Project characteristics adopted within this physical process assessment, as detailed in the supporting Technical Appendix, are summarised in Table 6.1-3 below. The parameters set out below define the 'Rochdale Envelope' realistic worst case scenario for each likely significant effect on the physical hydrodynamic environment. These are drawn from a range of development options set in Chapter 2.2 (Project Description). A maximum of one site (Telford, Stevenson or MacColl) will comprise 3.6 MW turbines with the other two sites comprising 5 MW machines as a minimum rating.

Table 6.1-3 Rochdale Envelope Parameter Relevant to the Hydrodynamics Impact Assessment

Type of Effect	Rochdale Envelope Scenario Assessed
Construction & Decommissioning	
None	N / A
Operation	
Changes to the Tidal Regime due to the Presence of the Turbine Foundations*	1*) Gravity Base Structure (GBS), or 2*) Jacket foundations.
Changes to the Wave Regime due to the Presence of the Turbine Foundations*	3.6 MW (site 1**) and 5 MW (sites 2&3***) layouts;
* (1) refers to the characteristics identified as absolute worst case; (2) refers to the characteristics identified as a realistic probable case ** Either Telford, Stevenson or MacColl *** The two other sites (Telford, Stevenson or MacColl)	

6.1.6 EIA Methodology

6.1.6.1 The assessment of likely significant effects on hydrodynamics has been informed by the results of site and operation specific numerical modelling, desktop assessment and with reference to the existing evidence base regarding effects of offshore wind farm development. Issues have been identified and assessed in accordance with the guidance provided in this respect by Cefas (2004, 2011) and EMEC & Xodus AURORA (2010).

6.1.6.2 The significance of the likely effects on the identified receptors is assessed using the following method and terminology.

6.1.6.3 Firstly, the magnitude of any impact is quantified to the extent practicable, considering all the dimensions of the predicted effect including:

- The nature of the change (i.e. what resources or receptors are affected and the size, scale or intensity of any changes);
- The spatial extent or proportion of the area impacted;
- The temporal extent of the impacts (i.e. duration, frequency, reversibility); and
- Where relevant, the probability of the impact occurring as a result of accidental or unplanned events.

6.1.6.4 The magnitude of the impact is considered as negligible, low, medium or high in relation to the following spatial and temporal scales.

6.1.6.5 Spatial Scales:

- Onsite – effects that are limited to the three proposed wind farm sites;
- Local – effects that are limited to the wind farm area and generally within the area of one tidal excursion (the distance travelled by water in and out of the EDA during one tidal cycle or a similar 'buffer' around the areas).
- Regional – effects that are experienced at a regional scale (e.g. the Moray Firth).

- National – effects that are experienced at a national scale; and
- Transboundary / International – effects that are experienced at an international scale i.e. affecting another country or international water.

6.1.6.6 Temporal Scales:

- Short term – effects that are predicted to last only for the duration of specific construction operations. e.g. noise for piling and plume dispersion;
- Medium term – effects that are predicted to last during the construction period (e.g. one to three years);
- Long term – effects that will continue beyond the construction period but will cease in time. (e.g. recovery of benthos, vessel movements);
- Temporary – effects that are predicted to be reversible and will return to a previous state when the impact ceases or after a period of recovery;
- Permanent – effects that cause a permanent change in the affected receptor or resource that endures substantially beyond the Project lifetime;
- Continuous – effects that occur continuously or frequently; and
- Intermittent – effects that are occasional or occur only under specific circumstances.

6.1.6.7 Secondly, the importance, value and / or sensitivity of the affected receptors or sites are estimated as low, medium of high. The sensitivity of the affected physical environment is evaluated in the context of the natural range of variability normally experienced in the parameter of interest. Further assignment of value or significance (e.g. to the consequential effect on ecological or socio–economic receptors) are provided by other topic assessments.

6.1.6.8 Thirdly, the significance of an effect of a given magnitude is determined on the basis of the magnitude and sensitivity as follows:

- Negligible significance – effects that are slight or transitory, and those that are within the range of natural environmental variability;
- Minor significance – effects of low magnitude and / or associated with low or medium value / sensitivity receptors or sites, or effects of medium magnitude affecting low value / sensitivity receptors or sites;
- Moderate significance – effects of low magnitude, affecting high value / sensitivity receptors or sites, or effects of medium magnitude affecting medium value / sensitivity receptors or sites, or effects of high magnitude affecting medium sensitivity receptors or sites; and
- Major significance – effects of high magnitude affecting high or medium value / sensitivity receptors or sites, or effects of medium magnitude affecting high value / sensitivity receptors or sites.

6.1.6.9 Effects of negligible or minor significance are not significant in terms of the EIA regulations.

6.1.6.10 Issues of concern relating to the construction, operation and decommissioning of the wind farms were previously considered in the initial Scoping Report (MORL, 2010) and Scoping Opinion response (Marine Scotland, 2011). In relation to the wave and tidal regimes, the following potential issues or effects were identified:

- Effects on the extent, distribution, function or structure of marine and coastal habitats (including those within Special Areas of Conservation (SACs) and Special Protected Areas (SPAs) , especially the East Caithness Cliffs SPA);
- Changes in the set and rate of the tidal stream with reference to MCA guidance MGN371;
- Changes to the potential for the development of vertical mixing fronts (oceanographic features in the outer Moray Firth); and
- Changes to the wave regime at recreational surfing venues.

6.1.6.11 The importance of considering cumulative / in–combination effects was noted by most consultees in relation to a wide range of issues.

6.1.7 Primary Impact Assessment: Three Proposed Wind Farm Sites

6.1.7.1 This assessment considers the likely significant effect of the three proposed wind farm sites in all three worst case scenario permutations of one 3.6 MW site (i.e. Telford, Stevenson or MacColl) plus two 5 MW sites. Assessment is made of the worst case foundation type and layout (the greatest number of Gravity Base Structure or GBS, foundations) but also for the most realistic alternative (the greatest number of jackets). Assessments are made both generally and more specifically on physical process receptors identified within the predicted areas of effect. Physical process receptors that are potentially sensitive to changes in the physical baseline environment are shown in Figure 3.4-6, Volume 6 a and may be grouped as follows:

- Smith Bank – a submerged bathymetric high in the Outer Moray Firth with a stable core of glacial tills covered by a veneer of sands and gravels of variable thickness and proportion. The form and function of the bank is relatively insensitive to changes in physical processes but is considered due to its proximity to the source of all effects from the wind farms;
- Designated sites – SPA, SAC, Sites of Special Scientific Interest (SSSI) and Ramsar sites within the Moray Firth. A full list of the sites considered and a summary of their morphological type may be found in Table 6.1-1 above. These receptors are variably potentially sensitive to local changes in tidal range, wave climate and sediment supply; and
- Recreational surfing venues – a full list of the sites considered and a summary of their baseline wave characteristics may be found in Technical Appendices 3.4 A and 3.4 B. These receptors are variably sensitive to local changes in tidal range and wave climate (Technical Appendix 3.4 A).

6.1.7.2 A change in tidal or wave regimes alone does not necessarily imply an effect, if there are no receptors present that are sensitive to the change. Consequential (indirect) impacts on sediment transport patterns and morphology are considered in Chapter 6.2 (Sedimentary and Coastal Processes).

6.1.7.3 Effects on these receptors are considered in relation to the construction, operation and decommissioning phases of the development in the following paragraphs.

Construction

6.1.7.4 The effect of all wind farm infrastructure once installed is considered in Paragraphs 6.1.7.6 to 6.1.7.36 (see 'Operation'). The effect of less than the total amount of infrastructure at an intermediate stage in the construction process is (proportionally) less than that reported for the operational phase of the development.

