DOGGER BANK
TEESSIDE A & B

March
2014

Environmental Statement Chapter 9 Marine Physical Processes

Application Reference: 6.9

Cover photograph: Installation of turbine foundations in the North Sea

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Contents

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Table of Tables

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Table of Figures

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Table of Appendices

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1 Introduction

1.1.1 This chapter of the Environmental Statement (ES) describes the existing environment with regard to marine physical processes and assesses the potential effects of Dogger Bank Teesside A & B during the construction, operation and decommissioning phases. This chapter also includes an assessment of the landfall site between the coastal towns of Redcar and Marske-by-the-Sea on the Borough of Redcar and Cleveland coast. It includes site-specific information related to bathymetry and topography, physical processes (wave and tidal regimes), sedimentary processes (sediment transport, erosion and deposition) and geomorphology.

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2 Guidance and Consultation

2.1 Legislation, policy and guidance

2.1.1 The assessment of potential effects upon marine physical processes has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision making documents for Nationally Significant Infrastructure Projects (NSIP). Those relevant to Dogger Bank Teesside A & B are:

- Overarching NPS for Energy (EN-1) (DECC 2011a); and
- NPS for Renewable Energy Infrastructure (EN-3) (DECC 2011b).

2.1.2 The specific assessment requirements for marine physical processes as detailed in the NPS are summarised in **Table 2.1**, together with an indication of the paragraph numbers of the ES chapter where each is addressed. Where any part of the NPS has not been followed within the assessment an explanation as to why the requirement was not deemed relevant, or has been met in another manner, is provided.

Table 2.1 NPS assessment requirements

NPS requirement	NPS reference	ES reference
The construction, operation and decommissioning of offshore energy infrastructure can affect the following elements of the physical offshore environment: • Waves and tides: the presence of the turbines can cause indirect effects on flood defences, marine ecology and biodiversity, marine archaeology and potentially, coastal recreation activities; • Scour effect: the presence of wind turbines and other infrastructure can result in a change in the water movements within the immediate vicinity of the infrastructure, resulting in scour (localised seabed erosion) around the structures. This can indirectly affect navigation channels for marine vessels and marine archaeology; • Sediment transport: the resultant movement of sediments, such as sand across the seabed or in the water column, can indirectly affect navigation channels for marine vessels; and • Suspended solids: the release of sediment during construction and decommissioning can cause indirect effects on marine ecology and biodiversity.	EN-3 Paragraph 2.6.189	Section 6.2 (construction sediment transport effects) Section 7.2 (operational tidal current effects) Section 7.3 (operational wave effects) Section 7.4 (operational sediment transport effects)
The Environment Agency (EA) regulates emissions to land, air and water out to 3nm. Where any element of the wind farm or any associated development included in the application to the IPC is located within 3nm of the coast, the EA should be consulted at the pre-application stage on the assessment methodology for impacts on the physical environment.	EN-3 Paragraph 2.6.191	Sections 3.3 and 5 (Dogger Bank Teesside A & B Export Cable Corridor and landfall assessment methodologies and worst case scenarios)

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NPS requirement	NPS reference	ES reference
Beyond 3nm, the Marine Management Organisation (MMO) is the regulator. The applicant should consult the MMO and Centre for Environment, Fisheries and Aquaculture Science (Cefas) on the assessment methodology for impacts on the physical environment at the pre-application stage.	EN-3 Paragraph 2.6.192	Sections 3.3 and 5 (wind farm and Dogger Bank Teesside A & B Export Cable Corridor assessment methodologies)
The assessment should include predictions of the physical effect that will result from the construction and operation of the required infrastructure and include effects such as the scouring that may result from the proposed development.	EN-3 Paragraph 2.6.194	Section 6 (construction effects) and Section 7 (operational effects)
As set out above, the direct effects on the physical environment can have indirect effects on a number of other receptors. Where indirect effects are predicted, the IPC should refer to relevant sections of this NPS and EN-1.	EN-3 Paragraph 2.6.195	The effects on other receptors are considered separately in **Chapter 10 Marine Water and Sediment Quality**, **Chapter 12 Marine and Intertidal Ecology**, **Chapter 13 Fish and Shellfish** and **Chapter 18 Marine and Coastal Archaeology.**
An assessment of the effects of installing cable across the intertidal zone should include information, where relevant, about increased suspended sediment loads in the intertidal zone during installation.	EN-3 Paragraph 2.6.81 (intertidal impacts)	Section 6 (construction effects) and Section 7 (operational effects). The effects of suspended sediment on intertidal habitat are considered separately in **Chapter 12 Marine and Intertidal Ecology.**
Where necessary, assessment of the effects on the subtidal environment should include: • Loss of habitat due to foundation type including associated seabed preparation, predicted scour, scour protection and altered sedimentary processes; and • Increased suspended sediment loads during construction.	EN-3 Paragraph 2.6.113 (subtidal impacts)	The effects of scour and changes to sedimentary processes on subtidal habitat are considered separately in **Chapter 12 Marine and Intertidal Ecology.** The effects of suspended sediment on subtidal habitat are considered separately in **Chapter 12 Marine and Intertidal Ecology.**
Heritage assets can be affected by offshore wind farm development in two principal ways [only one is relevant to the physical environment]: • From indirect changes to the physical marine environment (such as scour, coastal erosion or sediment deposition) caused by the proposed infrastructure itself or its construction.	EN-3 Paragraph 2.6.139 (historic environment)	The effects of scour and changes to sedimentary processes on the historic environment are considered separately in **Chapter 18 Marine and Coastal Archaeology.**

