3 Physical Environment (Offshore)

3.1 Hydrodynamic, Sedimentary and Coastal Processes

3.1.1 Baseline Information

Introduction

3.1.1.1 This chapter considers the likely significant effects of the modified offshore transmission infrastructure (modified OfTI) on the marine physical environment and draws upon the technical assessments previously undertaken for the MORL ES (MORL, 2012). A more detailed description of the methodologies and analyses used may be found in the supporting technical appendix: Metocean and Coastal Processes (Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes).

3.1.1.2 This section provides a summary characterisation of the marine physical environment in the vicinity of the modified OfTI. This includes:

- Bathymetry;
- Wind Climate;
- Hydrodynamics (Tidal Regime, Wave Climate and Stratification);
- Geology; and
- Sedimentary Processes.

3.1.1.3 A more detailed description may be found in the supporting technical appendix (Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes).

3.1.1.4 This baseline characterisation is used to inform the impact assessments that follow.

3.1.1.5 This baseline and the associated impact assessments are also used to inform the following assessments:

- Benthic Ecology (Chapter 4.1);
- Fish and Shellfish Ecology (Chapter 4.2); and
- Archaeology and Visual Receptors (Chapter 5.4).

3.1.1.6 This baseline section also includes relevant details including the following:

- Consultation with relevant statutory bodies;
- Detailed desk study and accompanying field survey to establish baseline conditions; and
- Consideration of the relevant key legislative and planning information.

Consultations

3.1.1.7 During the scoping consultations (described in more detail in Chapter 1.4 of this ES), methodologies and data sources were proposed to inform the baseline understanding of the hydrodynamic and sedimentary environments. The suggested methods included the use of previously collected and new field data, numerical modelling, desktop assessments and reference to previous studies.

3.1.1.8 Table 3.1-1 below summarises specific comments made during the 2014 scoping process. No specific comments were made regarding the development of a physical environment baseline. The baseline information provided in Section 3.1.1 and the impact assessments provided in Sections 3.1.2 and 3.1.3 below address the component issues and concerns outlined in the Table 3.1-1. Full details of all scoping responses are provided in Chapter 1, section 1.4 of this ES.

Table 3.1-1 Physical Process Issues and Concerns Expressed During the 2014 Scoping Process

Organisation	Consultation Response	MORL Approach
SNH/JNCC	[SNH/ JNCC] agree with the aspects 'scoped in' and 'scoped out' for the offshore assessment as set out [in the scoping report]. [SNH/ JNCC] consider it appropriate to focus attention on the two geological Sites of Special Scientific Interest ("SSSI") in the area – Cullen to Stake Ness Coast SSSI and Whitehills to Melrose Coast SSSI – adjacent to each of the potential landfall options at Sandend Bay and Boyndie Bay.	Impacts have been assessed as per the "scoped in" list. The two geological sites have been included in the impact assessments.
Aberdeenshire Council	Aberdeenshire Council request that consideration be given to the geological interests of Cullen to Stake Ness Coast SSSI and Whitehills to Melrose Coast SSSI. Aberdeenshire Council consider it appropriate that the potential effects of sea level rise (amongst other climate change variables) should be considered within the planning of the development (known as 'future-proofing'), particularly in respect of the cable landfall. Aberdeenshire Council state that the scoping report does not indicate whether impacts to the geological interest along this coast can be avoided or what mitigation is proposed. These should be addressed in the EIA. Aberdeenshire Council agree with the aspects 'scoped in' and 'scoped out' for the offshore assessment as set out in the scoping report. Aspects to be scoped in include: damage to geological features/designated sites.	As above.

Baseline Characteristics

3.1.1.9 The physical environment baseline characteristics of the modified OfTI corridor are summarised below, using a combination of the information collated and analysed via desktop studies and site specific surveys (Sections 3.1.1.41-3.1.1.48). The study area is shown in Figure 3.1-1.

Bathymetry

3.1.1.10 Water depths along the modified OfTI corridor are highly variable ranging from <10 m mean sea level (msl) in the shallow inshore area adjacent to the Banffshire coast to approximately 80 m msl in the Southern Trench, a long deep channel located in the southern part of the outer Moray Firth. The Southern Trench reaches depths of approximately 220 m msl off the Aberdeenshire coast to the east of the modified offshore export cable route corridor. Within the three consented wind farm sites, water depths are typically in the range 35 to 55 m msl, with depths increasing from west to east.

Water Levels

3.1.1.11 The modified OfTI is subject to semi-diurnal tidal variations in water level, with a mean spring range of approximately 3 m.

3.1.1.12 Storm surges may cause short term modification to predicted water levels and under an extreme (1 in 50-year return period) storm surge, water levels may be up to 1.25 m above predicted levels.

3.1.1.13 It is probable that relative sea levels will rise in this region during the course of the 21st Century and by 2050 is likely to be approximately 0.22 and 0.35 m higher than 1990 levels.

3.1.1.14 Climate change may be expected to slightly increase the mean water level over the lifetime of the modified OfTI; however, the tidal range about the new mean level is not likely to be measurably affected.

Currents

3.1.1.15 Depth-averaged peak spring current speeds range between approximately 0.2-0.5 m/s across the area covered by the modified OfTI, with the fastest speeds recorded along the northern margin of Telford wind farm. Within the consented wind farm sites, peak flood current speeds are approximately 10% faster than adjacent peak ebb current speeds due to the influence of the Pentland Firth. Relatively weaker currents are encountered along the modified offshore export cable route corridor.

3.1.1.16 Peak flood currents (directed approximately south or south south west into the Moray Firth) occur approximately 1.5 to 2 hours before high water at Wick; peak ebb currents (directed approximately north or north north east out of the Moray Firth) occur approximately 4 to 4.5 hours after high water at Wick. The exact phasing of individual tides varies slightly due the higher harmonics affecting tidal water levels in the region (causing consecutive high and low waters to modulate in height and range with a corresponding effect on peak current speed). Residual tidal currents (over a period of days to weeks) are directed south west or south south west into the Moray Firth.

3.1.1.17 Spring tidal excursion ellipses (which show the approximate path that a package of water would follow over the course of a mean spring tide) are quite strongly rectilinear near the coast and along the northern margin of Telford wind farm. At the coast, the major axes of the ellipses extend approximately 5 km in an east-southeast to west-northwest direction whereas within the consented wind farm sites the major axes are more typically orientated in a general north to south direction. Along much of the modified offshore export cable route corridor the spring tidal excursion ellipses are generally rotary in nature.

3.1.1.18 During an extreme (1 in 50-year return period) storm surge, current speeds may be more than twice that encountered under normal peak spring tide conditions along the modified offshore export cable route corridor.

3.1.1.19 Climate change is not expected to have any effect on the local tidal current regime (currents are largely controlled by the corresponding tidal range) over the lifetime of the modified OfTI.

Wind Climate

3.1.1.20 The prevailing wind direction is from the WSW, SW and W (225 to 270 ˚N), accounting for almost 30% of the record, and from the SSE, SE and ESE (157.5 to 112.5 ˚N), accounting for around 20% of the record. Wind speeds are in the range 2 to 15 m/s over 80% of the time. During extreme events (return period of one in ten years or more), wind speeds might peak as high as 30 or 35 m/s.

Waves

3.1.1.21 The wave regime in the outer Moray Firth includes both swell waves generated elsewhere in the North Sea and locally generated wind waves. The wave regime in the outer Moray Firth is typically characterised by fetch limited wave conditions (from the west and south-west). Longer period swell waves tend to come from offshore sectors only.

3.1.1.22 The largest waves come from the more exposed offshore sectors (from north through south east) although the southern end of the modified offshore export cable route corridor is sheltered from south-easterly waves. Offshore wave heights during extreme events from these directional sectors may be 6-7 m during relatively frequent (annual) events or as much as 9 m for the 50 year return period condition. However, waves coming from other directions within the Moray Firth are generally smaller during extreme events (4-5 m or up to 7 m, respectively) due to the relatively shorter distances available for wave growth.

3.1.1.23 The variable water depths along the modified offshore export cable route corridor mean that the ability of a given wave condition to exert influence on the seabed may also be variable. However, even in those areas where water depths exceed 30 m, storm waves sufficiently large to cause water motion at the seabed are not uncommon.

3.1.1.24 During a 1:1 year storm event, orbital currents are likely to approach 1 m/s at the northern end of the modified offshore export cable route corridor, in the relatively shallow (i.e. ~35 m msl) water over the crest of the Smith Bank. In the shallow (i.e. <20 m msl) water adjacent to the Banffshire coast, these wave induced orbital currents are expected to be even higher. Currents of this magnitude are considerably greater than tidal currents observed during peak spring tidal flows.

3.1.1.25 Climate change may cause variability in the inter-annual wave climate over the lifetime of the modified OfTI; however, no clear trends are apparent from inspection of available historical records.

Stratification

3.1.1.26 Stratification occurs in the coastal seas due to seasonal heating of the water and vertical fronts can develop between regions of freshwater influence. Previously published papers (e.g. Adams and Martin, 1986; Connor *et al*., 2006) were used to characterise stratification and fronts including their general location and characteristics in relation to primary productivity. The Buchan front is a relatively weak front located in the outer Moray Firth.

3.1.1.27 Applying general oceanographic theory, it is likely that the weak strength and natural position of the Buchan front in the outer Moray Firth is governed by the relative magnitude of tidal current flows in the adjacent inshore areas and of seasonal stratification in adjacent offshore areas.

3.1.1.28 Climate change is not expected to have any effect on the range of natural variability in the location or strength of stratification and fronts over the lifetime of the modified OfTI.

Geology

3.1.1.29 The offshore near-surface geology in the outer Moray Firth is composed predominantly of Cretaceous rocks whilst both Jurassic and Permo-Triassic rocks are encountered along the southern / inner margins of the Firth. An extensive blanket of Quaternary deposits is present across almost the entire Firth with sediment thicknesses of around 70 m commonly observed.

3.1.1.30 The Smith Bank (at the northern end of the modified offshore export cable route corridor) is a geologically constrained feature, i.e. it is a raised hard rock feature, overlain by a relatively thin veneer of more recently deposited marine sediments. The nature of these surficial marine sediments is described in the following section.

3.1.1.31 The Southern Trench (which is located between the Banffshire Coast and the three consented wind farm sites) is an enclosed deep that cuts through both Quaternary deposits and the underlying bedrock. The exact origin of the trench is unknown although may have been driven by different processes of fluvial and / or ice marginal erosion during the Quaternary period (Brooks *et al*., 2012).

Sedimentary Processes

3.1.1.32 Seabed sediments along the modified offshore export cable route corridor are variable, reflecting variability in both the prevailing hydrodynamic conditions and underlying geology. At both the northern end of the modified offshore export cable route corridor and in the vicinity of the landfall, seabed sediments generally consist of gravelly sands and sandy gravel; fine (silt and clay sized) particles are largely absent.

3.1.1.33 However, seabed sediments become progressively finer in deeper water along modified offshore export cable route corridor, becoming relatively muddy (i.e. Sand mud and Muddy sand) in the deepest parts, at the western end of the Southern Trench. The sediment character and distribution in these offshore sections is the result of the relatively benign tidal regime and the spatially variable effect of wave action at the seabed, depending upon the local water depth.

3.1.1.34 Along much of the modified offshore export cable route corridor, surficial marine sediments are generally thin (1-3 m) with the underlying glacial till very close to the surface.