6.1.7.5 Therefore, these effects are not considered explicitly during the construction phase.

Operation

6.1.7.6 The following paragraphs consider the effect of the wind farms on the wave and tidal regimes during the operational phase of the development. Full details of this assessment may be found in Technical Appendix 3.4 C.

Changes to the Tidal Regime Due to the Presence of the Wind Farm Foundations

6.1.7.7 Changes to the tidal regime (water levels and currents) may arise from interaction of the tide with obstacles in the water column, in this case the wind turbine foundations. The effect of individual foundations is principally controlled by the foundation shape and dimensions. The effect of the array is additionally controlled by the total number of foundations and their spacing and layout relative to the tidal axis. A change in the tidal regime (instantaneous current speeds or directions within the range of natural variability) is not considered to constitute an effect as there are no physical process receptors directly sensitive to such changes. Consequential (indirect) effects on the sedimentary environment are considered in Chapter 6.2 (Sedimentary and Coastal Processes). Other consequential (indirect) effects are also considered elsewhere in this document, where relevant in other topic chapters within this Environmental Statement (ES): Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Sensitive Receptor: Smith Bank

6.1.7.8 Neither GBS (see Figure 6.1-1, Volume 6 a) nor jacket foundations will have a measurable effect on tidal water levels or tidal current directions. Given the similarity in processes, a similarly low magnitude of effect on non–tidal (surge) water levels is also inferred (Technical Appendix 3.4 C).

6.1.7.9 Jacket foundations will also not have any measurable effect (> 0.01 m/s) on tidal current speed.

6.1.7.10 GBS foundations will only have a (barely) measurable effect on tidal currents during spring tidal periods (see Figure 6.1-2, Volume 6 a), contained mainly within the wind farms extent but also extending up to 2 km beyond the WDA site boundary. The main effect is a phase shift, simply advancing the peak current in time by five to ten minutes. Away from individual foundations, the peak flow speed in the region of the wind farm may also be locally reduced by approximately 0.01 m / s (i.e. not a measurable effect).

6.1.7.11 These direct effects of the array will persist for the operational lifetime of the development but are of very low magnitude, are relatively localised and are temporary (reverting to the baseline condition during neap tidal conditions and at all times following decommissioning). The effects will not directly affect Smith Bank beyond the range of natural variability. As such the impact cannot be classed as either positive or negative.

6.1.7.12 A negligible magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Sensitive Receptor: Designated Coastal Habitats

6.1.7.13 No measurable effect on the tidal regime is predicted to occur further than 2 km outside of the extent of the three proposed wind farms in any configuration and will therefore not affect any of the identified designated coastal locations in the Moray Firth.

6.1.7.14 A negligible magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Sensitive Receptor: Stratification Fronts

6.1.7.15 No measurable effect on the tidal regime is predicted to occur further than 2 km outside of three proposed wind farms in any configuration. As frontal features are the product of regional fresh water / saline patterns (unaffected by the wind farms) and the tidal regime (water depth and current speed), there will be no consequential effect on the strength or location of stratification fronts.

6.1.7.16 A low magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Changes to the Wave Regime Due to the Presence of the Wind Farm Foundations

6.1.7.17 Changes to the wave regime (joint statistics of height, period and direction) may arise from interaction of the waves with obstacles in the water column, in this case the wind turbine foundations. The effect of individual foundations is principally controlled by the foundation shape and dimensions; the effect of the array is additionally controlled by the total number of foundations and their spacing and layout relative to the wave coming direction. Wave action varies greatly on timescales of seconds (for an individual wave) to hours (a storm event); the regime is also subject to seasonal, annual and decadal variability. A change in an individual wave or storm event, or in the wave regime within the range of natural variability on these timescales, is not considered to constitute an effect as there are no physical process receptors directly sensitive to such differences. Consequential (indirect) effects on the sedimentary environment are considered in Chapter 6.2 (Sedimentary and Coastal Processes). Other consequential (indirect) effects are also considered, where relevant, in other chapters.

Sensitive Receptor: Smith Bank

6.1.7.18 The following assessment of likely significant effects the wave regime is based upon the analysis of spatial results from the wave model, with and without the GBS and jacket schemes present, over a representative set of extreme wave conditions. A range of results for GBS foundations are shown in Figure 6.1-3 to Figure 6.1-10 in Volume 6 a. Wave conditions naturally vary from calm conditions to maximum wave heights of 4 to 9 m depending upon the return period and direction; further natural variability in the order of 10 % is also expected on the basis of historical trends and the generally predicted effects of climate change.

6.1.7.19 In relation to wave height and period, the assessment finds that for jackets:

- Jacket foundations do not measurably affect wave height or period. i.e. localised maximum differences in significant wave height are < 0.1 m (2 %) and in wave period are < 0.3 s (2 to 3 %). Values are even less in most locations elsewhere within the wind farms sites.

6.1.7.20 For GBS:

- The main effect of the GBS foundations is to reduce the height of waves passing through the three proposed wind farms;
- When all three sites are present in various tested configurations, the maximum reduction in wave height, within the site boundary, varies between 0.7 and 1.2 m or 12 to 19 % of the incident wave height (varying between 4 to 9 m) for all coming directions and return periods. The greatest absolute effects are on the largest waves that also pass through the long axis of three proposed wind farms (i.e. from 45 and 90°N). The highest proportional effects are on the largest and smallest waves (i.e. from 315 and 90°N); the smallest proportional effects are on waves from 270°N;
- The area of maximum effect within the wind farms in every case is relatively small (length scale of order 1 km) and is located where waves have transitioned through the greatest width of the wind farm developments from that coming direction.
- The effect gradually develops in proportion to the distance travelled through the site (i.e. 50 % of the wind farm site will experience less than 50 % of the maximum level of effect reported above, and 25 % will experience less than 25 % of the maximum effect, etc.).
- Behind the sites, relative to the wave coming direction, the local reduction in wave height recovers towards ambient values at a non–linear rate (i.e. recovering quickly over small distances but smaller magnitude effects can persist over greater distances);
- These residual effects extend in the direction of wave travel (with some lateral spreading); and
- The maximum effect on wave period in all cases is approximately 0.3 s (3 to 5 %). The small magnitude of the effect is not measurable in practice.

In relation to wave direction, the assessment finds that there is no measurable effect on instantaneous wave direction (i.e. differences are < ±1°) as a result of either the jacket or GBS scenarios either locally or regionally.

6.1.7.21 The local effects of the GBS array on waves are of a small magnitude relative to the range of naturally occurring variability on annual and decadal timescales and do not cause the range to be exceeded. The reduction in wave height outside of the array is of a small magnitude (likely not measurable in practice in most areas).

6.1.7.22 The local (and regional) effects of the jacket array on waves are of a very small magnitude relative to the range of naturally occurring variability (and do not cause it to be exceeded). Effects are so small that they would not be measurable in practice.

6.1.7.23 A low magnitude of change, within the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Sensitive Receptor: Designated Coastal Habitats

6.1.7.24 In relation to wave height and period outside of the three proposed wind farms, the assessment finds that, for jackets:

- Jacket foundations do not affect waves by more than 0.05 m (1 %) significant wave height or 0.1 s (1 to 1.5 %) wave period outside of the wind farm sites (including the locations of all of the identified designated coastal habitats).