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NPS requirement	NPS reference	ES reference
Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures.	EN-1 Paragraph 5.5.6	Sections 6.3 and 6.4 (expert geomorphological assessment of landfall effects)
The ES should include an assessment of the effects on the coast. In particular, applicants should assess: • The impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast; • The implications of the proposed project on strategies for managing the coast as set out in Shoreline Management Plans (SMPs) (which provide a large-scale assessment of the physical risks associated with coastal processes and present a long term policy framework to reduce these risks to people and the developed, historic and natural environment in a sustainable manner), any relevant Marine Plans, River Basin Management Plans and capital programmes for maintaining flood and coastal defences; and • The vulnerability of the proposed development to coastal change, taking account of climate change, during the project's operational life and any decommissioning period	EN-1 Paragraph 5.5.7	Sections 6.3 and 6.4 (expert geomorphological assessment of landfall effects)
The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of Marine Conservation Zones, candidate marine Special Areas of Conservation (SACs), coastal SACs and candidate coastal SACs, coastal Special Protection Areas (SPAs) and potential coastal SPAs, Ramsar sites, Sites of Community Importance (SCIs) and potential SCIs and Sites of Special Scientific Interest (SSSI).	EN-1 Paragraph 5.5.9	The extent of physical process related change is discussed throughout this chapter. Potential impacts on designated sites, as a result of any such change, are addressed in **Chapter 8 Designated Sites**.

2.1.3 Discussion of the effects of Dogger Bank Teesside A & B on the elements described in EN-3 (offshore) and EN-1 (coastal) are provided in Section 6 (construction), Section 7 (operation) and Section 8 (decommissioning) of this chapter.

2.1.4 The principal guidance documents used to inform the assessment of potential effects on marine physical processes are as follows:

- Cefas. 2004. Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements. Report to the Marine Consents and Environment Unit (MCEU), June 2004; and
- Lambkin, D.O., Harris, J.M., Cooper, W.S. and Coates, T. 2009. Coastal process modelling for offshore wind farm environmental impact

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assessment: best practice guide. COWRIE COAST-07-08, September 2009.

2.2 Consultation

2.2.1 As part of the development of Dogger Bank Teesside A & B, Forewind has undertaken a thorough pre-application consultation process, which has included the following key stages:

- Scoping Opinion received from the Planning Inspectorate (June 2012);
- First stage of statutory consultation (in accordance with sections 42 and 47 of the Planning Act 2008) on Preliminary Environmental Information (PEI) 1 including the Scoping Report submitted to the Planning Inspectorate (May 2012); and
- Second stage of statutory consultation (in accordance with sections 42, 47 and 48 of the Planning Act 2008) on the draft ES designed to allow for comments before final application to the Planning Inspectorate.

2.2.2 In addition, consultation associated with the Dogger Bank Creyke Beck A & B application (Forewind August 2013) has been taken into account for Dogger Bank Teesside A & B where appropriate.

2.2.3 Forewind has also consulted specific groups of stakeholders on a non-statutory basis to ensure that they had an opportunity to inform and influence the development proposals. Consultation undertaken throughout the pre-application development phase has informed Forewind's design decision making and the information presented in this document. Further information detailing the consultation process is presented in **Chapter 7 Consultation**. A Consultation Report is also provided alongside this ES, as part of the overall planning submission.

2.2.4 A summary of the consultation carried out at key stages throughout the project, of particular relevance to marine physical processes is presented in **Table 2.2**. This table only includes the key items of consultation that have defined the assessment. A considerable number of comments, issues and concerns raised during consultation have been addressed in meetings with consultees and hence have not resulted in changes to the content of the ES. In these cases, the issue in question has not been captured in **Table 2.2**. A full explanation of how the consultation process has shaped the ES, as well as tables of all responses received during the statutory consultation periods, is provided in the Consultation Report to be submitted with the final application.

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Table 2.2 Summary of consultation and issues raised by consultees

Date	Consultee	Summary of issue	ES reference
December 2013 (section 42 consultation on the draft ES, statutory)	MMO	**Appendix 9A Marine Physical Processes Assessment of Effects Technical Report**, Section 4.4.6 and 4.4.7 (page 49) and **Chapter 9**. Section 6.3.6 (page 56). Clarification is required concerning the assumptions regarding the affirmation that the drill arisings spoil will transform into a sand wave. Furthermore, details should be provided of how the sand wave dimensions were derived.	Clarification on the morphology and dimension of the drill arisings mound is provided in Section 6.3
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	Section 4.13.1 (p.36) Coastal sediment sources, transport and sinks: It is recorded that the dunes and till cliffs have been eroding at a fairly constant rate along the coast between Redcar and Saltburn-by-the-Sea. Defences (in the form of groynes) are now in place along the coast. However the dunes continue to erode, forming a veneer in front of the till cliffs. Natural England has concerns regarding the impacts of the cofferdams preventing the transport of this eroded material. As such we would reiterate the previous advice we provided for the Creyke Beck Projects (see Relevant Representation submitted 08/11/13) and expect Forewind to apply the same additional condition within the DMLs. Although Natural England recognises the temporary nature of the cofferdams we suggest that to ensure no interruption of sediment movement along the coastline Forewind should monitor the sediment on the updrift side of the cofferdams and carry out bypassing if there is evidence of sediment levels increasing. Natural England would expect to be consulted on the Cable Burial Management Plan which should consider the detail of the cofferdams and potential impacts.	Confirmation that beach levels will be monitored is provided in Section 6.5
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	**Table 5.1** (p.42) Key design parameters forming the realistic worst case scenarios: Natural England questions whether the four smaller cofferdams still have the greatest effect in terms of interruption to sediment processes with regard to landfall. Forewind states that they will have a greater effect in terms of sediment excavated, but Natural England would like further clarification as to whether they will also create the greatest "block" to sediment movement.	The worst case scenario has been changed to two large cofferdams in Section 6.5
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	**Table 5.1** (p.41) Worst case scenarios - operation: Natural England would like further clarification to be provided to the extent of cable protection required for the project area. Currently, it is stated that the worst case scenario requirement for the export cable corridor would be to have linear cable protection from the subtidal zone to an unspecified distance offshore. Natural England understands that a full understanding of the requirements will not be known until pre-construction surveys are carried out. However, is it possible that more informed judgements can be made regarding the type, location and extent of cable protection along this of export cable corridor. The number of cables and therefore potential quantities of cable protection should be estimated in order to inform the	Modifications to the worst case scenario are included in Table 5.1 and detailed in Section 7.5