3.1.1.35 Across almost the entire Moray Firth an extensive blanket of Quaternary deposits (glacial tills) are present below the marine sand veneer. The thickness of this layer is commonly observed to be in excess of 100 m although is found to be less than 20 m in the vicinity of the wind farms. These sediments are underlain by a thick unit of firm to very hard Lower Cretaceous clay.

3.1.1.36 The available evidence suggests that (bedload) material is travelling into the Firth from the north, passing along the Caithness coast and towards the inner Moray Firth. In this region, tidal currents are largely incapable of mobilising anything larger than fine sand-sized and as a result, there is only limited net bedload transport of sediment due to tidal currents alone.

3.1.1.37 However, in shallower areas (i.e. less than 30 m msl) the combination of tidal and non-tidal currents and wave induced currents during storms results in considerably higher current speeds at the bed. As a result, it is likely that the commonly present medium-sized sand is regularly mobilised during storms.

3.1.1.38 During calm conditions, suspended sediment concentrations are typically very low (approximately < 5 mg/l). However, during storm events, near bed current speeds can be markedly increased due to the influence of waves stirring of the seabed. This can cause a short-term increase in suspended sediment concentration, theoretically in the order of 1,000s to 10,000s of mg/l very close to the seabed, 100s or 1,000s mg/l in the lower water column but only 10s of mg/l in the upper water column. Coarser sediments may be transported a short distance in the direction of ambient flow or down-slope under gravity before being re-deposited. Finer material that persists in suspension will eventually be transported in the direction of net tidal residual flow.

3.1.1.39 The coastline at the landfall site is generally characterised as a sandy pocket embayment. The beach is sandy with a shallow gradient and is backed by a mixture of coastal defences, managed ground and mature vegetated sandy dunes. The beach is constrained by rocky headlands and underpinned by a bedrock platform.

3.1.1.40 Climate change is not expected to have any effect on the type or distribution of sediments within the extent of and over the lifetime of the modified OfTI.

Desktop Studies

3.1.1.41 In order to characterise the physical environment along and in the vicinity of the modified offshore export cable route corridor, various publically available data sources were used. These included:

- Digital bathymetry data sets and publications from the UK Hydrographic Office (UKHO);
- Primary tide gauge data for the Moray Firth (available from the National Tide and Sea level Facility and UKHO);
- Extreme storm surge predictions from the Proudman Oceanographic laboratory (POL);
- Charted data from the British Geological Survey (BGS 1984, 1987);
- Previously collected seabed grab data (British Geological Survey, BGS); and
- Projections of future climate change available from UKCP09 (Lowe *et al*., 2009).

3.1.1.42 Further to the additional data sets acquired, a number of key reports have also been used which hold direct relevance to the modified OfTI. These include, but are not limited to:

- Coastal Cells in Scotland: Cell 3 - Cairnbulg Point to Duncansby Head (Ramsay & Brampton, 2000);
- JNCC Coastal Directory Series: Regional Report 3 North East Scotland; Cape Wrath to St Cyrus (Barne *et al*., 1996);
- Offshore Energy Strategic Environmental Assessment -- SEA 2 (DECC, 2011b); SEA 5 (Balson *et al*., 2001; Holmes *et al*., 2004);
- Sand banks, sand transport and offshore wind farms (Kenyon & Cooper, 2005);
- The Beaches of Northeast Scotland (Ritchie, Rose & Smith, 1979).
- The Beaches of Scotland (Ritchie & Mather, 1984); and
- United Kingdom Offshore Regional Reports Series: The Moray Firth (Andrews *et al*., 1990).

3.1.1.43 Observed data are inherently limited either in temporal or spatial resolution and extent. To reduce any residual uncertainties and to provide additional data for the MORL ES (MORL, 2012), numerical tidal and wave models were created. Full details of the numerical modelling tools used may be found in the MORL ES (MORL, 2012, Appendix 3.4 B).

Site Specific Surveys

3.1.1.44 The following surveys were undertaken by MORL in order to provide primary site specific data to the original Project. These data have been used in conjunction with other secondary data and literature (outlined in the above) to inform the baseline characterisation and impact assessments within the area of the modified OfTI.

3.1.1.45 One wave buoy and three seabed frames (collecting wave, current, water level and suspended sediment information) were deployed at strategic locations within the three consented wind farm sites by Partrac (MORL, 2012, Appendix 3.4 A: Metocean and Coastal Processes Baseline).

3.1.1.46 A seismic survey of sub-bottom geology in the wind farm sites was undertaken between May and September 2010 and is reported in MORL (2012, Appendix 3.4 A: Metocean and Coastal Processes Baseline).

3.1.1.47 An additional high resolution swath bathymetry survey, side scan sonar survey and seismic survey of sub-bottom geology within the modified OfTI corridor was undertaken in May and June 2014.

3.1.1.48 Sixty nine grab samples of surficial seabed sediments were collected within the three consented wind farm sites as part of the benthic ecology survey and reported in MORL (2012, Technical Appendix 4.2 A: Benthic Ecology Characterisation Study (Wind Farm Sites). A further eleven grab samples of surficial seabed sediments were collected along the modified OfTI export cable corridor in 2014 as part of the benthic ecology survey and are described fully in Technical Appendix 4.1 A: Subtidal Ecology Characterisation of this ES.

Legislative and Planning Framework

3.1.1.49 Legislative and planning frameworks do not provide specific requirements in relation to the baseline understanding of hydrodynamic, sedimentary and coastal processes. An understanding of the baseline environment is of course expected.

3.1.1.50 The methods used are however consistent with the guidelines for data collection in support of offshore wind farm environmental impact assessment provided by: Cefas (2004, 2011); COWRIE (2009) and EMEC & Xodus AURORA (2010).

3.1.2 Impact Assessment

Summary of Effects and Mitigation

3.1.2.1 This section considers the likely significant effects of the modified OfTI on the physical hydrodynamic environment (the tidal and wave regimes) and the physical sedimentary environment (patterns of sediment transport and geomorphological evolution). This assessment is informed by the baseline information described in Section 3.1.1 and Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes.

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

- Benthic Ecology (Chapter 4.1);
- Fish and Shellfish Ecology (Chapter 4.2); and
- Archaeology and Visual Receptors (Chapter 5.4).

3.1.2.3 The effects that were assessed are:

- Changes to the tidal regime due to the presence of the offshore export cable and offshore platforms (OSP);
- Changes to the wave regime due to the presence of the offshore export cable and OSPs;
- Increase in suspended sediment concentrations as a result of OSP installation activities and the presence of the OSP foundations;
- Increase in suspended sediment concentrations as a result of export cable installation activities;
- Disturbance of coastal morphology at the proposed landfall sites; and
- Scour effects due to the presence of the OSP foundations, export cables and cable protection measures.

Summary of Impacts

3.1.2.4 Receptors considered in this assessment are:

- The Smith Bank;
- Seabed within the offshore export cable route corridor;
- Designated Coastal Habitats;
- Recreational Surfing Venues; and
- Coastal morphology at the export cable landfall.

3.1.2.5 Receptors scoped into the assessment were identified on the basis of:

- Comments received during the scoping stage;
- Guidance on the assessment of marine physical processes for renewable energy developments (Technical Appendix 3.1 A: Hydrodynamic, Sedimentary and Physical Processes); and
- Understanding of the likely spatial and temporal scale of effects (this was informed in part by the findings presented in the MORL ES (2012)).

3.1.2.6 All impacts associated with hydrodynamic, sedimentary and coastal process related receptors were found to be of either negligible significance or minor significance.

Summary of Proposed Mitigation Measures and Residual Effects

3.1.2.7 Scour protection for cables and OSP foundations is proposed where required to prevent scour.

3.1.2.8 Table 3.1-2 below summarises the results of the impact assessment.

Table 3.1-2 Impact Assessment Summary

Effect	Receptor	Pre-mitigation Effect	Mitigation	Post-Mitigation Effect
Construction/Decommissioning				
Changes to the tidal and wave regimes (Cables)	The Smith Bank, Designated Sites and Recreational Surfing Beaches	Negligible Significance	None	Negligible Significance

Effect	Receptor	Pre-mitigation Effect	Mitigation	Post-Mitigation Effect
Increase in suspended sediment concentrations and changes in sediment type/thickness at the seabed as a result of export cable installation activities	The Smith Bank & seabed along the modified OfTI corridor	Minor Significance	None	Minor Significance
Increase in suspended sediment concentrations and changes in sediment type/thickness at the seabed as a result of OSP installation activities	The Smith Bank	Minor Significance	None	Minor Significance
Disturbance of coastal morphology at the landfall site	Inverboyndie Landfall, seabed along the cable corridor and SSSIs	Negligible Significance	None	Negligible Significance
Operation				
Changes to the tidal and wave regimes (Cables)	The Smith Bank, Designated Sites and Recreational Surfing Beaches	Negligible Significance	None	Negligible Significance
Changes to the tidal and wave regimes (OSPs)	The Smith Bank, Designated Sites and Recreational Surfing Beaches	Negligible Significance	None	Negligible Significance
Changes to the sediment transport regime due to the presence of the OSP foundations	The Smith Bank	Negligible Significance	None	Negligible Significance
	Designated Coastal Habitats	Minor Significance	None	Minor Significance
Scour effects due to the presence of the OSP foundations	The Smith Bank	Minor Significance	Scour protection	Negligible Significance
Scour effects due to the exposure of export cables	The Smith Bank & seabed along the modified OfTI corridor	Negligible Significance	Scour protection	Negligible Significance
Scour effects due to cable protection measures	The Smith Bank & seabed along the modified OfTI corridor	Negligible Significance	None	Negligible Significance
Decommissioning				
(Partial impacts only)	As 'Construction'	Negligible or Minor Significance	None	Negligible or Minor Significance

Introduction to Impact Assessment

3.1.2.9 This section describes the likely significant effects of the modified OfTI on physical processes in the marine environment and includes effects on water levels, currents, waves, sediment transport and geomorphology.

3.1.2.10 The baseline wave, tidal and sedimentary conditions are described above in Section 3.1.1 of this document and in the supporting Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes.

Details of Impact Assessment

3.1.2.11 This assessment considers the effects of the modified OfTI on physical process receptors identified within and nearby to the area covered by the modified OfTI. Physical process receptors that are potentially sensitive to changes in the physical baseline environment include:

- The Smith Bank – A submerged bathymetric high (30-50 m deep) in the outer Moray Firth with a core of stable 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 effects from the modified OfTI and wind farm infrastructure.
- Seabed within the modified offshore export cable route corridor – generally deeper than the Smith Bank (50-100 m along most of its length, shoaling towards the landfall). Predominantly sandy with gravel and mud in varying proportions. The proportion of mud generally increases in central parts of the Moray Firth and in deeper water. Sediments become coarser gravels offshore of the landfall. Sediments are sandy again within Inverboyndie Bay. The seabed along the modified offshore export cable route corridor is not subject to any special designations.
- Designated sites - SPA, SAC, SSSI and Ramsar sites on the Moray Firth coastline. A full list of the sites considered and a summary of their morphological type may be found in Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes. These receptors are potentially sensitive to local changes in tidal range, wave climate and sediment supply.
- Recreational surfing venues - A full list of the sites considered and a summary of their baseline wave characteristics may be found in the Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes. These receptors are variably sensitive to local changes in tidal range and wave climate.
- Inverboyndie landfall site - A sandy beach within an embayment bounded by rocky headlands. The beach at the landfall is backed by low coastal protection and the hinterland is both managed and vegetated. The local landfall site is surrounded by, but not part of, the Whitehills to Melrose Coast SSSI.