6.1.7.25 For GBS:

- The main effect of the GBS foundations is to reduce the height of waves passing through the sites and on to other receptor locations;
- When all three proposed wind farms are present, the maximum magnitude of effect on wave height for groups of designated sites are:
  - East Caithness Cliffs SAC: of the order 0.2 to 0.3 m (2 to 3 %) for waves from the east or south east (occurring 29 % of the time) and < 0.1 m (1 % of the baseline wave condition) for other directions (70.4 % of the time);
  - Moray Firth SAC and Open Coastal Sites: of the order 0.1 to 0.2 m (2 – 3 % of the baseline wave condition) for waves from the north, north east or east (54 % of the time) and < 0.1 m (up to 2 % of the incident wave condition) for other directions (46 % of the time); and
  - Inner Moray Firth and Enclosed Water Bodies: < 0.05 m (< 1 % of the baseline wave condition - i.e. no measurable effect) for all wave directions.
- Effects are only apparent in locations where waves have previously passed through the wind farm site boundary(s) – this condition only applies 29 % of the time for the East Caithness Cliffs SAC and 54 % of the time for the Moray Firth SAC and other open coastal sites (for any wave height). These are the proportions of time during which any effect might potentially arise – the maximum effects described above will occur even less frequently (for a few hours every 10 to 50 years);
- GBS foundations do not affect wave period (the time between individual waves) by more than 0.1 s (1 to 1.5 %) outside of the three proposed wind farms – this is not a measurable effect in practice;
- Beyond the extent of the three proposed wind farms, values recover towards ambient values at a non–linear rate (i.e. recovering relatively quickly over small distances but smaller magnitude effects can persist over greater distances); and
- These residual effects extend in the direction of wave travel (with some lateral spreading).

In relation to wave direction, the assessment finds that there is no measurable effect on wave direction (i.e., differences are < ±1°) as a result of either the jacket or GBS scenarios in the regional area.

6.1.7.26 The relative effect on extreme wave conditions is shown to be of a very low magnitude in relation to the range of natural variability. The assessed magnitude of the maximum levels of effect found within the three proposed wind farm sites remains low due to the limited spatial extent and infrequent nature of the effects at any given location. The effect on less extreme (more frequently occurring) conditions will be correspondingly smaller in both magnitude and extent.

6.1.7.27 The greatest relative and absolute effects will be felt by the East Caithness Cliffs SAC as it is closest to the development and the source of the effect. However, any level of effect will only occur for 29 % of the time (the proportion of time that waves come from a direction that passes through the development area before reaching this site) and this coastline is characterised by:

- Rocky cliffs that are not subject to significant erosion by waves on the timescale of the development;
- Morphology that is not dependent upon rates and directions of alongshore sediment transport; and
- Designation corresponding to the aerially exposed cliffs, which are above the high water elevation and therefore not dependent upon wave action.

6.1.7.28 This means that this particular location has a very low sensitivity to the assessed type of effect, which is localised and also of a low magnitude. The effects on other designated sites (generally considered to have a medium level of sensitivity to changes in offshore wave climate) are very low in magnitude both in absolute and relative terms.

6.1.7.29 The direct effects of the three proposed wind farm sites on waves at the designated coastal sites identified are of a low or very low magnitude relative to the range of naturally occurring variability and have no potential to cause any effect on any given site 50 to 70 % of the time. For the time when effects are potentially felt, the coastal environments are of a morphological type not sensitive to changes in the wave regime.

6.1.7.30 A low magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity and a small magnitude of change within the range of natural variability is also assessed to arise in areas of potentially medium sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Sensitive Receptor: Recreational Surfing Venues

6.1.7.31 This assessment of likely significant effects to the surfing wave regime follows the guidance provided by Surfers Against Sewage (2009). The assessment is informed by the analysis of wave model results with and without the GBS or jacket schemes present over a two–year period. Time series of wave conditions have been extracted from the model results immediately offshore of the identified surfing beaches in the study area (See Figure 3.1-1 and Figure 3.4-6, Volume 6 a). The same statistical and frequency analysis has been applied to each data set to obtain baseline values and the difference in either the frequency of occurrence of key conditions, or the frequency of occurrence of other event types resulting from the presence of the schemes. A more detailed description may be found in Technical Appendix 3.4 A.

6.1.7.32 Considering the three proposed wind farms in various configurations, GBS foundations were found to have no effect (> 0.01 m wave height or > 0.1 s wave period) at ten out of the 18 venues. Of the remaining eight venues, effects were typically limited to a 0.01 to 0.02 m decrease (up to a maximum of 0.09 m) in wave height, and with no effect on wave period or the frequency of occurrence of any representative conditions. Such differences in the height of individual waves will not be measurable in practice.

6.1.7.33 Jackets were found to have no effect (> 0.01 m wave height or > 0.1 s wave period) at 11 out of the 18 surfing venues. Of the remaining seven venues, effects were typically limited to a 0.01 to 0.02 m decrease (up to a maximum of 0.05 m) in wave height, and with no effect on wave period or the frequency of occurrence of any representative conditions. Such differences in the height of individual waves will not be measurable in practice.

6.1.7.34 A low magnitude of change within the range of natural variability is therefore assessed to arise in areas of medium sensitivity. The resulting effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Decommissioning

6.1.7.35 Where and when wind farm infrastructure is no longer present, there is no potential for any modification to the baseline wave and tidal regimes. The worst case scenario of the infrastructure associated with three wind farms being present is considered in the preceding sections. The effect of less than the total amount of infrastructure present at an intermediate stage in the decommissioning process will be (generally proportionally) less than that reported (as not significant) for the operational phase of the development (i.e. of a small magnitude and within the range of natural variability).

6.1.8 Proposed Monitoring and Mitigation

Construction

6.1.8.1 No mitigation measures are proposed.

Operation

6.1.8.2 No mitigation measures are proposed.

Decommissioning

6.1.8.3 No mitigation measures are proposed.

6.1.9 Secondary Assessment: Individual Wind Farm Sites

6.1.9.1 The effect of individual wind farms on the wave and tidal regimes has also been considered. More details of these assessments may be found in Technical Appendix 3.4 A. The three individual sites have been assessed on the basis of GBS foundations in a 3.6 MW layout (i.e. the largest number and closest spacing of turbines) and the largest corresponding likely effect on tidal processes and waves for a single site.

6.1.9.2 Table 6.1-4 below summarises the (post–mitigation) results of the secondary impact assessment. Consequential (indirect) effects on the sedimentary environment are considered in Chapter 6.2 (Sedimentary and Coastal Processes). Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Table 6.1-4 Secondary Assessment Summary

Effects	Telford	Stevenson	MacColl
Construction and Decommissioning			
(Partial impacts only)	As 'Operation'	As 'Operation'	As 'Operation'
Operation			
Changes to the Tidal Regime due to the Presence of the Turbine Foudations	Negligible Significance	Negligible Significance	Negligible Significance
Changes to the Wave Regime due to the Presence of the Turbine Foundations.	Negligible Significance	Negligible Significance	Negligible Significance

6.1.10 Sensitivity Assessment

6.1.10.1 The impact of two of the three proposed wind farm sites (i.e. where any two of the three wind farms are developed) on the wave and tidal regimes has also been considered. More details of these sensitivity assessments may be found in Technical Appendix 3.4 C. The site pairs have been assessed on the basis of GBS foundations in a 3.6 MW (site 1) + 5 MW (site 2) layout (i.e. the largest realistic number and closest spacing of turbines and the largest corresponding potential effect on tidal processes and waves for a pair of sites). It is noted that there is presently no decision as to which of the three sites might be built using 3.6 MW turbines and so different permutations are considered.