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Date	Consultee	Summary of issue	ES reference
		assessment.	
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	**Table 5.1** (p.41) Worst case scenarios – decommissioning: Natural England would like to highlight that the removal of cable protection is preferred at the time of decommissioning. The intention for cable removal at the time of decommissioning is not considered under the worst case scenario.	Cable removal has been added to the decommissioning part of Table 5.1
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	Section 6.3.6 (p.56-57) Fate of side-cast material from foundation installation: Natural England and JNCC have concerns with the approach and methodologies used to assess the re-distribution of side-cast material from foundation installation and question whether the predictions for non-suspended sediment are realistic, particularly as Forewind states that tidal currents are relatively weak. Although certain assumptions are made there is no actual modelling to demonstrate the extent and estimated duration of the distribution (also see comment 9, in relation to section 3.5.12). The potential for such side cast mounds to winnow away and for the sediment to be moved from the initial cone shape has not always proven to be realistic from past experiences with other offshore wind farms.	Clarification on the method and potential for winnowing (i.e. removal of fine sediment) is provided in Section 6.3
November 2013 (section 42 consultation on the draft ES, statutory)	JNCC/Natural England	• Section 7.5.3 (p.78) Effect on nearshore sediment transport of seabed cable protection: The worst case scenario is currently based on the assumption that there is no restriction on the length of cable protection in the nearshore, and therefore the assessment is based upon remedial protection across the whole of the nearshore subtidal zone to an unspecified distance offshore. Further details on the specific locations and extent of protection, as well as the sediment movement are required before Natural England can make a more informed conclusion as such great quantities of cable protection within the active zone is unjustified and unrealistic. Natural England understands the use of the worst case scenario (remedial protection across the whole of the near shore subtidal zone to an unspecified distance offshore) in this instance however geophysical/geotechnical surveys will add a degree of realism to this scenario. Natural England highlights that the preferred method of cable protection is cable burial and remedial protection should be used as a last resort with developers encouraged to explore all methods. Natural England requires further detail within the assessment to confirm that all options have been fully considered. In addition the worst case scenario is unclear as Forewind states that “*Remedial protection is anticipated to be up to about 15m wide and stand 1.3m above the surrounding seabed*”. Natural	Modifications to the worst case scenario and the effects of this are detailed in Section 7.5

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Date	Consultee	Summary of issue	ES reference
		England would highlight that it needs to be clear what the worst case scenario is. The potential for four cables requiring protection is mentioned in section 7.5.3 of the Environmental Statement. It is not clear whether these four cables are the total number of unbundled cables for the Teesside A & B export cables, as assessed in Creyke Beck A & B. The potential impacts of cable protection for four unbundled cables occurring in a parallel manner have not been considered within the worst case scenario. The potential for sediment transport to be prevented would be far greater for more than one cable with linear protection. The key areas of concern are the extent of protection, the location of protection and the cumulative impacts of multiple cables with protection where potentially four unbundled cables would cause greater linear impacts when considered together (rather than one indicative cable route). Physical processes should also be assessed in-combination with other plans and projects proposing to use cable protection along the Holderness coast.	
November 2013(section 42 consultation on the draft ES, statutory)	JNCC/Natural England	Section 7.5.8 (and previous sections) (p.79) Effect on nearshore sediment transport of seabed cable protection: Natural England supports the approach Forewind has taken in defining the active transport zone (i.e. down to the 10m contour) but this section notes "*Longshore sediment transport is generally to the southeast within the envelope of the Dogger Bank Teesside A & B Export Cable Corridor, but rates are relatively low. This is manifest in only small sediment build-up on the west side of the Redcar groynes (northwest of the cable corridor)*." Although small amounts of sediment would be indicative of limited sediment transport, there is no assessment of wider sediment transport links. Natural England questions whether there is any movement of material which is slightly further offshore (within the 10m contour) which may bypass this beach area but still feed other areas further south. In addition Natural England questions what the Shoreline Management Plan states about the sediment transport regime in the area, as this would provide additional information to confirm the findings from the physical evidence on the beach. Natural England requests that further information is presented to support the findings as the evidence around sediment transport appears to be limited.	Modifications to the worst case scenario and the effects of this are detailed in Section 7.5
November 2013(section 42 consultation on the draft ES, statutory)	JNCC/Natural England	Section 7.5.12 (p.80) Effect on nearshore sediment transport of seabed cable protection: Although this paragraph is based on the „worst case", Natural England requires clarification on where the conclusion to this paragraph was obtained (Model or evidence based). Further clarification is also required on the scour effects from remedial protection over time.	Clarification on method is provided in Section 7.5
November 2013(section 42	JNCC/Natural England	Potential case for inclusion within the "Interruption to sediment transport pathways". The possible installation of cable protection (currently assessed at a maximum worst case scenario – not a realistic worst case scenario) at construction phase and the more long-term impacts through the	The worst case scenario of four cables is made clear in Section 7.5