3.1.2.12 A change in tidal or wave regimes alone does not necessarily imply an effect if there are no receptors present which are sensitive to the change. Consequential (indirect) effects on sediment transport patterns and morphology are also considered.

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

Rochdale Envelope Parameters Considered in the Assessment

3.1.2.14 The range of parameters adopted within this physical process assessment are summarised in Table 3.1-3 below. The parameters set out below define the "Rochdale Envelope" realistic worst case scenario for each likely significant effect on the physical environment offshore. These are drawn from a range of development options set out in the project description in Chapter 2.2 (Project Description).

Table 3.1-3 Rochdale Envelope Parameters Relevant to the Impact Assessment

Type of Effect	Rochdale Envelope Scenario Assessed
Construction & Decommissioning	
Changes to the tidal and wave regimes	Up to four cables with a 0.25 m diameter, initially laid to the seabed, then buried or otherwise protected for their operational lifetime.
Increase in suspended sediment concentrations as a result of offshore export cable installation activities	Up to four parallel cable trenches excavated by energetic means (e.g. jetting). Single trench (i.e. multiple export cable trenches not simultaneously installed) with cross-section of disturbance 3 m wide by 3 m deep in 'V' shaped profile. 100% of material resuspended.
Increase in suspended sediment concentrations as a result of OSP foundation installation activities	Two OSPs. Foundation type assessed – jack-up.
Disturbance of coastal morphology at the landfall site	Open trenching or horizontal directional drilling (HDD) at the proposed landfall location.
Operation	
Changes to the tidal and wave regimes	Cables 0.25 m diameter, buried or otherwise protected for their operational lifetime.
	Two OSPs. Foundation type assessed – jacket.
Changes to the sediment transport regime due to the presence of the OSP foundations	Two OSPs. Foundation type assessed – jack-up.
Scour effects due to the presence of the OSP foundations	
Scour effects due to the exposure of transmission cables and due to cable protection measures	Offshore export cables and cable protection measures.

OSP Foundations

3.1.2.15 As part of the modified OfTI, a maximum of two OSPs will be installed within the MORL Zone. The final locations of these two OSP structures have not yet been established, but do not influence the overall outcome of the assessments due to their relatively small scale when compared to the offshore wind farm infrastructure.

3.1.2.16 OSPs may utilise a jacket or jack-up foundation type, both of which are similarly characterised as a lattice structure. Of these, the jacket is considered to have the greatest relative cross-sectional area and blockage effect. The base will be square in cross-section. The jack-up has the most number of pin-piles as it will be fixed to the seabed at the end of each primary member using up to four pin piles.

Installation Methods for OSP Pin Piles

3.1.2.17 Each pinned jack-up type OSP foundation requires up to 16 pin piles to be inserted into the seabed. The most efficient and preferred method for installation is to simply drive (hammer) each pile in turn to the required depth. In some circumstances the soil conditions along some or all of the profile may pose too much resistance for driving alone and a pilot hole must be drilled ahead of the pile (a drill-drive methodology). The drill arisings (cuttings) will then be released directly into the water column, or captured into a hopper and subsequently disposed of in a controlled manner.

3.1.2.18 Up to sixteen pin piles of 3 m diameter will be consecutively installed at each foundation (worst case a 3 m diameter hole, 60 m deep). It is assumed to take 12 hours to drill one pile, a drilling rate of 0.00139 m/s, releasing 0.00982 m^3/s or 26 kg/s of arisings. An allowance of 3 hours is made for repositioning between piles and 12 hours between foundations. These assumptions are the same as previously used in the MORL ES (MORL, 2012).

3.1.2.19 The geophysical survey data (collected in 2010) shows that the eastern part of the Moray Firth Round 3 Zone is generally characterised by a marine sand layer overlying a more consolidated till. The marine sand comprises, on average, 83 % sand, 8 % silt and 9 % clay material. The underlying till comprises, on average, 50 % sand, 20 % silt and 30 % clay material. The thickness of these layers has been determined, at each foundation location, using the subsurface geophysical data. The proportion of each sediment fraction being released is adjusted in time, according to the thickness of the marine sand layer and the drilling rate.

3.1.2.20 In the present study, the worst case assumption is that all sediments arise as a fully fluidised mixture. In practice, the nature of the arisings may vary considerably depending upon the exact geotechnical nature of the sub-soils and the drill head used. Also, arisings may consist of larger chunks which will be very differently transported and (locally) deposited.

3.1.2.21 Suction caissons are the alternative to pin piles for the jacket foundation type. Suction caissons are installed to a shallower depth without drilling and so are not expected to disturb the seabed sediments or, therefore, place sediment into suspension.

Scour Protection

3.1.2.22 The risk of scour destabilising or undermining marine structures is often mitigated by the use of scour protection. This may take various forms including: rock placement or gravel filter layers; geo-textile or frond matting; and concrete mattresses.

3.1.2.23 Scour protection is to be used in conjunction with all OSP foundation options. Scour protection for foundations will extend between 10 and 20 m from the edge of the structure for pin piled and suction caisson options, respectively. Scour protection for exposed cables will typically extend in the order of a few metres either side of the export cable location.

3.1.2.24 In the present study, the worst case assumption used is that there will be a sufficient window of time between installation of the foundation and the application of scour protection, which would allow the maximum possible dimensions of scour to develop.

Number and Length of Export Cables

3.1.2.25 The OfTI export cable route corridor is shown in Figure 3.1-1 and makes landfall in the vicinity of Inverboyndie. Up to four parallel cable trenches will be installed within the export cable corridor, each containing one cable. The cables and trenches will be separated by tens or hundreds of metres, depending on the water depth, and will not be installed simultaneously.

3.1.2.26 Should two substations be required, approximately 70 km of export and inter-platform cables will also be installed within the three consented wind farms.

3.1.2.27 The export cable diameter will be in the order of 0.25 m. Due to their necessary metal content and construction, the cables are relatively heavy (order of tens of kilograms per metre of length) and therefore unlikely to be moved directly by waves or currents once laid.

Offshore Export Cable Burial Methodology

3.1.2.28 The local geology and geomorphology of the seabed will determine the cable installation method used (Royal Haskoning and BOMEL, 2008). The proposed methods of cable installation generically include:

- Ploughing;
- Jetting; and
- Mechanical cutting tools.

3.1.2.29 Where seabed conditions do not allow for cable burial, concrete mattress or rock placement might be used to cover and protect surface laid cables.

3.1.2.30 The available information indicates that the majority of offshore wind farms use either ploughing or jetting methods to install cables.

3.1.2.31 Consistent with the proposed design and the evidence and case studies provided in Royal Haskoning and BOMEL (2008), the realistic worst case cable installation parameters are:

- The trench has a 'V' shaped profile 3 m wide at the surface and up to 3 m deep (1 m is the target depth);
- 100 % of sediment volume in the trench may be resuspended by any method;
- The material will likely arise as chunks but worst case assumption is that all sediments are fluidised as a fine suspension; and
- Cables will be separately (not simultaneously) installed.

Offshore Export Cable Landfall Methodology

3.1.2.32 The cable landfall is at Inverboyndie on the south coast of the Moray Firth. Inverboyndie Beach is a pocket embayment, enclosed by rocky headlands and with a sandy veneer overlying a rock platform. A more detailed description of this location is given in Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes.

3.1.2.33 The rocky coastal exposures surrounding Inverboyndie are designated as the Whitehills to Melrose Coast Site of Special Scientific Interest (SSSI). The designated feature is the 'structural and metamorphic geology', i.e. the accessibility, visibility and integrity of the rocky outcrops that are present on the exposed coastline. However, the natural absence of visible exposures on the sandy beach and hinterland at Inverboyndie mean that the landfall locality is not subject to the same designation.

3.1.2.34 The most likely cable landfall options are:

- The cable will be laid into a trench cut downwards into the beach surface and subsequently buried by backfilling the trench; or,

- A Horizontal Directional Drill (HDD) will be used to create an underground conduit for the cables, from a point onshore behind the beach, to a point offshore. The drilling will be initiated from the onshore end of the route and all drill arisings will be collected there.

EIA Methodology

3.1.2.35 The methodology and terminology for the assessment of significance of any impacts is the same as that described in the MORL ES (MORL, 2012, Section 6.1: Hydrodynamics (Wave Climate and Tidal Regime)) in relation to the wind farm infrastructure.

3.1.2.36 The significance of the potential impacts on the identified coastal process receptors (described in (Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes) has been assessed using the following method and terminology.

3.1.2.37 Firstly, the magnitude of any impacts has been quantified to the extent practicable, considering all the dimensions of the predicted impact 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.

3.1.2.38 The magnitude of the impact has been considered in relation to the following spatial and temporal scales.

3.1.2.39 Spatial Scales:

- Onsite – impacts that are limited to the wind farm area or cable corridor (i.e. the near-field study area);
- Local – impacts that are limited to the wind farm area or cable corridor and generally within the area of one tidal excursion (or a similar 'buffer' around the areas);
- Regional – impacts that are experienced at a regional scale e.g. the Moray Firth;
- National – impacts that are experienced at a national scale; and
- Transboundary / International – impacts that are experienced at an international scale i.e. affecting another country or international water.

3.1.2.40 Temporal Scales:

- Short-term – impacts that are predicted to last only for the duration of specific construction operations e.g. noise for piling and plume dispersion;
- Medium-term – impacts that are predicted to last during the construction period (e.g. 1-3 years);
- Long-term – impacts that will continue beyond the construction period but will cease in time (e.g. recovery of benthos, vessel movements);
- Temporary – impacts that are predicted to be reversible and will return to a previous state when the impact ceases or after a period of recovery;
- Permanent – impacts that cause a permanent change in the affected receptor or resource that endures substantially beyond the project lifetime;

- Continuous – impacts that occur continuously or frequently; and
- Intermittent – impacts that are occasional or occur only under specific circumstances.

3.1.2.41 Secondly, the importance, value and/or sensitivity of the impacted receptors or sites has been estimated. In the context of physical processes and in this report, the sensitivity of the impacted physical environment will be 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 impact on ecological or socio-economic receptors) will be subsequently provided by other topic assessments.

3.1.2.42 Thirdly, the significance of an impact of a given magnitude has been determined on the basis of the magnitude and sensitivity as follows:

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

3.1.2.43 Impacts of negligible and minor significance are considered to be not significant in relation to the present EIA regulations.

Impact Assessment
Construction
Changes to the Tidal and Wave Regimes (Transmission Cables)

3.1.2.44 Changes to the tidal and wave regimes as a consequence of the OSPs will be greatest once all the OSPs have been fully installed, i.e. during the operational phase. Any effects during the construction phase will be subordinate to those experienced during the operation phase and therefore have not been considered in this section.

3.1.2.45 Cables will be laid onto the seabed through the water column. It is intended to then bury the cables along most of their length. Where cable burial is not possible, cables will remain surface laid under cable protection measures (rock placement or mattressing). Introducing these materials and machines to the baseline environment will present some small blockage to water movements locally.

<u>Sensitive Receptor: The Smith Bank, Designated Sites and Recreational Surfing Venues</u>

3.1.2.46 The diameter of the transmission cables (order of 0.25 m) is too small to modify the ambient currents other than locally (to a distance of no more than the order of tens of centimetres from the cable) and only then when and where it is both submerged in the water and exposed above the seabed (as may happen during the construction period). As such, if the cable is laid and buried in one continuous operation, these effects will last for the order of seconds or minutes locally and would be small in comparison to the (also relatively small) disturbance associated with the presence and passage of the cable burial machine. If the cable is laid initially onto the seabed surface and buried more than a few hours later, more persistent but still small magnitude change to local currents may lead to local scour.