6.1.10.2 Table 6.1-5 below summarises the results of the sensitivity impact assessment. Consequential (indirect) effects on the sedimentary environment are considered in Chapter 6.2 (Sedimentary and Coastal Processes). Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Table 6.1-5 Sensitivity Assessment Summary

Effects	Site 1* (3.6MW) + Site 2** (5MW)
Construction and Decommissioning	
(Partial Impacts Only)	As 'Operation'
Operation	
Changes to the Tidal Regime due to the Presence of the Turbine Foundations	Negligible Significance
Changes to the Wave Regime due to the Presence of the Turbine Foundations	Negligible Significance
* One of Telford, Stevenson or MacColl ** Either one of the two remaining sites (Telford, Stevenson or MacColl)	

6.1.11 Proposed Monitoring and Mitigation: Secondary / Sensitivity Assessment

Construction

6.1.11.1 No additional monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

Operation

6.1.11.2 No additional monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

Decommissioning

6.1.11.3 No additional monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

6.1.12 Residual Impacts: Secondary / Sensitivity Assessment

6.1.12.1 The results of the secondary and sensitivity assessments lead to the same conclusions (for each site or pair of sites) as previously shown in Table 6.1-2 above for the primary assessment.

6.1.13 Habitats Regulations Appraisal

6.1.13.1 Likely effects from the construction, operation and decommissioning of the generating station on the wave and tidal regime are of negligible significance and therefore do not give rise to Habitats Regulations Appraisal concerns. The effects on the physical marine environment considered in this chapter are also considered with respect to the requirements for Habitats Regulation Appraisal in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Ornithology).

6.1.14 References

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6.2 Sedimentary and Coastal Processes

6.2.1 Summary of Effects and Mitigation

6.2.1.1 This chapter provides an impact assessment of the likely significant effects on the sedimentary and coastal processes of the three proposed wind farm sites and their regional setting. The OSPs and the export cable route are assessed in Chapter 9.2 (Sedimentary and Coastal Processes). A more detailed description may be found in the supporting technical appendices: Metocean and Coastal Processes (Technical Appendix 3.4 A, B and C, ABPmer (2012a)).

6.2.1.2 This assessment is informed by the following baseline chapters:

- Chapter 3.1 (Bathymetry);
- Chapter 3.2 (Geology);
- Chapter 3.3 (Wind Climate);
- Chapter 3.4 (Hydrodynamics); and
- Chapter 3.5 (Sedimentary and Coastal Processes).

6.2.1.3 This impact assessment is also used to inform the following assessments:

- Chapter 6.1, 9.1 and 13.1 (Hydrodynamics: Wave Climate and Tidal Regime);
- Chapter 7.1, 10.1 and 14.1 (Benthic Ecology);
- Chapter 7.2, 10.2 and 14.2 (Fish and Shellfish Ecology);
- Chapter 8.5, 11.5 and 15.5 (Archaeology and Visual Receptors); and
- Chapter 9.2 and 13.2 (Sedimentary and Coastal Processes).

6.2.1.4 This chapter comprises the following:

- EIA Methodology;
- Primary Impact Assessment;
- Monitoring and Mitigation;
- Secondary Impact Assessment;
- Monitoring and Mitigation; and
- Residual Effects.

Summary of Effects

6.2.1.5 This chapter considers the likely significant effects of the offshore generating station on the physical sedimentary environment (patterns of sediment transport and geomorphological evolution). The effects on sedimentary and coastal processes that were assessed for the three proposed wind farm sites include:

- Increase in suspended sediment concentrations as a result of foundation installation activities;
- Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities;
- Increase in suspended sediment concentrations as a result of inter-array cable installation activities;
- Indentations left on the seabed by jack-up vessels and large anchors;
- Changes to the sediment transport regime and geomorphology, due to the presence of the turbine foundations and exposure of inter-array cables and cable protection measures; and
- Scour effects due to the presence of the turbine foundations.

6.2.1.6 Receptors considered in this assessment are shown in Figure 3.4-6, Volume 6 a and include:

- Smith Bank; and
- Designated Coastal Habitats (as detailed in Technical Appendix 3.4 A).

Proposed Mitigation Measures and Residual Effects

6.2.1.7 A certain degree of mitigation is already embedded within the design and best practice engineering methodologies for the use of the equipment that will be employed in this development and is included where relevant within the preceding impact assessment. No further mitigation measures are proposed.

6.2.2 Residual Impacts – Primary Impact Assessment

6.2.2.1 Table 6.2-1 below summarises the results of the impact assessment.

Table 6.2-1 Primary Impact Assessment Summary

Impact	Receptor	Pre-Mitigation Effect	Mitigation	Post-Mitigation Effect
Construction				
Increase in suspended sediment concentrations as a result of foundation installation activities	Smith Bank	Minor Significance	None	Minor Significance
Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	Smith Bank	Minor Significance	None	Minor Significance

Impact	Receptor	Pre-Mitigation Effect	Mitigation	Post-Mitigation Effect
Increase in suspended sediment concentrations as a result of inter-array cable installation activities	Smith Bank	Negligible Significance	None	Negligible Significance
Indentations left on the seabed by jack-up vessels and large anchors	Smith Bank	Negligible Significance	None	Negligible Significance
Operation				
Changes to the sediment transport regime and geomorphology, due to the presence of the turbine foundations*	Smith Bank	Not Significant	None	Not Significant
	Designated Coastal Habitats	Negligible Significance	None	Negligible Significance
Scour effects due to the presence of the turbine foundations	Smith Bank	Minor Significance	Scour protection	Minor Significance
Scour effects due to the exposure of inter-array cables and cable protection measures	Smith Bank	Negligible Significance	Scour protection	Negligible Significance
Decommissioning				
(Partial impacts only)	As 'Construction'	Negligible or Minor Significance	None	Negligible or Minor Significance

6.2.3 Introduction

6.2.3.1 This chapter describes the likely significant effects of the three proposed wind farms on sediment transport and geomorphology as physical processes in the marine environment. Some effects arise as an indirect result of effects on water levels, currents and waves, considered in Chapter 6.1 (Hydrodynamics: Wave Climate and Tidal Regime).

6.2.3.2 The baseline sedimentary and geomorphological conditions are described in Chapter 3.5 (Sedimentary and Coastal Processes) and the supporting Technical Appendix: Metocean and Coastal Processes (Appendix 3.4 A) ABPmer (2012a).

6.2.3.3 More details regarding the design, calibration and validation of the numerical models used to inform the assessments in this section may be found in the supporting Technical Appendix (Appendix 3.4 B) ABPmer (2012b).

6.2.3.4 More details regarding the impact assessment methods used and results obtained and reported in this chapter may be found in the supporting Technical Appendix (Appendix 3.4 C) ABPmer (2012c).

6.2.4 Rochdale Envelope Parameters Considered in the Assessment

6.2.4.1 The range of characteristics adopted within this physical process assessment, as detailed in Technical Appendix 3.4 B, are summarised in Table 6.2-2 below. The parameters set out below define the 'Rochdale Envelope' realistic worst case scenario for each likely significant effect on the physical hydrodynamic environment. These are drawn from a range of development options set out in Chapter 2.2 (Project Description).