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Date	Consultee	Summary of issue	ES reference
consultation on the draft ES, statutory)		operational phase could impact the Flamborough & Filey Coast pSPA/ Flamborough Head SAC sites. Natural England notes that secondary scour is not expected to be significant as a result of cable protection. However it is not clear whether Forewind have included the potential effects of the cumulative linear impacts of potentially four cables if an unbundled approach is taken (ie, worst case scenario).	
June 2012 (Scoping)	Secretary of State	The existing environment is described in this section outlines the further survey work that will be undertaken and the timescale for its completion. The purpose of each survey is noted but there are no proposed methodologies. The methodologies should be developed in consultation with JNCC, Natural England and the MMO.	The adopted methodologies are described in detail in Section 3
June 2012 (Scoping)	Secretary of State	The applicant states that the onshore and offshore cables may be left in situ as part of the decommissioning of the development. The EIA should assess the impacts of this option including the potential for cable exposure as a result of coastal changes and hydrological processes, including a monitoring plan and suitable mitigation measures.	Decommissioning effects are described in Section 8
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 6.2.2, Effects on geology, proposes to scope out the effect on underlying offshore geology. As highlighted in section 28.3.3 of the Scoping Report any topics to be scoped out must be properly justified. This should include specification of what is being considered the "underlying geology" and explanation of why and how this won't be affected, including depth below shallower geology and sediments. Should any effects upon geology be identified further information on the secondary effect upon other marine processes or ecology should be outlined.	Effects on geology are scoped out of the assessment as foundation installation would not materially change the underlying geology
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 6.2.3, Effects on hydrodynamic processes, proposes to scope out the effect of construction infrastructure upon the hydrodynamic regime. As highlighted in Section 28.3.3 of the Scoping Report any topics to be scoped out must be properly addressed and justified and this should include detail of the construction infrastructure including dimensions, location, length of time that it will be left in place and movements, as well as any associated infrastructure such as moorings. Interaction between the infrastructure and hydrodynamic regime should be provided with an explanation of why the regime isn't affected.	Construction infrastructure was scoped out of the assessment of construction effects (Section 6)
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 6.2.6, Effects on hydrodynamic processes and 6.2.7 Effects on sediment transport processes propose to assess the operational effects on the hydrodynamic and sediment transport processes. We are encouraged that the EIA will consider both near-field and far-field effects on hydrodynamic conditions. This assessment should be informed by appropriate hydrodynamic information for the development area and modelling studies. In-combination effects need also be considered, especially given the large number of turbines proposed and the overlap of the project with the Annex I sandbank habitat of the Dogger Bank cSAC. JNCC also advise that screening for an Appropriate Assessment in relation to potential effects on hydrodynamic and sedimentary processes will be required.	Operational effects on hydrodynamic processes and sediment transport are described in Section 7

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Date	Consultee	Summary of issue	ES reference
June 2012 (Scoping)	JNCC/Natural England	The assessment on hydrodynamic processes should also consider the potential effects of the development proposal upon the coastline, coastal processes and designated sites by impediment to sediment transport; and the interaction of turbines and their effect upon hydrodynamic and sediment processes as a group, as well as individually.	Effects on sediment transport at the coast are covered in Section 7.5 (related to potential remedial cable protection)
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 6.2.9 states that decommissioning and construction impacts will be similar and therefore proposes to scope out geology and hydrodynamic processes out of the EIA. The decommissioning effects must be addressed, particularly as this will include the removal of structures with a resultant change to the marine environment, hydrodynamic and sediment processes and potentially the remobilisation of sediments which have built up around infrastructure.	Decommissioning effects are described in Section 8
June 2012 (Scoping)	JNCC/Natural England	As stated earlier in this letter, the effect of Spoils (Scoping Report, 2.3.13) should be addressed in the EIA for the effect upon benthic habitats and communities; turbidity and general water quality; and the potential for increasing or inhibiting sediment transport. Particular thought should be given to the impact of arisings from drilling into chalk as these have been seen to persist in the marine environment at other sites.	The effect of 'spoils' is addressed in Section 6.3
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 6.5.1 states that there is an aggregate extraction licence area located on the south western edge of Tranche A. The aggregate area referred to is still in the application process (i.e. not licensed), but as Forewind pointed out that does not mean that extraction activities will not occur at this site in the future. Potential future extraction activities within Tranche A should be assessed within the cumulative impact assessment.	Cumulative effects with aggregate extraction sites are dealt with in Sections 10.8 and 10.9
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, Chapter 6, Marine Physical Processes, contains limited, to no scope for the assessment of the export cable and landfall effects. As such we would welcome early consultation. Provided below is an outline of issues that should be addressed along with the general comments provided at the beginning of this letter, as well as the comments under Intertidal and Subtidal Ecology Chapter 9. However this is not exhaustive and further consultation is required.	The assessment of export cable and landfall effects are covered in Sections 6 and 7.5
June 2012 (Scoping)	JNCC/Natural England	Scoping Report must consider construction and operation impacts upon short and long-term coastal management, the shoreline management plans, potential changes in the coastline and associated requirements for coastal defences. The effects of any such requirements must be included and assessed by the EIA.	Effects at the coast are explained in Sections 6 and 7.5
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 9.2.17, Potential Impacts during Decommissioning, Disturbance to intertidal habitats, identifies the intention to leave cables in situ in the intertidal. This proposal should be considered in detail within the ES and encompass on-going coastal changes, coastal retreat and beach/seabed lowering. The potential for exposure of the cables and effects upon coastal processes as well as the requirement for later protection or removal of the cables should be included. The ES must consider the potential need for a monitoring plan for exposure, or effects	Decommissioning effects are described in Section 8