3.1.2.47 The diameter of the transmission cables is also too small to modify the ambient wave regime (height, period, direction). The cable may however interact locally with the oscillatory water motion under individual waves as described in the previous paragraph in relation to tidal currents, if the waves present are sufficiently large to cause movement of water at the seabed.

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

3.1.2.49 The nature, magnitude, sensitivity and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Increase in Suspended Sediment Concentrations (SSC) and Changes in Sediment Type/Thickness at the Seabed as a Result of Offshore Export Cable Installation Activities

3.1.2.50 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 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 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 ES chapters (Chapter 4.1: Benthic Ecology, Chapter 4.2: Fish and Shellfish Ecology and Chapter 5.4: Archaeology).

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3.1.2.51 On the basis of the evidence base (Royal Haskoning & BOMEL, 2008), cable installation by burial into the seabed along the modified offshore export cable route corridor will have a relatively large magnitude effect on SSC (elevated to order 100s to 10,000s mg/l). However, the effect will be short-term (order of seconds to minutes, depending on the sediment grain size and degree of aggregation) and will be largely localised to the cable installation location (main effect within 10s of metres).

3.1.2.52 Previously undertaken monitoring of SSC levels during similar cable installation works (e.g. ABPmer, HR Wallingford & CEFAS, 2010) have consistently validated this general assumption.

3.1.2.53 In order to quantify the likely estimated levels of effect in the present study, the following assessment presents a worst case scenario for energetic sediment release, expressed per metre of trench length.

- The maximum trench dimensions for all proposed burial methods are 3 m wide at the surface x 3 m deep with a 'V' shaped profile = 4.5 m^3/m sediment disturbance;
- It is assumed that in the worst case, all of the material disturbed will be ejected from the trench = 4.5 m^3/m sediment release;

- The porosity of the material is conservatively estimated as 20 % void = 3.6 m^3/m sediment material release;
- The material is likely a quartz mineral with density 2650 kg/m^3 = 9,540 kg dry mass sediment release per metre of trench dug;
- The resulting levels of SSC depend upon the volume of water into which this sediment volume is mixed (which is in turn dependent upon the height of sediment ejection, the settling rate of the sediment and the ambient current speed); and
- The resulting thickness of sediment deposition depends upon the area of seabed over which this sediment volume is deposited (also dependent upon the height of sediment ejection, the settling rate of the sediment and the ambient current speed).

3.1.2.54 The elevation to which the sediment might be ejected is not known with certainty and may vary between burial methodologies, sediment types and the nature of the hydrodynamic regime at the time of the release. A lower height of ejection will result in a higher level of SSC and thickness of deposition but with a smaller footprint of effect, and vice versa. This uncertainty is addressed here by providing results for a range of nominal ejection heights.

3.1.2.55 Surficial seabed sediments are typically sands or gravelly sands within the three consented wind farms, however, these are generally only present as a relatively thin surface layer (~0.5 m thick). The dominant grain sizes present in these sandy surface sediments are medium sands (250-500 µm diameter). In the sandy layers, the fine material content is known to be small (<5 %) and any gravel content will deposit directly to the seabed locally. The settling velocity of such medium sands is approximately 0.05 m/s (using equations from Soulsby (1997).

3.1.2.56 Below the sandy veneer are till deposits, characterised as stiff clays with coarse inclusions. It is most likely that this material will arise as large chunks, depositing directly to the seabed locally without remaining in suspension. For the purposes of the present study, a worst case assumption is that all sediments arise as a fully fluidised mixture. The settling velocity of such fine material is approximately 0.0001 m/s (using equations from Soulsby (1997).

3.1.2.57 The typical peak tidal current speed in the three consented wind farms and so at the start of the OfTI export cable corridor is 0.5 m/s on mean spring tides and 0.25 m/s on mean neap tides. Values are typically lower elsewhere along the corridor. The value 0.25 m/s is used here as a condition representative of most normal states of flow during individual tides and over the spring-neap cycle.

3.1.2.58 These values are applied in Table 3.1-4 to Table 3.1-6 below to quantify the total effect per metre of trench length dug. The table assumes that the total mass of sediment (9,540 kg) is resuspended evenly up to a (variable) ejection height. The time required for sediment to settle (at 0.05, 0.005 or 0.0001 m/s for gravel, sand or fines, respectively) through the nominal height of ejection is calculated to yield the duration of the effect. The length scale of the effect is the furthest distance travelled by the plume (in a downstream direction), found as the product of the ambient current speed (0.25 m/s) and the duration of the effect. The estimate of mean SSC is found by dividing the total mass of sediment by the volume of the triangular wedge of water through which the sediment will settle ([ejection height x downstream distance] ÷ 2). The average thickness of any resulting seabed deposit is found by dividing the total volume of sediment (4.5 m^3) by the footprint (length scale of the effect x 1 m).

3.1.2.59 Table 3.1-4 to Table 3.1-6 below provide an indicative range of results for trenching along the cable route, which may include a variety of sediment types, including nominally gravelly, sandy and muddy sections.

Table 3.1-4. Extent and magnitude of effect of export cable trenching in gravels (settling velocity 0.5 m/s)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mg/l)	Average Thickness of Deposit (m)
1	2	<1	38,160,000	9.000
5	10	3	1,526,400	1.800
10	20	5	381,600	0.900
25	50	13	61,056	0.360

Table 3.1-5. Extent and magnitude of effect of export cable trenching in medium sands (settling velocity 0.05 m/s)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mg/l)	Average Thickness of Deposit (m)
1	20	5	3,816,000	0.900
5	100	25	152,640	0.180
10	200	50	38,160	0.090
25	500	125	6,106	0.036

Table 3.1-6. Extent and magnitude of effect of export cable trenching in fine sediments (settling velocity 0.0001 m/s)

Ejection Height (m)	Duration of Effect (s)	Length Scale of Effect (m)	Indicative Mean SSC (mg/l)	Average Thickness of Deposit (m)
1	10000	2500	7,632	0.002
5	50000	12500	305	<0.001
10	100000	25000	76	<0.001
25	250000	62500	12	<0.001

3.1.2.60 The assessment shows that cable burial will lead to:

- Levels of SSC potentially elevated above the natural range of variability, but:
  - Only over a small distance or area;
  - Only close to the seabed; and
  - Only as a temporary effect and typically lasting only a short time.
- The resulting thickness of deposition may exceed the range of natural variability in seabed level, but:
  - Only over a small distance or area; and
  - Fine grained material will likely be dispersed and deposited over such a wide area that the thickness will not be measurable in practice (<1 mm).

3.1.2.61 A critical thickness of sediment deposition with relevance to benthic ecology is 0.05 m. Given the finite dimensions of the trench, the maximum possible distance from the trench over which displaced sediment of any type might deposit to a thickness of 0.05 m is 90 m, i.e. affecting an area of 90 m^2 seabed, per metre of trench installed. Dispersion over a larger area would lead to a smaller thickness of deposition. In practice the deposition is likely to be confined to a smaller area, with a correspondingly greater average thickness. Such a thickness of sediment is in the same order as that which might be disturbed and redeposited during a large storm event.

3.1.2.62 With regards to fine sediments, it is more likely that if resuspension occurs, sediments will disperse throughout much of the water column and, as shown in Table 3.1-6, resulting levels of SSC and the thickness of any subsequent deposits would be very small and within the range of natural variability.

3.1.2.63 Consistent with the findings of Royal Haskoning and BOMEL (2008), locally redeposited sands and gravels will be of the same type as that naturally present and so will not cause any change to the seabed sedimentary character. Where fine material is deposited onto another sediment type in a sufficient thickness, it may temporarily affect sediment character until it is dispersed. Once deposited, all sediment will join the natural sedimentary environment and essentially ceases to present any further effect.

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

3.1.2.65 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 and an effect of **minor significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.66 It is noted here that within MORL (2012), an assessment was made relating to potential effects associated with the installation of two cable trenches whereas the modified OfTI includes for up to four cable trenches. However as previously stated, these cables will not be installed simultaneously so each event will be discrete from one another. Accordingly, the nature, magnitude, sensitivity and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Increase in Suspended Sediment Concentrations and Changes in Sediment Type/ Thickness at the Seabed as a Result of OSP Foundation Installation Activities

3.1.2.67 An increase in SSC may arise during any drilling activities used for pin piling the foundations. 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 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 ES chapters (Chapter 4.1: Benthic Ecology, Chapter 4.2: Fish and Shellfish Ecology and Chapter 5.4 Archaeology).

<u>Sensitive Receptor: The Smith Bank</u>

3.1.2.68 The release of sediment into the upper water column during drilling works will initially lead to a local increase in suspended sediment concentration. 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.

3.1.2.69 To quantitatively estimate the likely magnitude and extent of the increase in SSC, currents from the calibrated and validated tidal model were used in conjunction with a plume dispersion model (MORL, 2012). It was found that in the worst case, drilling pin piles for jack-up foundations would yield the following:

- The maximum localised increase in SSC is predicted to be 30-40 mg/l, depending on the state of the tide and the local water depth at the time and location of the release. These maximum levels of effect are contained within 50-100 m of the dredger and only occurring during sediment release;

- SSC in the advected main plume (centred along the downstream tidal axis) is reduced to 20 mg/l or less by 500-1,000 m downstream and to 10 mg/l or less by 2,000-3,000 m downstream;
- The effects described above are only present during and up to 1 hour after the cessation of drilling, after which time, SSC is reduced to < 4 mg/l due to dispersion and deposition to the seabed;
- In principle, the maximum length of the advected main plume is initially limited to the tidal excursion (7.1 km on spring tides, 3.6 km on neap tides) but will normally be less than this as each drilling (release) event lasts less than one half tidal cycle;
- Fine material deposited to the seabed can be resuspended by stronger currents during spring tides (> 0.3-0.4 m/s) or by storm events, leading to a dispersed low level increase in SSC of 1 to 2 mg/l;
- Sands deposited to the seabed will merge with the naturally present sedimentary environment and pose no further impact if subsequently reworked;
- Re-suspended material is mostly re-deposited to the seabed (SSC <1 mg/l) when current speeds fall below the locally critical value (i.e. during neap tides and around slack water periods during spring tides); and
- The dispersed small magnitude effects on SSC are advected in a net south or south westerly direction outside of the site, i.e. the direction of residual transport by tidal currents.

3.1.2.70 The resulting thickness of deposition may exceed the range of natural variability in seabed level, but:

- Only over a small distance or area; and
- Fine grained material will likely be dispersed and deposited over such a wide area that the thickness will not be measurable in practice (<1 mm).

3.1.2.71 Effects are generally of a magnitude consistent with the natural range of variability (<5 mg/l during calm periods to 100s to 1,000s 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.

3.1.2.72 Drilling in the marine environment is a well-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 likely limit levels of SSC resulting from the normal operation of such machines to levels that are generally acceptable according to a broad range of standards and in a variety of different environments.

3.1.2.73 A small 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.

3.1.2.74 The nature, magnitude and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The duration and extent of the predicted potential effect are however reduced, due to the smaller number of OSPs being installed (2 instead of 8).