Table 6.2-2 Rochdale Envelope Parameters Relevant to the Sedimentary and Coastal Processes Impact Assessment

Type of Effect	Rochdale Envelope Scenario Assessed
Construction & Decommissioning	
Increase in suspended sediment concentrations as a result of foundation installation activities	Dredging overspill (silts and clays) at 30 kg / s during Gravity Base Structures (GBS) bed preparation, 95 m pit diameter, 5 m pit depth, 3.6 + 5 + 5 MW site layouts.
Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	Drill arisings (sands, silts and clays) at 26 kg / s during installation of pin piled jacket foundations by drilling, four pin piles, 3.0 m diameter, 60 m burial, 3.6 + 5 + 5 MW site layouts.
Increase in suspended sediment concentrations as a result of inter-array cable installation activities	Trenching by energetic means (e.g. jetting). Single trench with cross-section of disturbance 1 m wide by 3 m deep in a 'U' shaped profile. 100 % of material re-suspended.
Indentations left on the seabed by jack-up vessels and large anchors	Jack-up legs 100 m^2 footprint. Anchors 1.5 to 3 m length scale.
Operation	
Changes to the sediment transport regime and geomorphology, due to the presence of the turbine foundations*	1) GBS, 3.6 + 5 + 5 MW site layouts. 2) Jacket, 3.6 + 5 + 5 MW site layouts.
Scour effects due to the presence of the turbine foundations	All foundation types, 3.6 + 5 + 5 MW site layouts.
Scour effects due to the exposure of inter-array cables and cable protection measures	Inter-array cables and cable protection measures
*** (1) refers to the characteristics identified as worst case; (2) refers to the characteristics identified as a realistic probable alternative case**	

6.2.5 EIA Methodology

6.2.5.1 The methodology and terminology for the assessment of significance of any effects will be the same as that described in Chapter 6.1 (Hydrodynamics: Wave Climate and Tidal Regime).

6.2.5.2 Issues of concern relating to the construction, operation and decommissioning of the wind farm were previously considered in the initial Scoping Report (MORL, 2010) and Scoping Opinion response (Marine Scotland, 2011). In relation to the sedimentary and geomorphological regimes, the following potential issues or effects were identified:

- Sediment dynamics (changes to sediment transport pathways, suspended sediment concentrations and resulting sediment deposition):
  - Effects upon the extent, distribution, function or structure of marine and coastal habitats (SACs and SPAs);
  - Effects upon sites of potential archaeological interest; and
  - Potential for changes in sediment mobility that might affect navigable water depth with reference to MCA guidance MGN371.
- Footprint of seabed lost (footprint of foundations, of scour around foundations and of installation vessels):
  - Effects upon the extent, distribution, function or structure of marine and coastal habitats (SACs and SPAs).
- Cable burial:
  - Concern regarding effects on local habitats where undertaken. However, the temporary and localised nature of any effect is acknowledged.

6.2.6 Primary Impact Assessment: Three Proposed Wind Farm Sites

6.2.6.1 This assessment considers the effects of the three proposed wind farm developments in all permutations of one 3.6 MW site (i.e. Telford, Stevenson or MacColl) and two 5 MW sites. Assessments are made both generally and more specifically on physical process receptors identified within the predicted areas of effect. Physical process receptors that are potentially sensitive to changes in the physical baseline environment are shown in Figure 3.4-6, Volume 6 a and include:

- Smith Bank - A submerged bathymetric high in the Outer Moray Firth with a stable core of glacial tills covered by a veneer of sands and gravels of variable thickness and proportion. The form and function of the bank is relatively insensitive to changes in physical processes but is considered due to its proximity to the source of all effects from the wind farms; and
- Designated sites - SPA, SAC, SSSI and Ramsar sites within the Moray Firth. A full list of the sites considered and a summary of their morphological type may be found in Appendix 3.4 A. These receptors are potentially sensitive to changes in local tidal range, wave climate and sediment supply.

6.2.6.2 This chapter considers both direct and consequential (indirect) effects on sediment mobility, transport patterns and morphology.

6.2.6.3 Effects on these receptors are considered in relation to the construction, operation and decommissioning phases of the development in the following paragraphs.

Construction

6.2.6.4 The following paragraphs consider the effects of the wind farms on the sedimentary regime and morphological features during the construction phase for the three proposed wind farms. Full details of this assessment may be found in Technical Appendix 3.4 C.

Increase in Suspended Sediment Concentrations as a Result of Foundation Installation Activities

6.2.6.5 An increase in Suspended Sediment Concentration (SSC) will occur where sediments are disturbed during energetic operations at or below the seabed. The magnitude of the effect locally will depend upon the sediment release rate. The nature of the effect and its extent and magnitude in the far field will depend upon the characteristics of the sediments being released (controlling the duration of time spent in suspension), the water depth (affecting the volume of water for dispersion and dilution) and the current speed and direction, both at the time of release and the residual current over longer periods of time (affecting rates and direction of dispersion). A change in levels of SSC locally does not necessarily imply an effect, if there are no receptors present that are sensitive to the change. Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); and Chapter 7.2 (Fish and Shellfish Ecology).

Sensitive Receptor: Smith Bank

6.2.6.6 The release of sediment into the upper water column during either dredging or drilling works will initially lead to a local increase in SSC. The resulting sediment plume will be advected with ambient tidal currents and will be subject to general processes of dispersion, deposition and re-suspension over time. The extent of the dispersion (to background levels of effect) is shown below to be limited to Smith Bank. For this reason, the more distant Designated Site receptors have not been separately assessed as there is a negligible magnitude of change.

6.2.6.7 To quantify the likely magnitude and extent of the increase in SSC, currents from the numerical tidal model were used in conjunction with a plume dispersion model. Realistic sediment release types and rates were estimated based upon the available geotechnical data and typical dredging operation methodologies. An example of the pattern of sediment plume dispersion from dredging activities is shown in Fig 3.5-5, Volume 6 a. A more detailed description of the results of this modelling may be found in Technical Appendix 3.4 B.

6.2.6.8 SSC is an additive quantity and so the calculated effect of the works indicates the predicted increase above ambient values.

6.2.6.9 Dredging as part of bed preparation for GBS foundations will lead to:

- An increase in SSC of 30 to 35 mg / l above ambient levels depending on the tidal state and the local water depth at the time and location of the release. These maximum levels of effect are contained within 50 to 100 m of the dredger and only occurring during sediment release;
- A maximum increase in SSC of 20 mg / l or less above ambient levels within 500 to 1,000 m in a plume downstream and to 10 mg / l or less within 2,000 to 3,000 m downstream;
- Both of the above levels of effect are only present during dredging and no more than 1 hour after cessation of dredging; and
- A more widely dispersed residual increase in SSC of 1 to 4 mg / l above ambient levels.

6.2.6.10 Effects are generally of a magnitude consistent with the natural range of variability (< 5 m/ l during calm periods to 100’s to 1,000’s mg / l near to the seabed during storm events). Local effects around the dredger may however be potentially in excess of the natural range of variability in the upper water column but will be localised and temporary.

6.2.6.11 Marine aggregate dredging is a relatively standard and established practice and so will be subject to a number of embedded mitigation measures in the design of the machinery and methodologies normally employed. This will limit levels of SSC resulting from the normal operation of such machines to levels that are acceptable according to a broad range of standards and in a variety of environment types.

6.2.6.12 Overall, a low magnitude of change that may locally and temporarily exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a negative effect of **minor significance** and therefore not significant in terms of the EIA Regulations.

6.2.6.13 Drilling to install jacket pin piles will lead to:

- An increase in SSC of 30 to 40 mg / l above ambient levels depending on the tidal state and the local water depth at the time and location of the release. These maximum levels of effect are contained within 50 to 100 m of the dredger and only occur during sediment release;
- A maximum increase in SSC of 20 mg / l or less by 500 to 1,000 m above ambient levels in a plume downstream and to 10 mg / l or less by 2,000 to 3,000 m downstream;
- Both of the above levels of effect are only present during drilling and no more than 1 hour after cessation of drilling; and
- A more widely dispersed increase in SSC of 1 to 4 mg / l above ambient levels in some other areas.