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Date	Consultee	Summary of issue	ES reference
		upon the coastal processes caused by cables, over the lifetime of the project and if left permanently in situ.	
June 2012 (Scoping)	JNCC/Natural England	Scoping Report, 9.2.18, Impacts upon Subtidal ecology, (Decommissioning) identifies that decommissioning impacts on the subtidal will be similar to the construction phase. As with the intertidal, any intention to leave infrastructure in situ must be clearly outlined and assessed in the ES. Additionally, specific consideration of the decommissioning will be required particularly related to coastal changes which are expected to occur during the operational phase.	Decommissioning effects are described in Section 8
June 2012 (Scoping)	MMO	It is noted from the project description that scour protection may be needed and could consist of protective aprons, mattresses, frond devices and rock and gravel dumping. This description also indicates that a detailed cable burial and protection assessment will be carried out to identify the target burial depth in each area and that specifications regarding landfall cable burial will take future coastal erosion into account.	A description of the worst case remedial protection is included in Table 5.1
June 2012 (Scoping)	MMO	The approach to adopt a precautionary approach to impact assessment where uncertainty exists (Section 3.3.17, page 39) has been noted.	Table 5.1 describes the worst case scenarios used in the assessment
June 2012 (Scoping)	MMO	It is acknowledged that mitigation and monitoring measures are outside the remit of this document (Section 3.8.2 and 3.8.3, page 44).	N/A
June 2012 (Scoping)	MMO	We consider that the existing environment is accurately described in section 6.1 (pages 69 to 73) with regard to geology, hydrodynamics, meteorology and geomorphology.	N/A
June 2012 (Scoping)	MMO	No impacts to the underlying geology of the development area are predicted and this issue may be scoped out of the EIA (as suggested in 6.2.2, page 73) provided foundation penetration is restricted to the surface sediment layers.	N/A
June 2012 (Scoping)	MMO	The potential impacts during construction are listed as temporary influences on hydrodynamics, disturbance to the seabed and an increase in suspended sediment (Sections 6.2.3 and 6.2.4, page 73).The temporary, localised impacts of construction infrastructure can be scoped out of the EIA as suggested.	Construction infrastructure was scoped out of the assessment of construction effects (Section 6)
June 2012 (Scoping)	MMO	Operational impacts on hydrodynamic processes are suitably described (Section 6.2.6, page 75) as localised scour and (potentially) far-field effects on the wave and tidal regime. We concur that these far-field effects need to be tested thoroughly through a modelling study. Such testing is important because of its implications for the future cumulative impacts of the wider proposed Dogger Bank zone.	Operational effects are described in Section 7
June 2012 (Scoping)	MMO	Operational effects on sediment transport processes are predicted to be restricted to scour (Section 6.2.7, page 75). Although the report is correct to state that tidal will therefore be of key importance	Operational effects are described in Section 7

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Date	Consultee	Summary of issue	ES reference
		in assessing impacts to the sediment transport regime.	
June 2012 (Scoping)	MMO	We concur that decommissioning impacts are to be similar to construction impacts (Section 6.2.9, page 75).	Decommissioning effects are described in Section 8
June 2012 (Scoping)	MMO	We approve of the focus on the cumulative effects of this and other activities on physical processes (during operation) and sediment transport (during all project phases) (Section 6.5.1, page 75).	Cumulative effects are described in Section 10
June 2012 (Scoping)	MMO	Potential construction impacts on water and sediment quality are expected to be restricted to the accidental release of chemicals and discrete short-term seabed disturbance leading to the re-suspension of sediments that may contain contaminants (Section 7.2.2 and 7.2.3, page 80).	The water and sediment quality impacts are considered separately in **Chapter 10 Marine Water and Sediment Quality**
June 2012 (Scoping)	MMO	During operation, potential impacts are expected to be indirect and the result of the disturbance and re-suspension of contaminated sediments. These impacts are expected to be localised and associated with scour around foundation structures (section 7.2.6, page 80).	The water and sediment quality impacts are considered separately in **Chapter 10 Marine Water and Sediment Quality**
June 2012 (Scoping)	MMO	Section 28.3.2 (page 232) includes a list of aspects that are proposed to be scoped out of the EIA. Of relevance to coastal processes are the following aspects: • Impacts on offshore geology • Impacts of the presence of construction plant on offshore geology and hydrodynamic regime. • Impacts of the decommissioning process on offshore geology and hydrodynamic regime. Scoping out these aspects is appropriate provided the foundation structures used do not penetrate the overlying sediment layer and intrude into the underlying geological formations, in which case the first aspect should be included in the ES.	Effects on geology are scoped out of the assessment as foundation installation would not materially change the underlying geology

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3 Methodology

3.1 Study area

3.1.1 The development at Dogger Bank is anticipated to be taken forward in four tranches (A to D). The location of Tranche A covering 2,000km^2 of seabed across the south western part of the Dogger Bank Zone (**Figure 3.1**) was identified through the Zone Appraisal and Planning (ZAP) process undertaken in 2010 (EMU Ltd 2010). The first project areas identified were Dogger Bank Creyke Beck A & B; these projects are collectively referred to as Dogger Bank Creyke Beck and have a proposed installed capacity of up to 2.4GW (up to 1.2GW in each). Following the identification of Tranche A in 2010, Tranche B (approximately 1,520km^2) was identified in 2011 as the second area for development.

3.1.2 The second application by Forewind will cover two further project areas; Dogger Bank Teesside A & B (**Figure 3.1**). These two projects are also anticipated to have a combined installed capacity of up to 2.4GW. The entirety of Dogger Bank Teesside A is located in Tranche B, whereas Dogger Bank Teesside B straddles both tranches A and B. Two further projects have been identified within Tranche C of the Dogger Bank Zone, which lies north of Tranche A, these are Dogger Bank Teesside C & D.

3.1.3 Electricity from Dogger Bank Teesside A & B will be transferred to shore by export cables, which will be routed to a landfall site between the coastal towns of Redcar and Marske-by-the-Sea. The proposed works to install the cables will be both offshore and onshore, as the cables extend from the wind farms to the coast. A 1,500-m wide export cable corridor has been delineated with the flexibility to place the cables anywhere within the corridor. The Dogger Bank Teesside A & B Export Cable Corridor will consist of two portions, an in-Zone cable corridor linking the project boundaries to the zone exit point and an export cable corridor linking the zone exit point to the cable landfall (**Figure 3.1**). The corridor is 157km long from the zone exit point to the beach at Redcar/Marske-by-the-Sea and 220km from the western boundary of Dogger Bank Teesside B to the beach.