Disturbance of Coastal Morphology at the Landfall Site

3.1.2.75 The modified OfTI will be buried through the nearshore, intertidal, beach and hinterland areas of the modified export cable landfall location. The disturbance caused by this operation may potentially lead to resuspension of sediments and a disruption to coastal processes. A full cable landfall impact assessment has been undertaken and results presented in Technical Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes. Key details are summarised below.

<u>Sensitive Receptor: Export Cable Landfall, Seabed Along the Modified OfTI Corridor, Cullen to Stake Ness Coast SSSI & Whitehills to Melrose Coast SSSI</u>

3.1.2.76 Open trenching techniques involve mechanically excavating a trench through the beach and hinterland to the jointing bay. The offshore export cable is placed in the trench, which is then backfilled. Open cut trenching can be a fast, economical means of installing cables but the technique poses some engineering challenges in a tidal environment to keep the trench open during tidal inundation.

3.1.2.77 Excavating a trench across the nearshore and intertidal zone has the potential to affect local morphology and sedimentary processes, including the relative bed level, seabed mobility and local longshore sediment transport. Trench excavation would be completed (potentially requiring ongoing excavations to maintain the trench opening and depth during subsequent tidal cycles) before the cable is installed and the trench backfilled. It is possible that the excavation will include both the temporary removal of sand and cutting of rock in places to locate the cable below the minimum expected bed level. A temporary jointing pit may be used during installation, which may be located in or above the intertidal zone. Given that the main operations will likely be undertaken during relatively calm conditions (when longshore transport rates are minimal) and only lasting a short period of time (expected to be no more than a few days), the only expected effect on coastal processes is likely to be a temporary and localised increase in SSC and the temporary presence of either a trenched depression or furrow in the beach. With or without backfilling, a trench in sand will be quickly incorporated back into the natural environment within at most a few tidal inundations. No more extensive or longer term effect is expected.

3.1.2.78 To justify the assumption of no potential for long term interaction between open trenched export cables and the coastal zone, the export cable burial design should meet the following conditions during the expected lifetime of the installation:

- Where practicable, the export cable will be suitably deeply buried from onshore to the depth of closure (the area of seabed normally exchanging sediment with the beach on seasonal and inter-annual time scales) to prevent export cable exposure. This depth will be determined as part of the detailed engineering plan and will also consider any requirements for protection; and
- Any fixed onshore infrastructure (with the exception of the temporary jointing pit) will be located onshore of the high-water mark and any important coastal features, accounting for any predicted coastal retreat.

3.1.2.79 If practicable, HDD may be used instead of trenching to create an underground conduit for the cable between the offshore and onshore parts of the route at the landfall. This method has historically been shown to cause minimal direct disturbance to the existing coastline and will also not leave any infrastructure exposed in the active parts of the beach (onshore or offshore) and so will not affect littoral processes.

3.1.2.80 To justify the assumption of no potential for interaction between the cables and the coastal zone, the HDD route design would meet the following conditions during the expected lifetime of the installation:

- The seaward exit point of the HDD will be located as far offshore as practicable towards the depth of closure;
- The cable will also be buried to a suitable depth between the seaward exit of the HDD and the depth of closure; and
- The landward exit point of the HDD will be located onshore of the high-water mark and any important coastal features, accounting for any predicted coastal retreat.

3.1.2.81 The majority of drill arisings will be captured at the onshore end of the HDD route and so will not cause any effects with regards to water quality during installation.

3.1.2.82 A quantitative assessment (based on the sediment types present and the typical intra-annual wave regime at the landfall location, derived from the wave models) indicates that the beach closure depth in the vicinity of the proposed landfall location is in the order of 11 m. It is conservatively assumed that this depth is relative to the Lowest Astronomical Tidal water level (LAT). There can be no potential for the offshore export cable to interact with the wave, tidal or sedimentary regimes directly associated with maintaining the beach, provided that an adequate depth of burial (either through trenching or HDD, or a combination of both) is achieved between the beach and offshore of the present day 11 m depth contour. Climate change will lead to mean sea level rise and so will not affect the identified locations on the basis of present day bathymetry.

3.1.2.83 The effects of offshore export cable landfall operations are generally of a magnitude consistent with the natural range of variation in beach morphology. The main effects during installation will be localised (order of metres). Effects of open trenching will also be temporary (order of hours to days) in most locations except where dune crests or vegetation are disturbed (order of days to months or years). During the operational phase, provided a sufficient burial depth is achieved and the landward jointing station is located sufficiently far back to account for rollback of the dunes in the lifetime of the installation, the cable landfall will have no further potential to affect the morphology of the coastline.

3.1.2.84 This effect is therefore of **negligible significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.85 The nature, magnitude, extent, duration and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Operation

Changes to the Tidal and Wave Regimes (Transmission Cable)

3.1.2.86 Cables will be buried beneath the seabed or under cable protection measures. Introducing materials to the baseline environment that are proud of the seabed will present some small blockage to water movements locally.

<u>Sensitive Receptor: The Smith Bank, Designated Sites and Recreational Surfing Venues</u>

3.1.2.87 It is anticipated that during operation, the offshore export cables will be buried either in a trench or under other protective materials. Buried cables present no obstacle to flows and so will not interact with the tidal and wave regimes. The dimensions of cable protection materials (maximum approximately 1 m high and in the order of 2-3 m wide with a sloped profile) are small both in an absolute sense and relative to the water depth. As such, cable protection measures have very little potential to interact with, or therefore to affect the ambient wave and tidal regimes.

3.1.2.88 Sections of offshore export cable and/or cable protection measures that are (or become) exposed on the seabed have the potential to interact locally with tidal and wave flows but are of too small a physical scale to modify the regimes. The extent of any effect is similar to that described in relation to local scour.

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

3.1.2.90 The nature, magnitude, extent, duration and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Changes to the Tidal and Wave Regimes (OSPs)

3.1.2.91 Changes to the tidal and wave regimes (water levels and currents and the joint statistics of wave height, period and direction) may arise from interaction of tidal currents and individual waves with obstacles in the water column (in this case the OSP foundations). The effect of individual foundations is principally controlled by the foundation shape and dimensions. The effect of multiple foundations is additionally controlled by the total number of foundations, their spacing and layout relative to tidal currents or wave direction. A change in tides or waves (instantaneous magnitude and direction within the range of natural variability) alone is not considered to constitute an effect as there are no physical process receptors that are directly sensitive to such changes. Consequential (indirect) effects on the sedimentary environment are considered in the following assessment section. Other consequential (indirect) effects are also considered, where relevant in other ES chapters (Chapter 4.1: Benthic Ecology, Chapter 4.2: Fish and Shellfish Ecology and Chapter 5.4 Archaeology).

<u>Sensitive Receptor: The Smith Bank, Designated Sites and Recreational Surfing Venues</u>

3.1.2.92 An assessment of the effect on tidal and wave regimes of up to 339 turbine foundations and eight OSPs in the three consented wind farms was provided in the MORL ES (MORL, 2012, Chapter 13.1). The effect of the three sites together was shown to be not significant. It is noted that the consented wind farms will actually contain fewer (up to 186) turbines.

3.1.2.93 A single jacket OSP foundation presents blockage to waves equivalent to less than one of the individual GBS foundations previously tested. The additional effect of two OSPs also located within or immediately adjacent to the array is therefore much smaller than the array scale effect of all turbine foundations, as previously assessed in the MORL ES (MORL, 2012; Chapter 13.1). A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity. This effect is therefore of **negligible significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.94 The nature and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude, duration and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8).

Changes to the Sediment Transport Regime Due to the Presence of the OSP Foundations

3.1.2.95 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: The Smith Bank

3.1.2.96 It is the combined wave and tidal regimes that ultimately control sediment transport and therefore the seabed form. It was shown in the MORL ES (MORL, 2012) that the OSPs (realistically only considered in conjunction with the associated wind farm developments) cause no significant change to the speed, direction or asymmetry of tidal currents. It was also shown that an array of 339 turbine jacket foundations will have little or no measureable effect (<2%) on wave height, wave period or direction.

3.1.2.97 Given no significant effect on the parameters controlling patterns of sediment transport, in particular the direction and asymmetry of tidal currents, there will be no corresponding difference in the potential rates and directions of sediment transport (provided that the supply of sediment is available for transport). There will, therefore, be no change to the form or function of the Smith Bank.

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

3.1.2.99 The nature and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude, duration and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8).

Sensitive Receptor: Designated Coastal Habitats

3.1.2.100 As described above, there will be no measureable effect on sediment transport rates through the three consented wind farms as a result of their presence (including the OSP foundations).

3.1.2.101 There will therefore be no effect on the form or function of designated coastal habitats located outside of the wind farm sites.

3.1.2.102 A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low to medium sensitivity. This effect is therefore of **minor significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.103 The nature and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude, duration and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8).

Scour Effects Due to the Presence of the OSP Foundations

3.1.2.104 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. A full scour assessment for the OSPs has been undertaken and results presented in Appendix 3.1 A: Hydrodynamics, Sedimentary and Coastal Processes. Key details are summarised below.

<u>Sensitive Receptor: The Smith Bank</u>

3.1.2.105 There is a potential for scour to develop where and when scour protection is not applied, possibly in the interim period between installation of the foundation and placement of the protection.

3.1.2.106 The jack-up foundations for OSPs may cause a maximum local scour depth of approximately 3.9 m. In reality, this depth is unlikely to be attained, at least in all locations around a given foundation, due to the use of scour protection and the presence of erosion resistant strata beneath the relatively thin layer of marine sediments that are present. The presence of gravel in the upper sandy layers will likely also lead to bed armouring in the scour pit that will restrict the overall depth or rate of scour development. Also, the consolidated till surface at approximately 0.5-2 m below the seabed is described as layered sandy silty clays of variable density and hardness (MORL ES, 2012, Technical Appendix 3.4 A: Metocean and Coastal Processes Baseline) and therefore is likely to be generally cohesive, consolidated and largely more resistant to erosion than non-cohesive (sandy) sediments.

3.1.2.107 The extent of scour from the edge of a foundation 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 separation between individual large items of infrastructure is in the order of hundreds of metres 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, e.g. between OSP and WTG foundations. The net additional footprint of scour from OSPs will be a proportionally small increase in the predicted area for all wind farm foundations (i.e. <1% of 0.54% of the total site area affected).

3.1.2.108 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 assumes that the seabed is potentially mobile and comprises uniform non-cohesive sediment. 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 directly cause rapid initial scour but can increase the rate of initial scour development.

3.1.2.109 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 around OSPs, especially alone but also in conjunction with the wind farm infrastructure are limited to only a small proportion of the area of each of the three consented wind farms and an even smaller proportion of the area of the Smith Bank.

3.1.2.110 A small 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. This effect is therefore of **minor significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.111 The nature, duration and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller dimensions of individual OSPs relevant to scour (jack-ups instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8).

Scour Effects Due to the Exposure of Offshore Export Cables

3.1.2.112 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 scour to occur. The removal of sediment from underneath a section of export cable exposed on the seabed can lead to free-spanning and further sediment erosion; exposed export cables are also at greater risk of physical damage. Exposure and scour is primarily an engineering risk, often mitigated using export cable burial and scour protection.

3.1.2.113 The export cables will be buried where seabed conditions allow. Where seabed conditions do not allow for adequate burial, cables may be partially buried or surface laid and protected with other means.

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

3.1.2.115 Exposure of the export cable has the potential to cause localised scouring of sediment, leaving a depression and/or a relative change in sediment character that will persist until the export cable is either buried or otherwise removed. The extent and depth of scour may vary over time and may be limited under certain physical conditions; however, a conservative approach has been 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.