6.2.6.14 Effects are generally of a magnitude less than the natural range of variability (< 5 mg / l during calm periods but 100's to 1,000's mg / l near to the seabed during storm events). Local effects around the dredger may however be potentially in excess of the natural range of variability in the upper water column but will be localised and temporary.

6.2.6.15 Overall, a low magnitude of change that may locally and temporarily exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a negative effect of **minor significance** and therefore not significant in terms of the EIA Regulations.

Construction Phase: Accumulation of Sediment and Change of Sediment Type at the Seabed as a Result of Foundation Installation Activities

6.2.6.16 Sediment re-suspended by installation operations at or below the seabed will be initially transported and eventually re-deposited to the seabed. Rapid accumulations of a sufficient thickness may constitute an effect if and where a receptor is sensitive to the change. The sensitivity of a receptor may vary depending upon the nature of the deposited sediment, which may be different to the pre-existing seabed surface. Consequential (direct) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Sensitive Receptor: Smith Bank

6.2.6.17 As illustrated in Fig 3.5-6, Volume 6 a, the net effect of dredging as part of bed preparation for multiple GBS foundations will lead to:

- An accumulation of fine material (silts and clays) over a wide area to the south-south-west of the three proposed wind farms (coarser materials are considered to be retained in the dredger); and
- The estimated thickness of the deposit is less than 1 mm, accumulating gradually over the whole construction period which is likely to be both undetectable in practice and also subject to progressive dispersion in this time by natural processes.

6.2.6.18 The net effect of drilling to install multiple jacket pin piles will lead to:

- A localised accumulation of sandy material up to 1 to 5 m thick in the near vicinity (within up to 200 m) of each foundation;
- An accumulation of fine material (silts and clays) over a wide area to the south-south-west of the three proposed wind farms with the same extent of effect as shown in Fig 3.5-6, Volume 6 a; and
- The estimated thickness of the deposit is less than 1 mm accumulating gradually over the whole construction period, which is likely to be both undetectable in practice and subject to progressive dispersion by natural processes.

6.2.6.19 Natural variability in total water depth occurs in the form of: bathymetry (35 to 55 mCD); tidal water levels (2 to 4 m); non-tidal influences (up to 1 m); and predicted mean sea level rise due to climate change over the lifetime of the three proposed wind farms (0.08 to 0.14 m).

6.2.6.20 Natural variability in seabed level occurs in the form of: active bed forms (order 0.01 to 0.10 m); partial re-suspension or fluidisation of the upper seabed during extreme storm events, followed by re-deposition and consolidation (up to 0.3 m); local net sediment accumulation or erosion (potentially highly spatially and temporally variable).

6.2.6.21 The effects of dredging and drilling whilst installing foundations in terms of thickness of accumulation are of a magnitude consistent with the natural range of variability. The accumulation of a variable thickness of fine sediment outside of the site may modify slightly the sediment surface type in that area. This sediment accumulation is expected to be reworked and dispersed to background concentrations by storms in short to medium time-scales.

6.2.6.22 A low to medium magnitude of change that may locally and temporarily exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a temporary negative impact of **minor significance** and therefore not significant in terms of the EIA Regulations.

Increase in Suspended Sediment Concentrations as a Result of Inter-Array Cable Installation Activities

6.2.6.23 An increase in SSC will arise where sediments are disturbed during energetic operations at or below the seabed. The magnitude of the effect locally will depend upon the sediment release rate. The nature of the effect and its extent and magnitude in the far field will depend upon the nature of the sediments being released (controlling the duration of time spent in suspension), the water depth (affecting the volume of water for dispersion and dilution) and the current speed and direction, both at the time of release and the residual current over longer periods of time (affecting rates and direction of advection). A change in levels of SSC locally does not necessarily imply an effect, if there are no receptors present that are sensitive to the change. Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Sensitive Receptor: Smith Bank

6.2.6.24 Cable installation will have a relatively high magnitude effect on SSC (elevated to order 100's to 10,000's mg / l). However, the effect will be short-term (order seconds to minutes) and will be largely localised to the cable installation location (main effect within 10's of meters). Once re-deposited, the re-suspended sediment will join the natural sedimentary environment and therefore ceases to present any further effect. As such, because of their relatively distant location from the source of the potential effect, Designated Site receptors have not been separately assessed.

6.2.6.25 The effects of cable burial on SSC are of a magnitude potentially in excess of the natural range of variability. However, the effect will be localised and temporary.

6.2.6.26 A small to medium magnitude of change locally and temporarily exceeding the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in a temporary negative effect of **minor significance** and therefore not significant in terms of the EIA Regulations.

Indentations Left on the Seabed by Jack-up Vessels and Large Anchors

6.2.6.27 Jack-up barge legs and anchors are used to provide a stable or fixed working platform for installation vessels. On completion of the operation, these may leave an impression when extracted from the seabed. The exact nature of the initial disturbance will likely vary depending upon the design and dimensions of the leg or anchor, and the geotechnical properties of the seabed soils locally.

Sensitive Receptor: Smith Bank

6.2.6.28 Jack-up barge legs may leave an impression on the seabed. The scale of the depression left by a single leg soon after extraction is estimated to be a 12 m diameter conical pit, approximately 3.7 m deep from ambient bed level in the centre and possibly also surrounded by a raised area of seabed. In the short to medium term, the pits will tend to become shallower and less distinct as storm events re-suspended the raised sediment material around the edges of the pit and either redeposit it into the pit or move it elsewhere. There will be an initial tendency for some sediment being transported through the area to accumulate in the pits if they are sufficiently deep to reduce current speed and / or wave action locally. However, this tendency will decrease rapidly as the pits flatten. In the medium to long-term, the pits are likely to be filled by natural sediment transport on time scales in the order of one to five years following construction.

6.2.6.29 Anchors may also leave an impression on the seabed. The footprint length scale of the disturbance remaining soon after removal of an anchor will be approximately similar to the size of the anchor itself (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. 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. As the sediment is essentially only locally redistributed in a small footprint, no tendency for it to intercept regional sediment transport is expected.

6.2.6.30 In the case of both jack-up legs and anchors, because no sediment has been introduced from elsewhere or removed and the sediment veneer is considered to be largely uniform within the upper 5 m, the sedimentary texture of the disturbed surface will be similar to that of the surrounding seabed.

6.2.6.31 The effects of jack-up legs and anchors are therefore of small magnitude, have only a localised on-site effect, are largely temporary on short to medium term time-scales and do not impact upon the identified sensitive physical environmental receptors beyond the range of natural variability.

6.2.6.32 A low magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting significance of effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Operation

6.2.6.33 The following paragraphs consider the effect of the wind farm on the sedimentary regime and morphological features during the operational phase of the development. More details of this assessment may be found in Appendix 3.4 C (ABPmer, 2011c).

Changes to the Sediment Transport Regime Due to the Presence of the Wind Farm Foundations

6.2.6.34 The sediment transport regime (rates, directions and the nature of sediment transport) is controlled by the interaction of surficial seabed sediments with the tidal and wave regimes locally.

Sensitive Receptor: Smith Bank

6.2.6.35 It is the combined wave and tidal regimes that ultimately control sediment transport and therefore the seabed form within the study area. It was shown in 6.2.6.10 above that the development causes no significant change to the speed, direction or asymmetry of tidal currents. It was also shown that GBS foundations will cause a reduction in instantaneous significant wave height within the three proposed wind farms of up to 19 % (but more typically 5 to 10 % or less across most of the site area) and only up to 5 % in the outside of the site area, which is of the same order as inter-annual and inter-decadal variability in storm intensity. Jackets will have little or no measurable effect (< 2 %) on wave height. Neither GBS nor jacket foundations will measurably affect wave period or direction.