3.1.4 The receptors to potential changes in physical and sedimentary processes occur both locally and regionally to Dogger Bank Teesside A & B. Hence, the physical environment study area encompasses the Dogger Bank Zone, the area of seabed between Dogger Bank and Redcar/Marske-by-the-Sea, and the Redcar and Cleveland coast. Assessment of the physical environment is considered over two spatial scales:

- Far-field: the southern North Sea area surrounding the development site, Export Cable Corridor and landfall, over which remote effects may occur and interact with other activities; and

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- Near-field: the footprint of the development that resides in the marine and coastal environments, including the wind turbine foundations, export cable corridor and landfall.

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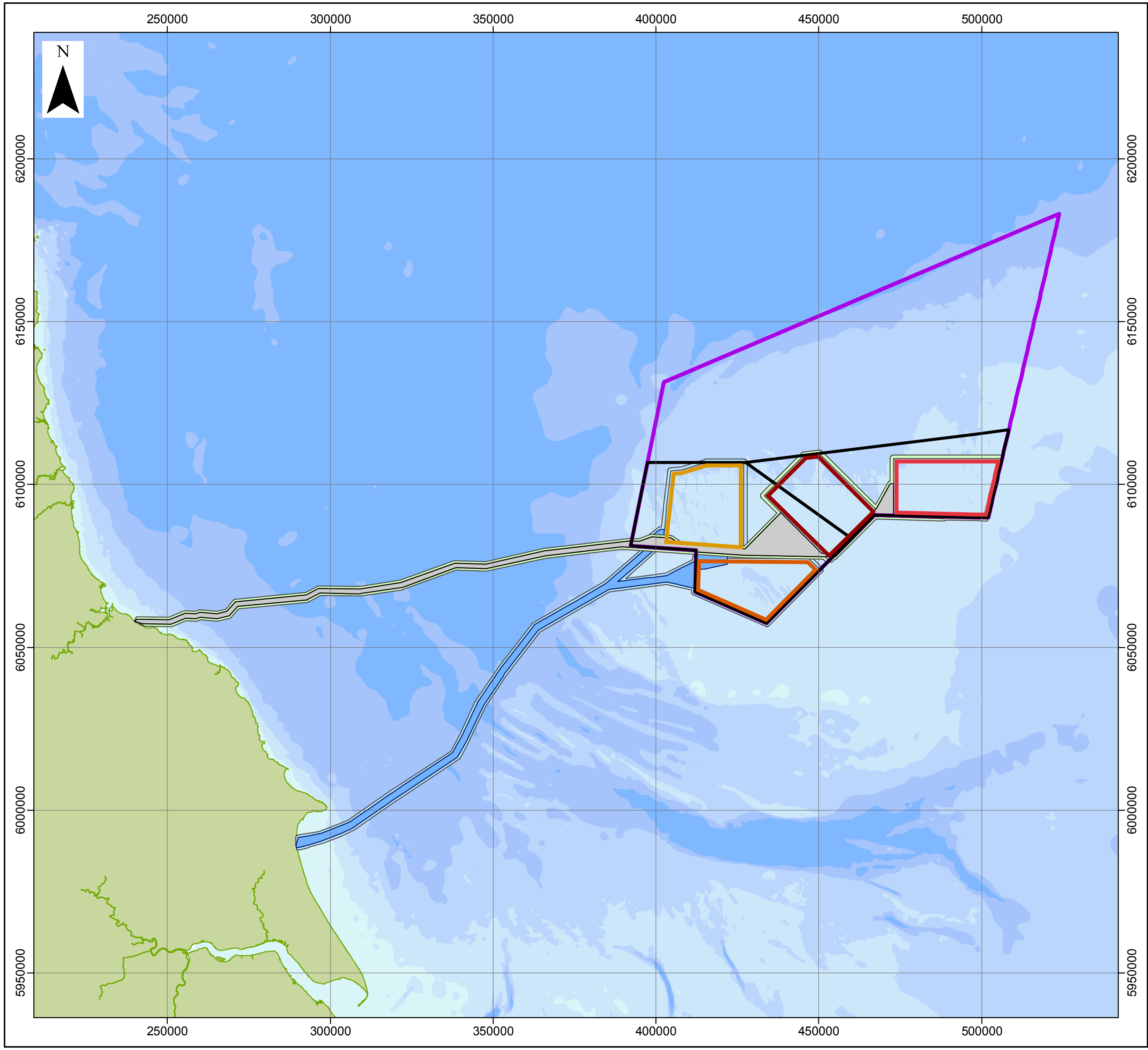

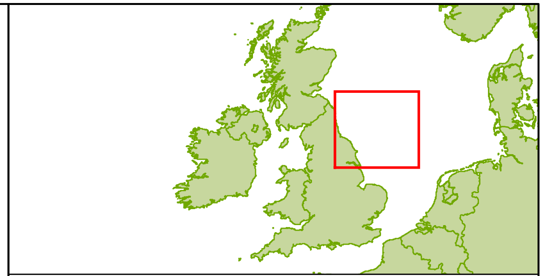

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area

0 20 40
Kilometres

Data Source:
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 3.1 Location of Dogger Bank Teesside A & B

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-410**

SCALE	PLOT SIZE	DATUM	PROJECTION
1:1,800,000	A4	WGS84	UTM31N

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3.2 Characterisation of existing environment - methodology

3.2.1 Three conceptual models were completed by Royal HaskoningDHV to support the characterisation of the Dogger Bank Zone (including the in-Zone cable corridor), the Dogger Bank Teesside A & B Export Cable Corridor and the landfall site (Appendices A, B and C of **Appendix 9A**). Numerical modelling to support both the baseline understanding and the assessment has been carried out by the Danish Hydraulic Institute (DHI) – see Section 3.3 for more details on modelling techniques adopted to characterise the existing environment.