3.1.2.116 Cables can be buried to reduce the risk of snagging or other direct contact damage and, therefore, normally present no scour risk. 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.

Sensitive Receptor: The Smith Bank & seabed along the modified OfTI corridor

3.1.2.117 The diameter of the offshore export cable is likely to be in the order of 0.25 m and up to four cables might be laid in individual trenches separated by tens or hundreds of metres, depending on the local water depth. From Whitehouse (1998), a conservative estimate for all cases (current, wave or combined scour) is that the maximum depth of scour beneath a section of exposed cable will be between one and three times the cable diameter (i.e. order of 0.75 m) and the maximum horizontal extent of any scour effect will be up to fifty times the cable diameter (i.e. order of 12.5 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. This may then become buried by predominantly sandy material following recovery of the seabed if self-burial of the cable occurs.

3.1.2.118 The effects of scour potentially resulting from the exposure of offshore export cables onto the seabed are considered to be of a small magnitude relative to the range of naturally occurring variability. Effects on morphology or sediment surface texture will be localised to the cable route.

3.1.2.119 This effect is therefore of **negligible significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.120 The nature, magnitude, sensitivity and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Scour Effects Due to Cable Protection Measures

3.1.2.121 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.

<u>Sensitive Receptor: The Smith Bank & seabed along the modified OfTI corridor</u>

3.1.2.122 Protection measures that might be deployed onto surface laid or otherwise exposed sections of the offshore export cables may take various forms, but will most likely comprise:

- Rock placement; or
- Concrete mattressing.

3.1.2.123 Protection measures are used to mitigate the engineering risk posed by scour and exposure of the offshore export cable to external damage. The measures will prevent scour from developing around the cable; however, the area occupied by the scour protection might also be similarly considered as a modification to the sedimentary environment and may cause a more limited depth and area of secondary scour to develop.

3.1.2.124 There is insufficient information available to accurately quantify the effect of all possible types of protection measure, which may vary greatly in design and scale. The maximum thickness of the protection will be in the order of 1 m. The total width of the protection material will be in the order of 2-3 m either side of the offshore export cable itself, likely with a sloping or tapering profile.

3.1.2.125 The slope angle presented by sections of protected cable would be in the order of 5-9° which is within the natural range of bed slope angles associated with bed forms and so will not affect patterns of sediment transport following the initial period of accumulation.

3.1.2.126 Alternatively, conditions may not be favourable for sediment accumulation. Where this is due to very low transport rates (e.g. in the central part of the outer Moray Firth), the presence or absence of an obstacle will therefore not cause any further effect. Where this is due to a tendency for the protection material to create turbulence and secondary scour, the action of the (upstream) scour will be to actively resuspend and transport sediment over the obstacle, again therefore not causing any further effect.

3.1.2.127 The effects of cable protection measures are considered to be of a small magnitude relative to the range of naturally occurring variability and will not have a measurable effect on sediment transport beyond a short to medium term period of initial adjustment. Effects on morphology or sediment surface texture will be localised to the cable route.

3.1.2.128 This effect is therefore of **negligible significance** and therefore not significant in terms of the EIA Regulations.

3.1.2.129 The nature, magnitude, extent, duration and significance of the predicted potential effect from the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

Decommissioning

3.1.2.130 Where and when the modified OfTI is no longer present, there is no potential for any effect on the baseline wave and tidal regimes. The worst case scenario of the modified OfTI being present is considered in the preceding sections. The effect of less than the proposed total amount of OfTI 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).

3.1.2.131 In relation to sedimentary and coastal processes, it is considered that the methods likely 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 construction. Therefore, the types of effect from decommissioning and their significance can only be considered to be similar to or less than that already provided above (either negligible significance or of minor significance).

3.1.2.132 Whether removed or left in-situ, decommissioned cables have no greater potential effect upon sediment transport and coastal morphology than as described above for the construction and operational phases, respectively.

3.1.2.133 The same conclusions were reached in the MORL ES (MORL, 2012).

Proposed Monitoring and Mitigation

Construction

3.1.2.134 No mitigation measures are proposed.

Operation

3.1.2.135 Where burial depth cannot be achieved, cable armouring will be implemented (e.g. rock placement or concrete mattressing). The suitability of installing rock or concrete mattresses for cable protection, especially around the structure bases, will be assessed based on the seabed current data across the proposed development area and the assessed risk of impact damage.

3.1.2.136 During operation, the export cable will be monitored to ensure that cables remain buried and any scour effects remain within the range of that predicted in the ES.

Decommissioning

3.1.2.137 No mitigation measures are proposed.

Habitat Regulations Appraisal

3.1.2.138 Likely effects from the construction, operation and decommissioning of the modified OfTI on the wave and tidal regime and 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 section are also considered with respect to the requirements for Habitats

Regulation Assessment in other ES chapters (Chapter 4.1: Benthic Ecology, Chapter 4.2: Fish and Shellfish Ecology and Chapter 4.4: Marine Ornithology).

3.1.3 Cumulative Impact Assessment

Summary

3.1.3.1 This section presents the results of an assessment into the potential cumulative effects upon hydrodynamic, sedimentary and coastal processes arising from the whole Project (the modified OfTI plus Telford, Stevenson and MacColl) in conjunction with other existing or reasonably foreseeable marine coastal developments and activities (Table 3.1-7). MORL's approach to the assessment of cumulative effects is described in Chapter 1.3: Environmental Impact Assessment.

3.1.3.2 The MORL ES (MORL, 2012) provided a detailed assessment of potential effects from all relevant developments, both individually and cumulatively. The preceding impact assessment demonstrates that the nature, magnitude, extent, duration and significance of the potential effects from the modified OfTI are the same or less than previously assessed in the MORL ES (MORL, 2012). Comparable aspects of the other, now consented, developments considered for cumulative effects have either stayed the same, or have been refined (reduced) since the previous assessments were made. Therefore, the nature, magnitude, extent, duration and significance of cumulative effects also remain the same or are reduced.

Table 3.1-7 Cumulative Impact Summary

Effect/Receptor	**Residual Significance Level for Modified TI**	**Whole Project Assessment:** **Modified TI + Stevenson, Telford and MacColl**	**Mitigation Method**
Construction			
Changes to the Tidal and Wave Regimes	Negligible	n/a (Impacts subordinate to those assessed for operational phase)	None proposed
Total Cumulative Impact Assessment ***(Whole project + developments as listed in section 3.1.3.4)***	n/a (Impacts subordinate to those assessed for operational phase)		
Increase in suspended sediment concentrations and changes in sediment type/thickness at the seabed (receptor: The Smith Bank)	Minor significance	Minor significance	None proposed

Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Disturbance of coastal morphology at the landfall site (Inverboyndie landfall)	Negligible significance	Negligible significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Negligible significance		
Operation			
Changes to the tidal regime (receptor: The Smith Bank)	Negligible significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes to the tidal regime (receptor: Designated Sites)	Minor significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes to the tidal regime (receptor: Stratification Fronts)	Not assessed	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		

Changes to the wave regime (receptor: The Smith Bank)	Negligible significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes to the wave regime (receptor: Designated Coastal Habitats)	Minor significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes to the wave regime (receptor: Recreational Surfing Venues)	Negligible significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes in sediment transport (receptor: The Smith Bank)	Negligible significance	Minor significance	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Changes in sediment transport (receptor: Designated Coastal Habitats)	Negligible significance	Minor significance	None proposed

Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Scour Effects	Negligible significance	Minor significance	Scour protection
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	Minor significance		
Decommissioning			
Partial impacts only for all effects and receptrs	As 'Construction'	As 'Construction'	None proposed
Total Cumulative Impact Assessment (Whole project + developments as listed in section 3.1.3.4)	As 'construction' – Negligible / minor significance depending on effect and receptor		

Assessment of Cumulative Effects

3.1.3.3 A whole Project assessment has been done for the likely significant cumulative effects of the modified OfTI in conjunction with the three consented wind farms (Telford, Stevenson and MacColl).

3.1.3.4 The following wind farm developments were considered in detail for the total cumulative impact assessment for the whole Project:

- MORL Western Development Area (WDA); and
- BOWL wind farm and associated OfTI.

3.1.3.5 Additional developments and projects within the Moray Firth were also considered when scoping the total cumulative impact assessment:

- MORL Offshore Met Mast;
- Beatrice Wind Farm Demonstrator Project;
- Burghead wave energy project;
- Mains Carbon capture and storage site;
- Nigg, Ardeseir and Invergordon port works;
- SHE-T Offshore HVDC reinforcement; and
- Buckie and Macduff waste disposal sites.

3.1.3.6 However, these additional developments and projects are considered to have no potential for cumulative interaction for one or more of the following reasons.

- The development is located more than one tidal excursion from the whole Project;
- The development has no direct fetch for wave effects to interact with that from the whole Project (i.e. there is no pathway connecting the wind farm sites and the other source of effect); and/or
- The dimensions of the development (or the effects they give rise to) are so small that it will not conceptually have any measurable effect on the tidal, wave or sedimentary regimes.

Methodology

3.1.3.7 The assessment methodology has followed that outlined in the Moray Firth Offshore Wind Developers Group Discussion Document (MORL, 2012, Technical Appendix 1.3 D: MFOWDG Cumulative Assessment Document).

3.1.3.8 To assess cumulative effects upon the wave climate and tidal regime, the effect of different layouts and types of turbine foundations was simulated using calibrated and validated numerical models. The relative difference between the two sets of results was found and used to describe and assess the relative effects. By testing the realistic worst cases and testing the effects as the difference between scheme and baseline results, any uncertainties in either the design of the development or the absolute accuracy of the numerical modelling are minimised; this approach complies with the best practice guidance in this regard (COWRIE, 2009).

Worst Case Scenario for Projects Where Detailed Assessment is Possible

3.1.3.9 The worst case parameters for the modified OfTI are as provided in this ES Project Description, Chapter 2.2.

3.1.3.10 A summary of the worst case parameters previously assessed in the MORL ES (MORL, 2012) for the offshore generating station is provided below in Table 3.1-8. The worst case layout of the MORL offshore generating station in conjunction with the BOWL wind Farm was 139 x 3.6 MW turbines in Telford and 100 x 5 MW turbines in each of Stevenson and MacColl. This distribution placed the greatest density of turbines closest to the nearest coastline and therefore resulted in the greatest predicted far-field effects.

3.1.3.11 The number of turbines actually consented is much smaller (up to 186 to be built instead of 339 assessed as the realistic worst case). As the foundation type and dimensions are not changed, the number of occurrences and so total duration of individual impacts, and array scale effects, will therefore be proportionally reduced to approximately 55% of the previously assessed values.