6.2.6.36 Given no significant effect on the driving parameters, in particular the direction and asymmetry of tidal currents, there will be no corresponding difference in the potential rates and directions of sediment transport through the three proposed wind farm sites (provided that the supply of sediment is available for transport).

6.2.6.37 This report has considered the potential for the construction of the wind farms to affect the character or abundance of surface sediments (e.g. as a result of ground preparation, drilling or cable burial activities) and found it to be not significant. Whilst some short to medium term localised increases in sediment thickness are expected, there is not predicted to be a significant change in the textural properties of the sediment available for transport. This supports the further conclusion that actual sediment transport rates through the site will not be affected by the planned development.

6.2.6.38 The conceptual effect of a reduction in wave height on sediment transport pathways in the three proposed wind farms and resulting morphology is:

- The areas within the three proposed wind farms may tend to accumulate sediment at a slightly higher rate than would have otherwise occurred during the operational lifetime of the development; and
- The supply of sediment to areas located further into the Moray Firth might be slightly less than would have otherwise occurred during the operational lifetime of the development.

6.2.6.39 However, as stated above, the absolute difference in sediment transport attributable to the wind farm is less than the potential for natural variability over the same period. There will, therefore, be no significant effect on the form or function of Smith Bank.

6.2.6.40 A low magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity. The resulting significance of effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Sensitive Receptor: Designated Coastal Habitats

6.2.6.41 It was demonstrated above that there will be no significant effect on sediment transport rates through the three proposed wind farms as a result of their presence. The main effects on tidal currents and waves are generally confined to the three proposed wind farm site extents and are of a lower magnitude beyond the site boundaries. Therefore, there will be no corresponding effect upon the rate of sediment supply to other parts of the Moray Firth.

6.2.6.42 The effect of the wind farm array on wave height, period and direction at the location of designated coastal habitats has been considered in paragraph 6.2.6.35, and was found to be not significant both in absolute terms and in the context of natural variability. There will, therefore, be no corresponding effect upon the rates or directions of nearshore sediment transport at these locations.

6.2.6.43 There will therefore be no effect on the form or function of designated coastal habitats (see Chapter 12.2: Habitat Regulations Appraisal Summary).

6.2.6.44 A low magnitude of change within the range of natural variability is therefore assessed to arise in areas of low to medium sensitivity. The resulting significance of effect is of **negligible significance** and therefore not significant in terms of the EIA Regulations.

Introduction of Scour Effects Due to the Presence of the Wind Farm Foundations

6.2.6.45 Scour can occur as the result of a localised increase in erosion potential, caused by the interaction between obstacles and water movements near to the seabed. As such, extensive scour is not naturally present in the marine environment and its introduction may constitute a further area of modification to the nature and level of the seabed. In addition to the slopes that may develop, the surface of the scour pit may develop a sediment texture different to that of the ambient seabed due to the difference in sediment transport potential.

Sensitive Receptor: Smith Bank

6.2.6.46 There is a potential for scour to develop where and when scour protection is not applied, including the interim period between installation of the foundation and placement of the associated protection during the construction phase. Any scour that does not develop will then persist in some form for the operational lifetime of the structure until it is removed during decommissioning and the seabed has recovered to baseline conditions.

6.2.6.47 Using empirical relationships described in Whitehouse (1998), the equilibrium scour depth for each foundation type resulting from waves and currents, both alone and in combination, has been calculated for different foundation sizes. Results have also been up-scaled for the numbers of turbines in different development scenarios and the total area found as a proportion of the wind farm(s) area. The tabulated results may be found in the supporting Technical Appendix 3.4 C.

6.2.6.48 Overall, in terms of scour depth the GBS is predicted to cause the largest effect with a maximum depth of, approximately, 9 to 12 m local to the structure. In reality, this depth is unlikely to be attained, at least in all locations around a given foundation, due to potential constraints arising from the sub-surface geology. The presence of gravel in the upper sandy layers will likely lead to bed armouring (the development of a relatively coarse and erosion-resistant surface layer) in the scour pit that will restrict the overall depth or rate of scour development. Also, the consolidated till surface at, approximately, 0.5 to 2 m below the seabed is described as layered sandy silty clays of variable density and hardness (Osiris, 2011a), and therefore is likely to be generally cohesive, consolidated and largely more resistant to erosion than non-cohesive (sandy) sediments.

6.2.6.49 The extent of scour from the edge of each foundation is also tabulated in Appendix 3.4 C. This is calculated assuming the profile of the scour pit is an inverted cone with slopes at the angle of repose for sand (32°). It is noted that the minimum separation between turbine locations is approximately 600 m and the greatest extent of scour from the centroid of a foundation location is only 51 m. Therefore, scour effects are not predicted to interact or coalesce between foundations.

6.2.6.50 The greatest volume of scoured material from a single foundation results from the 65 m GBS or GBS plinth with a scoured volume of 26,663 m^3 per turbine. As already described, this full volume may not be attained due to geological conditions in the site (and embedded mitigation from the likely placement of scour protection materials within a few metres of the seabed surface as an integral part of the engineering design).

6.2.6.51 The various three site scenarios (rated 3.6, 5, 5 MW) result in the largest total footprint of scour, which is still no more than 0.56 % of the total area of the three proposed wind farms. Other foundation types result in a smaller area of effect.

6.2.6.52 The time theoretically required for the majority of equilibrium scour pit development around a foundation is in the order of hours to days under flow conditions sufficient to induce scour. This makes the assumption of a mobile uniform non-cohesive sediment substrate. Approximately symmetrical scour will only develop following sufficient exposure to both flood and ebb tidal directions. Waves of a sufficient size to interact with the seabed do not typically cause rapid initial scour directly, but can increase the rate of initial scour development.

6.2.6.53 The effects of the foundations in causing scour are of a small to medium magnitude relative to the range of naturally occurring variability in seabed level but do not cause the normal range of water depths to be exceeded. The effects of scour are limited to only a small proportion of the area of each of the three proposed wind farms and an even smaller proportion of the area of Smith Bank.

6.2.6.54 A low to medium magnitude of change that does not exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting effect is of **minor significance** and therefore not significant in terms of the EIA Regulations.

Introduction of Scour Effects Due to Exposure of Inter-Array Cables and Cable Protection Measures

6.2.6.55 Scour can occur as the result of a localised increase in erosion potential, caused by the interaction between obstacles and water movements near to the seabed. As such, extensive scour is not naturally present in the marine environment and its introduction may constitute a further area of modification to the nature and level of the seabed. In addition to the slopes that may develop, the surface of the scour pit may develop a sediment texture different to that of the ambient seabed due to the difference in sediment transport potential.

Sensitive Receptor: Smith Bank

6.2.6.56 Structures introduced into the marine environment and located near to the seabed will interact with the naturally present hydrodynamic and sedimentary regimes, resulting in the potential for sediment scour to occur. The removal of sediment from underneath a section of cable exposed on the seabed can lead to free-spanning and further sediment erosion; exposed cables are also at greater risk of physical damage and will require further intervention to rebury or protect them. Exposure and scour is primarily an engineering risk, and will be mitigated using cable burial or cable protection and scour protection around the turbines. Cables will be buried where seabed conditions allow, and where conditions do not allow - surface lay and protected by rock armour or concrete mattressing.

6.2.6.57 Inter array cables are typically between 0.09 and 0.16 m in diameter and weigh between 18 to 40 kg / m. Typically only one cable is required to connect two adjacent turbines, however, it is possible that more than one cable (and route) might converge at offshore substations. Offshore substations are considered in more detail in Chapter 9.2 (Sedimentary and Coastal Processes).