3.2.2 Project-specific data was collected for Dogger Bank Teesside A & B across the Dogger Bank Zone and along the Dogger Bank Teesside A & B Export Cable Corridor. These data were input to the conceptual models as appropriate. Due to sufficient existing data, no new data was collected along the Redcar/Marske-by-the-Sea coastline ((Appendix C of **Appendix 9A**). A summary of the data that has been used to inform this chapter is discussed in the following paragraphs.

Geophysical data

3.2.3 Geophysical data was collected during four main survey campaigns completed for different purposes at different stages of the project:

- Zonal characterisation of the Dogger Bank Zone at a wide 2.5km transect spacing;
- Detailed survey of Tranche A at a narrow 100m transect spacing (only the north eastern part of this tranche is relevant where some of Dogger Bank Teesside B is located);
- Detailed survey of Tranche B at a narrow 100m transect spacing; and
- Detailed survey of the Dogger Bank Teesside A & B Export Cable Corridor between the Dogger Bank Zone and the landfall.

3.2.4 Full details of the methods of these surveys, along with charts of the geophysical survey transect lines and outputs are provided in Appendices A and B of **Appendix 9A**.

3.2.5 Gardline (2011a) collected geophysical data across the entire Dogger Bank Zone to provide a broad characterisation of the potential development area and to inform the zone characterisation process. This survey was carried out between May 2010 and August 2010 and deployed single and multibeam echo sounder, side-scan sonar, and sub-bottom profilers (pinger, sparker and mini airgun). The survey was run in a square grid pattern with transect lines 2.5km apart, meaning that around 15% of the Dogger Bank Zone's surface was covered by side scan and bathymetry (200m swathe along each transect).

3.2.6 GEMS (2011) carried out a geophysical survey of Tranche A to support development of projects within this area. The survey was carried out between July 2010 and December 2010 and included collection of side-scan sonar, sub-bottom profiling (pinger and sparker), bathymetry (single and multibeam echosounder) and acoustic ground discrimination (AGDS). The main

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geophysical lines were run 100m apart with 500m spaced cross lines, achieving 100% coverage of Tranche A with side scan and bathymetry.

3.2.7 Gardline (2013a) carried out a geophysical survey of Tranche B between June 2011 and October 2011, and between March 2012 and May 2012. The main geophysical lines were run at 100m apart with 500m or 1,000m spaced cross lines, achieving 100% coverage of side scan and bathymetry. The Tranche B data includes seabed characterisation (side-scan sonar, AGDS), sub-bottom profiling (pinger, sparker and mini airgun), and bathymetry (single and multibeam echosounder).

3.2.8 Gardline (2013b) collected geophysical data along two 500-m wide sections of the Dogger Bank Teesside A & B Export Cable Corridor between May 2012 and July 2012. Data collection included bathymetry (multi-beam echosounder), seabed features (side-scan sonar) and sub-bottom profiling. The main geophysical lines were run approximately 100m apart along the majority of the length of the sections of export cable achieving 100% coverage of side scan and bathymetry. For the Dogger Bank Teesside A & B Export Cable Corridor nearer to the coast, geophysical survey lines were approximately 25m apart up to 5km from the coast and then approximately 50m apart up to 16km from the coast.

Geotechnical data

3.2.9 Fugro (2011) collected 56 boreholes and wireline logs (45 in Tranche A) and 96 cone penetration tests (CPTs) across the Dogger Bank Zone between October 2010 and December 2010. The distribution of these is shown in **Figure 3.2**, but note that at each location (114 locations), one or more of the different types of geotechnical data collection has been undertaken. The boreholes were logged and various geotechnical tests were performed *in situ* and in the laboratory.

3.2.10 In addition, Fugro (2012) carried out a geotechnical survey in Tranche B in August 2012, collecting 17 borehole logs with combined CPTs and GEO (Danish Geotechnical Institute) (2012) collected 80 CPTs across Tranche B and eight CPTs in Tranche A between May and June 2012.

Benthic data

3.2.11 Gardline (2011b) collected 103 seabed sediment grab samples across Tranche A (**Figure 3.2**) as part of the wider benthic survey campaign undertaken between May 2011 and August 2011. All of these samples were analysed for particle size distribution.

3.2.12 Gardline (2012) also investigated 55 sites across Tranche B at which seabed sediment grab samples were taken from 51. The remaining four sites were not sampled due to the presence of hard substrate unsuitable for grab sampling. Particle size analysis and faunal analyses were carried out on all 51 samples. Gardline (2013b) collected 39 seabed sediment grab samples along the Dogger Bank Teesside A & B Export Cable Corridor (**Figure 3.2**). All of these samples were analysed for particle size distribution.