Table 3.1-8 Summary of MORL Three Consented Wind Farms Worst Case Parameters (as previously assessed but with commentary on consented parameters)

Previously Assessed Realistic Worst Case Parameters	Scenario Previously Assessed
Changes to the Tidal Regime	
Installation of 339 turbines (186 turbines consented)	65 m diameter Gravity Base Structures (GBS)
Changes to the Wave Regime	
Installation of 339 turbines (186 turbines consented)	65 m diameter Gravity Base Structures (GBS)

Previously Assessed Realistic Worst Case Parameters	Scenario Previously Assessed
Increase in Suspended Sediment Concentrations	
Installation of 339 turbines (186 turbines consented)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Inter-array cable burial	Energetic trenching tool, 'V' shaped trench 3 m wide and up to 3 m deep, 100% resuspension.
Sediment accumulation and change of sediment type at the seabed	
Installation of 339 turbines (186 turbines consented)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Changes to the Sediment Transport Regime	
Installation of 339 turbines (186 turbines consented)	65 m diameter Gravity Base Structures (GBS)
Scour Effects	
Installation of 339 turbines (186 turbines consented)	65 m diameter GBS

3.1.3.12 A summary of the worst case design parameters for the BOWL wind farm and associated OfTI in terms of the wave climate and tidal regime used in the original assessment provided below in Table 3.1-9. These parameters were consistent with the descriptions and assessments contained in the Beatrice Offshore Wind Farm Environmental Statement (BOWL, 2012). The number of turbines actually consented for BOWL is much smaller with 125 (or up to 140 if certain conditions can be met) to be built instead of the 227 assessed as the realistic worst case in the original assessment. As the foundation type and dimensions are not changed, the number of occurrences and so total duration of individual impacts and array scale effects will therefore be proportionally reduced to between approximately 55-62% of the previously assessed values.

Table 3.1-9 Summary of BOWL Worst Case Parameters (as previously assessed but with commentary on consented parameters)

Previously Assessed Realistic Worst Case Parameters	Scenario Previously Assessed
Changes to the Tidal Regime	
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	60 m diameter Gravity Base Structures (GBS)
Changes to the Wave Regime	
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	60 m diameter GBS
Increase in Suspended Sediment Concentrations	

Previously Assessed Realistic Worst Case Parameters	Scenario Previously Assessed
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Inter array and transmission cable burial	Energetic trenching tool, 'V' shaped trench 3m wide and up to 3m deep, 100% resuspension.
Sediment accumulation and change of sediment type at the seabed	
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Changes to the Sediment Transport Regime	
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	60 m diameter GBS
Scour Effects	
Installation of 277 turbines (125 turbines consented but with the potential for up to 140 turbines as per conditions)	60 m diameter GBS

Western Development Area

3.1.3.13 The WDA comprises part of the MORL zone. The three consented windfarms (Telford, Stevenson and MacColl) are located within the Eastern Development Area of the MORL zone. The maximum capacity which could be installed in the entire MORL zone is 1.5 GW.

3.1.3.14 The WDA may be developed for a maximum of 500 MW of capacity subject always to the overall cap of 1.5 GW for the MORL zone. In total the consented capacity of the modified Project and the WDA will not exceed 1.5 GW.

3.1.3.15 The connection between the WDA and the three consented wind farms necessitates a slightly different approach to assessment, as the effects arising from the "worst case" for the modified Project cannot simply be added to the "worst case" scenario for the WDA. Instead, assessment of the likely significant cumulative effects of the modified Project and the WDA will therefore follow a similar format to that undertaken for the sensitivity assessments of the individual wind farm proposals in the Offshore Generating Station Impact Assessment chapters of the MORL ES (MORL, 2012).

3.1.3.16 The total capacity of the MORL zone is capped at 1.5 GW and so the additional placement of 100 x 5MW turbines in the WDA would be offset by an equivalent reduction in the number of turbines elsewhere in the zone.

3.1.3.17 The number of turbines actually consented for the EDA is much smaller (186 to be built instead of 339 assessed as the realistic worst case). As the foundation type and dimensions are not changed, the number of occurrences and so total duration of individual impacts, and array scale effects, will therefore be proportionally reduced to between approximately 55-62% of the previously assessed values.

3.1.3.18 The worst case parameters for the WDA as previously assessed in terms of the wave climate and tidal regime are provided below in Table 3.1-10.

Table 3.1-10 Summary of MORL WDA Worst Case Parameters (as previously assessed but with commentary on consented parameters)

Previously Assessed Realistic Worst Case Parameters	Scenario Previously Assessed
Changes to the Tidal Regime	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	65 m diameter GBS
Changes to the Wave Regime	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	65 m diameter GBS
Increase in Suspended Sediment Concentrations	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Sediment accumulation and change of sediment type at the seabed	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	Dredging for GBS bed preparation. Drill arisings from jacket pin pile installation.
Changes to the Sediment Transport Regime	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	65 m diameter GBS
Scour Effects	
Installation of 139 turbines in the WDA in conjunction with 200 in the three consented wind farms (186 turbines consented in the three wind farms)	65 m diameter GBS

Cumulative Assessment

3.1.3.19 The types of effects considered in this assessment are:

- Changes to the tidal regime;
- Changes to the wave regime;
- Increase in SSC;

- Sediment accumulation and change of sediment type at the seabed;
- Changes to the sediment transport regime; and
- Scour effects.

3.1.3.20 The receptors identified for consideration in this cumulative assessment are:

- The Smith Bank;
- Seabed along the offshore export cable route;
- Designated coastal habitats; and
- Recreational surfing venues.

Construction

3.1.3.21 This section considers the cumulative effects of the combined modified OfTI and the three consented wind farms – i.e. the whole Project; and the whole Project with all other developments on hydrodynamic, sedimentary and coastal processes during the construction phase. More details of this assessment may be found in MORL (2012); Appendix 3.4 C: Metocean and Coastal Processes Impact Assessment.

Changes to the Tidal and Wave Regimes

3.1.3.22 Prior to the installation of wind farms or offshore transmission infrastructure, there is no potential for any significant modification to the baseline wave and tidal regimes. The worst case scenarios of all wind farm infrastructure installed during the operational phase is considered in the following section. The effect of less than the total amount of infrastructure at an intermediate stage in the construction process is (generally proportionally) less than that reported in the following section for the operational phase of the combined wind farm developments. Therefore, these effects are not considered explicitly during the construction phase.

Increases in Suspended Sediment Concentrations and Changes in Sediment Type/Thickness at the Seabed
Modified OfTI and Telford, Stevenson and MacColl wind farms
Sensitive Receptor: The Smith Bank

3.1.3.23 Cumulative effects of multiple and simultaneous sources of sediment release may potentially arise due to simultaneous pin-pile drilling, bed preparation activities and/or cable installation.

3.1.3.24 With regards to increases in suspended sediment concentrations, an impact assessment has previously been carried out for the individual sources of sediment release considered for the modified OfTI (Section 3.1.2) and for the three consented wind farms in the MORL ES (MORL, 2012; Chapters 6.1: Hydrodynamics (Wave Climate and Tidal Regime) and 6.2; Sedimentary and Coastal Processes).

3.1.3.25 If foundation installation activities occur simultaneously at multiple adjacent locations, there is a potential that plumes of increased SSC will interact. The maximum cumulative result of interaction between sediment plumes is an additive increase in SSC.

3.1.3.26 However, given the minimum spacing of the turbines and the width of the plume, if the adjacent locations are not aligned along the direction of the tidal current, there is no potential for the plumes to interact. If the adjacent locations are aligned to the tidal axis, turbine foundations are located a minimum of 600 m (crosswind) or 840 m (downwind) apart so the downstream level of SSC in the sediment plume from the upstream source will have decreased to 20 mg/l or less. At most, this may cause the levels of SSC adjacent to the downstream source to increase from 30-40 mg/l, to 50-60 mg/l. The SSC level of the more disperse effects (1- 5 mg/l) outside of the main plume during operations and in the area of plume following cessation of operations are unlikely to be changed as a result of cumulative effects.

3.1.3.27 Locally within the wind farms, foundation installation will likely be completed before cables are laid. The majority of the export cable route is too far from the wind farms for an overlap in sediment plumes to occur. For operational safety, it is also unlikely that cables will be simultaneously buried less than 10s of metres from each other or from any other operation. Therefore, only the low-level dispersal effects from dredging or drilling activities (order of 1-5 mg/l) have the potential to combine with the higher magnitude local effects of cable burial (1,000s to 10,000s of mg/l). Therefore, there is no potential for (measurable) cumulative interaction between cable burial and foundation installation activities.

3.1.3.28 The cumulative effects of plume interaction from a variety of sources are of a magnitude consistent with the natural range of variability (order 1,000 to 10,000 mg/l nearbed and order 10 to 100 mg/l higher in the water column). Local effects around cable burial machines may potentially be in excess of the natural range of variability but will also be only localised and temporary.

3.1.3.29 For the whole Project, a small to medium magnitude of change in SSC 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 cumulative effect of **minor significance.**

3.1.3.30 The nature, magnitude, extent, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012).

3.1.3.31 With regards to changes in sediment thickness and type at the seabed, relatively thick (up to several metres) sediment accumulation will occur in the near-field vicinity of foundations where pin piles are installed by drilling. These deposits will be localised and therefore will not coalesce between foundations or between wind farm sites, posing no cumulative effect.

3.1.3.32 The maximum thickness of sediment accumulation in the far-field predicted to result from the three consented wind farms and modified OfTI is less than 1 mm. The effects of dredging as part of bed preparation for GBS foundations in terms of thickness of accumulation are generally of a magnitude consistent with the natural range of variability and so will not affect total water depths. The accumulation of a variable thickness of fine sediment to areas presently indicated to be mostly sands or sandy-gravels outside of the combined wind farm developments may temporarily change the sediment surface texture in that area; however, these fine sediment accumulations are expected to be reworked and dispersed to background concentrations by storms on short to medium time-scales.

3.1.3.33 A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity. The resulting cumulative effect in relation to sediment type and thickness is therefore of **minor significance**.

3.1.3.34 For the whole Project including modified OfTI, the nature, magnitude and significance of the predicted potential cumulative effects are the same as previously assessed for the original whole Project in the MORL ES (MORL, 2012). The duration and extent of the predicted potential effect are however reduced, due to the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed

<u>Total Cumulative Impact (All Developments)</u>

3.1.3.35 The potential for cumulative impacts with the BOWL development and WDA is considered to be limited, with a small to medium magnitude of change in SSC / bed thickness that may locally and temporarily exceed the range of natural variability anticipated to arise in areas of low sensitivity. The total cumulative effect will therefore remain very similar to that assigned to the cumulative assessment of the modified OfTI and Telford, Stevenson and MacColl wind farms (i.e. **minor significance**).

Disturbance of Coastal Morphology at the Landfall Site

3.1.3.36 No potential for cumulative impacts on coastal morphology at the landfall have been identified. The effect therefore remains of **negligible significance** and not significant in terms of the EIA Regulations.

Operation

Changes to the Tidal Regime

<u>Modified OfTI and Telford, Stevenson and MacColl Wind Farms</u>
<u>*Sensitive Receptor: The Smith Bank*</u>

3.1.3.37 Using GBS or jacket foundations for all turbines in the combined modified OfTI and wind farm developments will have no measurable effect on tidal water levels or tidal current directions. Using jacket foundations for turbines will also have no measurable effect on tidal current speed.

3.1.3.38 Using GBS foundations for all turbines will only have a (nearly) measurable effect on tidal currents during spring tidal periods. The main effect is a phase shift, simply advancing the current peak in time by 5-10 minutes. The peak flow speed in the region of the wind farms will also be reduced by approximately 0.03 m/s (not a measurable effect). Given the similarity in the controlling physical processes, a similarly low order of effect on non-tidal (surge) water levels is inferred.

3.1.3.39 The relative contribution of the two jacket foundations for the OSPs is negligible, approximately 0.3% of the (not measureable) total effect of using jacket foundations for all turbines.

3.1.3.40 The effects of the combined modified OfTI and wind farm developments on water levels and currents will persist for the operational lifetime of the developments. However, they are of very low magnitude, have only a local effect and do not directly affect any of the identified sensitive physical environmental receptors beyond the range of natural variability.