6.2.6.58 Whitehouse (1998) summarises various studies that provide empirical estimates of equilibrium scour depth underneath pipelines (similar in principle to cables). The predicted scour depth in all cases is primarily dependent upon the diameter of the cable. It is also noted that the cable must be significantly exposed for local scour to occur at all and that an oblique orientation of the cable to the ambient tidal or wave forcing will also reduce the predicted effect.

6.2.6.59 Should the cable become exposed, it may cause scouring of the underlying sediments. If the cable is taut or stiff, sections of the cable might become elevated relative to the lowered bed level. If the cable is not taut or stiff, then it will sag to remain in contact with the seabed, irrespective of how much scour occurs. This has been previously observed to lead to self burial of pipelines due to sediment migration into the depression created which partially buries the obstruction, causing further scour to cease and allowing ambient sediment transport to refill the scour depression. Given the weight of the cable, if exposed it will not be moved on the seabed by either the naturally present tidal or wave regimes.

6.2.6.60 The resulting equilibrium scour dimensions may vary under different circumstances and depending on the dominant forcing (the relative dominance of wave or tidal action at the time). A conservative estimate for all cases is that the maximum depth of scour will be between one and three times the cable diameter (i.e. 0.09 to 0.48 m) and the maximum horizontal extent of any scour effect will be up to fifty times the cable diameter (i.e., 4.5 to 8 m). As such, any depression created will not necessarily be steeply sided. In predominantly sandy areas, the surface of the scour pit will be of similar character to the ambient bed. In more gravelly areas, a gravel lag veneer may initially form as finer sands are preferentially winnowed, but may then become buried with predominantly sandy material following recovery of the seabed if self-burial occurs.

6.2.6.61 The effects of scour potentially resulting from the exposure of 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.

6.2.6.62 A low magnitude of change that does not exceed the range of natural variability is therefore assessed to arise in an area of low sensitivity. The resulting significance of effect is of **minor significance** and therefore not significant in terms of the EIA Regulations.

Decommissioning

6.2.6.63 It is considered that the methods to be employed during decommissioning will be of a similar general nature but overall less energetic and disturbing a smaller volume of sediment than previously assessed in relation to wind farm construction. Therefore, the effects from decommissioning and their significance can only be considered to be similar to or less than that already provided above (i.e. either not significant or of minor significance).

6.2.7 Proposed Mitigation

Construction

6.2.7.1 No mitigation measures are proposed.

Operation

6.2.7.2 Offshore generating station infrastructure will be suitably monitored for unintended exposure if previously buried and for unwanted scour if exposed above the seabed. Scour protection may be applied to turbine foundations or to sections of cable that would otherwise be exposed at the seabed surface. Cable protection has dual purposes in both preventing scour and protecting the cable from external damage. The width of seabed about cable routes and the area around foundations potentially affected by either scour or protection materials is generally similar.

Decommissioning

6.2.7.3 No mitigation measures are proposed.

6.2.8 Secondary Assessment: Individual Wind Farm Sites

6.2.8.1 The impact of individual wind farms on the sedimentary regime has also been considered. More details of these assessments may be found in Technical Appendix 3.4 C (ABPmer, 2012b). The three individual sites have been assessed on the basis of a 3.6 MW layout, i.e. the largest number and closest spacing of turbine foundations and the largest corresponding potential effect on sedimentary processes for a single site.

6.2.8.2 Table 6.2-3 below summarises the results of the secondary impact assessment. Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Table 6.2-3 Secondary Assessment Summary

Impact	Telford	Stevenson	MacColl
Construction and Decommissioning			
Increase in suspended sediment concentrations as a result of foundation installation activities	Minor Significance	Minor Significance	Minor Significance
Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	Minor Significance	Minor Significance	Minor Significance
Increase in suspended sediment concentrations as a result of inter-array cable installation activities	Negligible Significance	Negligible Significance	Negligible Significance
Indentations left on the seabed by jack-up vessels and large anchors	Negligible Significance	Negligible Significance	Negligible Significance
Operation			
Changes to the sediment transport regime and geomorphology, due to the presence of the turbine foundations*	Negligible Significance	Negligible Significance	Negligible Significance
Scour effects due to the presence of the turbine foundations	Minor Significance	Minor Significance	Minor Significance
Scour effects due to the exposure of inter-array cables and cable protection measures	Negligible Significance	Negligible Significance	Negligible Significance

6.2.9 *Sensitivity Assessment*

6.2.9.1 The impact of pairs of wind farm sites on the sedimentary regime has also been considered. More details of these sensitivity assessments may be found in Technical Appendix 3.4 C (ABPmer, 2012b). The site pairs have been assessed on the basis of a 3.6 MW (site 1) + 5 MW (site 2) layout, i.e. the largest number and closest spacing of turbine foundations and the largest corresponding potential effect on sedimentary processes for a pair of sites. It is noted that there is presently no decision as to which of the three sites might be built using 3.6 MW turbines and so all possible permutations are considered.

6.2.9.2 Table 6.2-4 below summarises the results of the sensitivity impact assessments, which are the same as reported previously for the primary and secondary assessments. The significance results of the sensitivity assessments (as indicated in the table) were the same for all possible combinations of the three proposed wind farms. Other consequential (indirect) effects are also considered, where relevant, in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Archaeology).

Table 6.2-4 Sensitivity Assessment Summary

Impact	Site 1* (3.6MW) + Site 2** (5MW)
Construction and Decommissioning	
Increase in suspended sediment concentrations as a result of foundation installation activities	Minor Significance
Accumulation of sediment and change of sediment type at the seabed as a result of foundation installation activities	Minor Significance
Increase in suspended sediment concentrations as a result of inter-array cable installation activities	Negligible Significance
Indentations left on the seabed by jack-up vessels and large anchors	Negligible Significance
Operation	
Changes to the sediment transport regime and geomorphology, due to the presence of the turbine foundations*	Negligible Significance
Scour effects due to the presence of the turbine foundations	Minor Significance
Scour effects due to the exposure of inter-array cables and cable protection measures	Negligible Significance
* One of Telford, Stevenson or MacColl ** Either one of the two remaining sites (Telford, Stevenson or MacColl)	

6.2.10 *Proposed Monitoring and Mitigation: Secondary / Sensitivity Assessment*

Construction

6.2.10.1 No monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

Operation

6.2.10.2 No monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

Decommissioning

6.2.10.3 No monitoring or mitigation measures are proposed as a result of the secondary or sensitivity assessments.

6.2.11 Residual Effects: Secondary / Sensitivity Assessment

6.2.11.1 The results of the secondary and sensitivity assessments lead to the same conclusions (for each site or pair of sites) as previously shown in Table 6.2-1 above for the primary assessment.

6.2.12 Habitats Regulations Appraisal

6.2.12.1 Likely effects from the construction, operation and decommissioning of the generating station on sedimentary and coastal processes are of negligible significance and therefore do not give rise to Habitats Regulations Appraisal concerns. The effects on the physical marine environment considered in this chapter are also considered with respect to the requirements for Habitats Regulation Assessment in other chapters: Chapter 7.1 (Benthic Ecology); Chapter 7.2 (Fish and Shellfish Ecology); and Chapter 8.5 (Ornithology). Also see Chapter 12.2 (Habitats Regulations Appraisal Summary).

6.2.13 References

ABPmer, 2011a. Moray Firth Round 3 Zone: Physical Processes Baseline Assessment. ABPmer Report R1869.

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