3.1.3.41 A small magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity resulting in an effect of **minor significance**.

3.1.3.42 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Sensitive Receptor: Designated Coastal Habitats

3.1.3.43 No measurable effect on the tidal regime is predicted to occur further than one tidal excursion (order of 7 km) outside of the extent of the combined modified OfTI and wind farm developments.

3.1.3.44 A small magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in an effect of **minor significance**.

3.1.3.45 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed

Sensitive Receptor: Stratification Fronts

3.1.3.46 No measurable effect on the tidal regime is predicted to occur further than one tidal excursion (order of 7 km) outside of wind farms. As these features are the product of regional fresh water/saline patterns (unaffected by the combined wind farm developments) and the tidal regime (water depth and current speed), there will be no consequential effect on the strength or location of stratification fronts.

3.1.3.47 A small magnitude of change within the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in an effect of **minor significance**.

3.1.3.48 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Total Cumulative Impact (all developments)

3.1.3.49 The potential for cumulative impacts with the BOWL development and WDA is considered to be limited, with a small magnitude of change anticipated to occur but within the range of natural variability in areas of low sensitivity. The total cumulative effect will therefore remain very similar to that assigned to the cumulative assessment of the Modified OfTI and Telford, Stevenson and MacColl wind farms (i.e. **minor significance**).

Changes to the Wave Regime

Modified OfTI and Telford, Stevenson and MacColl wind farms

Sensitive Receptor: The Smith Bank

3.1.3.50 Wave conditions naturally vary from calm conditions to maximum wave heights of 4-9 m depending upon the strength of the wind and its 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.

3.1.3.51 In relation to wave height and period, it was previously shown in MORL (2012) that when using jacket foundations for all wind turbines in the cumulative developments:

- Jacket foundations do not measurably affect wave height or period, i.e. differences in significant wave height are <0.1 m (1.5%) and in wave period are <0.1 s (1- 1.5%) in the near-field (and even less in the far-field).

3.1.3.52 And when using GBS foundations for all wind turbines in the cumulative developments:

- The maximum reduction in wave height within the consented wind farm areas varies between 0.4-1.6 m or 6-24% of the incident wave height (which varies between 4-9 m) for all directions and return periods. The greatest absolute effects are on the largest waves (i.e. from 90°N). The greatest absolute and proportional effects are for the largest waves passing through the longest axis of the combined sites (i.e. from 45-90°N) the smallest proportional effects are on waves from 270°N.

3.1.3.53 The relative contribution of the two jacket foundations for the OSPs is negligible: it is approximately 0.3% of the (already not measureable) total effect of using jacket foundations for all turbines.

3.1.3.54 A small magnitude of change, typically within the range of natural variability is therefore assessed to arise in an area of low sensitivity, resulting in an effect of **minor significance**.

3.1.3.55 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

<u>Sensitive Receptor: Designated Coastal Habitats</u>

3.1.3.56 In relation to wave height and period outside of the consented wind farm areas, it was previously shown in MORL (2012) that when using jacket foundations for all wind turbines in the cumulative developments:

- Jacket foundations do not affect waves by more than 0.05 m (1%) significant wave height or 0.1 s (1-1.5%) wave period in the far-field.

3.1.3.57 When using GBS foundations for all wind turbines in the cumulative developments:

- When the combined wind farm developments are present, the maximum magnitude of effect on wave height for the following designated sites are:
  - o East Caithness Cliffs SPA: of the order 0.4-0.5 m (4-5% of the incident wave condition) for waves from the east or south east (occurring 29% of the time), of the order 0.2-0.3 m (2-3% of the incident wave condition) for waves from the north east or south (41.4% of the time) and <0.1 m (1% of the incident wave condition) for other directions (29.6% of the time);
  - o Moray Firth SAC and open Coastal Sites: of the order 0.1-0.2 m (2-3% of the incident 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

- o Inner Moray Firth and enclosed water bodies: <0.05 m (<1% of the incident wave condition, i.e. no measurable effect) for all wave coming directions.

3.1.3.58 The relative contribution of the two jacket foundations for the OSPs is negligible, approximately 0.3% of the (already not measureable) total effect of using jacket foundations for all turbines.

3.1.3.59 A medium magnitude of change but 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 **minor significance**.

3.1.3.60 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Sensitive Receptor: Recreational Surfing Venues

3.1.3.61 This assessment of likely significant effects to the wave regime is based upon the analysis of wave model results with and without GBS present in the combined wind farm developments over a two year period (see MORL, 2012; chapter 13.1 for details) Time series of wave conditions have been extracted from the model results immediately offshore of the identified surfing beaches in the vicinity of the modified OfTI. The same statistical and frequency analysis has been applied to each data set to obtain baseline values and the difference in the frequency of occurrence of key event types resulting from the presence of the combined wind farm developments.

3.1.3.62 Considering the cumulative effects of the combined wind farm developments, GBS foundations were found to have no effect >0.01 m wave height or >0.1 s wave period at eight out of eighteen venues. Of the remaining ten venues, effects were typically limited to a 0.02-0.09 m decrease in wave height (only one site, Lossiemouth, was higher at 0.14 m), but no effect on wave period or the frequency of occurrence of any representative conditions. The relative contribution of the two jacket foundations for the OSPs is negligible in comparison to the effects described above associated with the consented wind farm areas.

3.1.3.63 A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity, resulting in an effect of **minor significance**.

3.1.3.64 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Total Cumulative Impact (all developments)

3.1.3.65 The potential for cumulative impacts with the BOWL development and WDA is considered to be limited, with a medium magnitude of change (but within the range of natural variability) anticipated to arise in areas of low sensitivity and a small magnitude of change anticipated to arise in areas of potentially medium sensitivity.

The total cumulative effect will therefore remain very similar to that assigned to the cumulative assessment of the Modified OfTI and Telford, Stevenson and MacColl wind farms (i.e. **minor significance**).

Changes to the Sediment Transport Regime
Modified OfTI and Telford, Stevenson and MacColl wind farms
Sensitive Receptor: The Smith Bank

3.1.3.66 It is the combined wave and tidal regimes that ultimately control sediment transport and therefore the seabed form and function on the Smith Bank. It was shown in the MORL ES (MORL, 2012, Section 13.1) that the cumulative effect of the combined wind farm developments causes no significant change to the speed or directions of tidal currents, irrespective of the foundation type used. It was also shown that GBS foundations will cause a reduction in instantaneous significant wave height within the combined wind farm developments of up to 21% (but more typically 10% or less across most of the site area) and up to 5% in the far-field. The maximum magnitude of effect on waves is therefore of the same order as natural inter-annual and inter-decadal variability in storm intensity. Using jacket foundations for the turbine foundations will have little or no measurable effect (< 1%) on wave height. Using GBS or Jacket foundations will not measurably affect wave period or direction.

3.1.3.67 Given no significant effect on the physical processes that control it, there can be no corresponding effect on potential rates and directions of sediment transport through the combined wind farm developments.

3.1.3.68 The MORL ES (MORL, 2012, Section 13.1) considered the potential for the construction of the wind farm to affect the character or abundance of surface sediments (e.g. as a result of ground preparation, drilling or inter-array 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 expected to be a significant change in the textural properties or quantity of the sediment available for transport. This supports the further conclusion that actual sediment transport rates through the combined wind farm developments will not be affected by the planned development.

3.1.3.69 The worst case effect of a reduction in wave height on sediment transport pathways and resulting morphology in the combined wind farm developments is:

- The area within the combined wind farm developments 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.

3.1.3.70 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.

3.1.3.71 There will, therefore, be no effect on the form or function of the Smith Bank.

3.1.3.72 A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low sensitivity resulting in an effect of **minor significance**.

3.1.3.73 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Sensitive Receptor: Designated Coastal Habitats

3.1.3.74 The previous section concludes that there will be no significant effect on sediment transport rates through the combined wind farm developments as a result of their presence. The main effects on tidal currents and waves are generally confined to the wind farm site extents and are of a lower magnitude elsewhere. Therefore, there will therefore be no corresponding effect upon the rate of sediment supply to other parts of the Moray Firth.

3.1.3.75 The effect of the combined wind farm developments on wave height, period and direction at the location of designated coastal habitats has been considered in Chapter 13.1: Hydrodynamics (Wave Climate and Tidal Regime) in the MORL ES (2012), 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.

3.1.3.76 There will therefore be no effect on the form or function of designated coastal habitats.

3.1.3.77 A small magnitude of change within the range of natural variability is therefore assessed to arise in areas of low to medium sensitivity, resulting in an effect of **minor significance**.

3.1.3.78 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller blockage presented by individual OSPs (jackets instead of GBS foundations) and the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Total Cumulative Impact (all developments)

3.1.3.79 The potential for cumulative impacts with the BOWL development and WDA is considered to be limited, with a small magnitude of change anticipated to occur but within the range of natural variability in areas of low sensitivity. The total cumulative effect will therefore remain very similar to that assigned to the cumulative assessment of the Modified OfTI and Telford, Stevenson and MacColl wind farms (i.e. **minor significance**).

Scour Effects

Modified OfTI and Telford, Stevenson and MacColl wind farms

Sensitive Receptor: The Smith Bank

3.1.3.80 There is a potential for scour to develop around obstacles to flows, where and when scour protection is not applied. Where scour protection is applied, scour might possibly occur in the interim period between installation of the object and placement of the protection.

3.1.3.81 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 cumulative numbers of foundations in the combined wind farm developments and the total area found as a proportion of the wind farm(s) area.

3.1.3.82 The largest total footprint of scour is assessed to occur in response to the lowest rated GBS scenario (i.e. the greatest number of turbines) at less than 1% of the total area of the three consented wind farms. Other foundation types and rating scenarios result in a smaller relative area of effect.

3.1.3.83 Where and when exposed, export and inter-array cable infrastructure might also induce some local scour but only of a very small magnitude (order of 10s of centimetres). Scour associated with gravity based OSP foundations is of a similar order to that of the turbine foundations and is considered as a minor increase to the values already presented.

3.1.3.84 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 consented wind farms and an even smaller proportion of the area of the Smith Bank.

3.1.3.85 A small 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 cumulative effect is therefore of **minor significance**.

3.1.3.86 The nature, duration and significance of the predicted potential cumulative effect including the modified OfTI are the same as previously assessed in the MORL ES (MORL, 2012). The magnitude and extent of the predicted potential effect are however reduced, due to the smaller number of OSPs being installed (2 instead of 8) and the smaller number of turbines actually consented in the three wind farms than previously assessed.

Total Cumulative Impact (all developments)

3.1.3.87 The potential for cumulative impacts with the BOWL development and WDA is considered to be limited, with a small magnitude of change anticipated to occur but within the range of natural variability in areas of low sensitivity. The total cumulative effect will therefore remain very similar to that assigned to the cumulative assessment of the Modified OfTI and Telford, Stevenson and MacColl wind farms (i.e. **minor significance**).

Decommissioning

3.1.3.88 Following removal of the wind farms and offshore transmission infrastructure, there is no potential for any modification to the baseline wave and tidal regimes. The worst case scenario of all wind farm infrastructure present is considered in the preceding section. The effect of less than the total amount of infrastructure present at an intermediate stage in the decommissioning process will be (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).

3.1.3.89 It is considered that the methods likely 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 construction. Therefore, the types of effect from decommissioning and their significance can only be considered to be similar to or less than that already provided above (either **negligible significance** or of **minor significance**).

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