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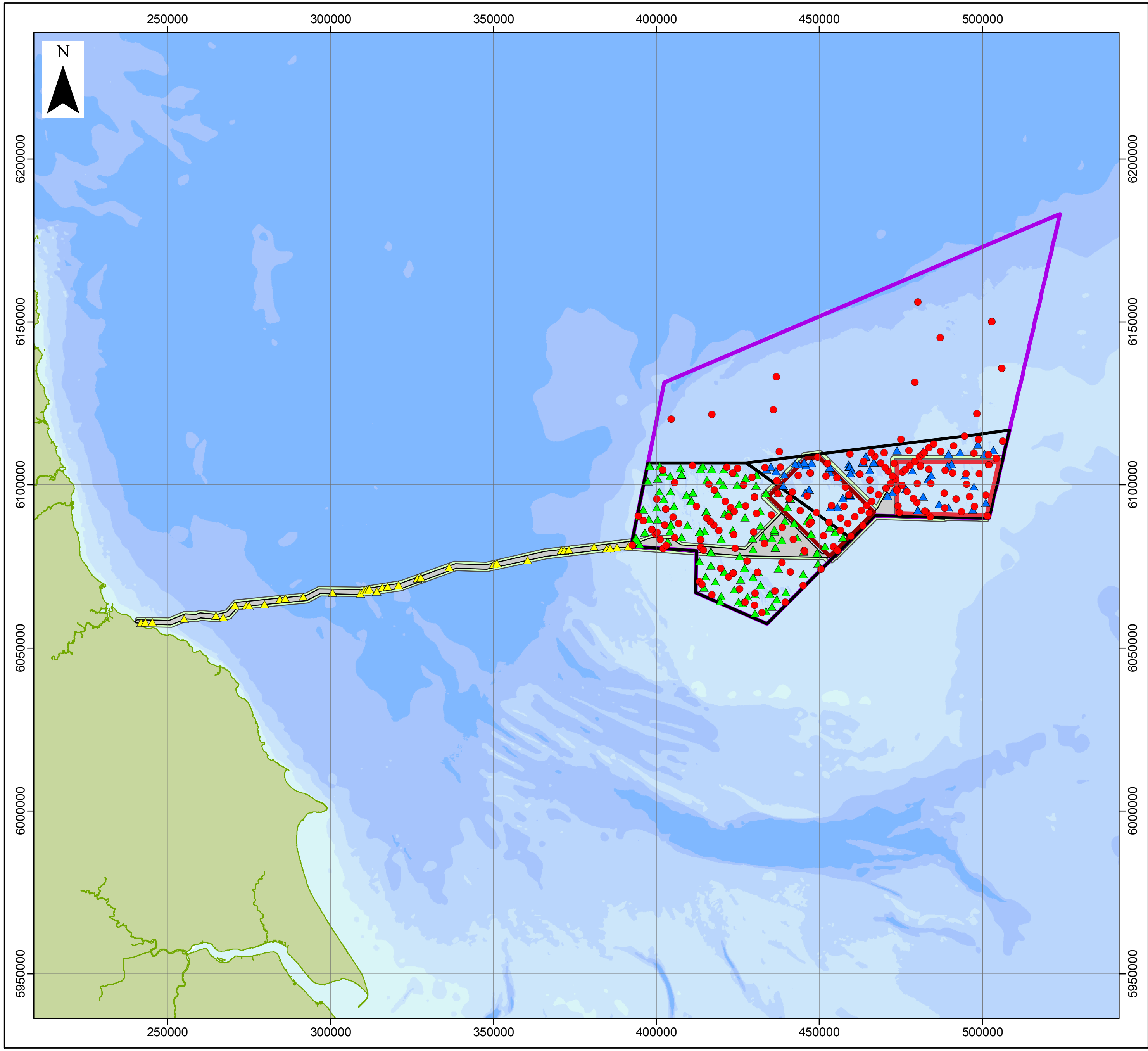

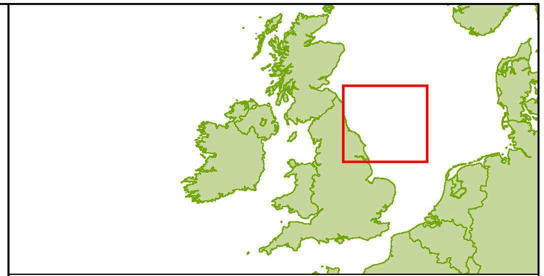

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area
- Geotechnical sample location
- Tranche A seabed sediment sample location
- Tranche B seabed sediment sample location
- Export cable corridor seabed sediment sample location

0 20 40
Kilometres

Data Source:
Dogger Bank geotechnical sample locations from Fugro (2010)
Tranche A & B geotechnical sample locations from GEO (2012)
Tranche A seabed sediment sample locations from Gardline Environmental Limited survey (2011)
Teesside Export Cable Corridor & Tranche B seabed sediment sample locations from Gardline Environmental Limited survey (2012)
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK TEESSIDE A & B

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Figure 3.2 Seabed sediment sample locations

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1	25/06/2013	Draft	FK	DB
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3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-411**

SCALE	1:1,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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Meteorology and oceanography (metocean) data

3.2.13 Currently, there are three locations where Forewind has deployed instruments to collect time series metocean data; the northern limit of the Dogger Bank Zone, inside Tranche A and inside Tranche B (**Figure 3.3**). At all these locations, wave and tidal current data have been collected using wave-riders and Acoustic Doppler Current Profilers (ADCPs). The time series of data that has been collected is listed in **Table 3.1**.

Table 3.1 Metocean data available from the deployments in the Dogger Bank Zone

Location	Coordinates and water depth	Currents		Waves	
		Start	End	Start	End
Tranche A Waverider	54° 51.72', 01° 59.83' (22m)	-	-	23/09/2010	31/03/2013
Tranche A ADCP	54° 51.61', 01° 59.64' (22m)	29/02/2012	31/03/2013	-	-
Tranche B Waverider	55° 05.90', 02° 42.04' (26m)	-	-	29/02/2012	31/03/2013
Tranche B ADCP	55° 05.90', 02° 42.04' (26m)	29/02/2012	31/03/2013	-	-
Northern Waverider	55° 29.54', 02° 09.71' (45m)	-	-	06/11/2011	31/03/2013
Northern ADCP (1)	55° 29.54', 02° 09.71' (52m)	07/11/2010	16/06/2012	-	-
Northern ADCP (2)	55° 29.46', 02° 09.58' (52m)	09/05/2012	16/06/2012	-	-

3.2.14 In addition to the new data collection, Mathiesen and Nygaard (2010) and Mathiesen *et al*. (2011) provided modelled metocean data for eight locations within the Dogger Bank Zone (**Figure 3.3**).

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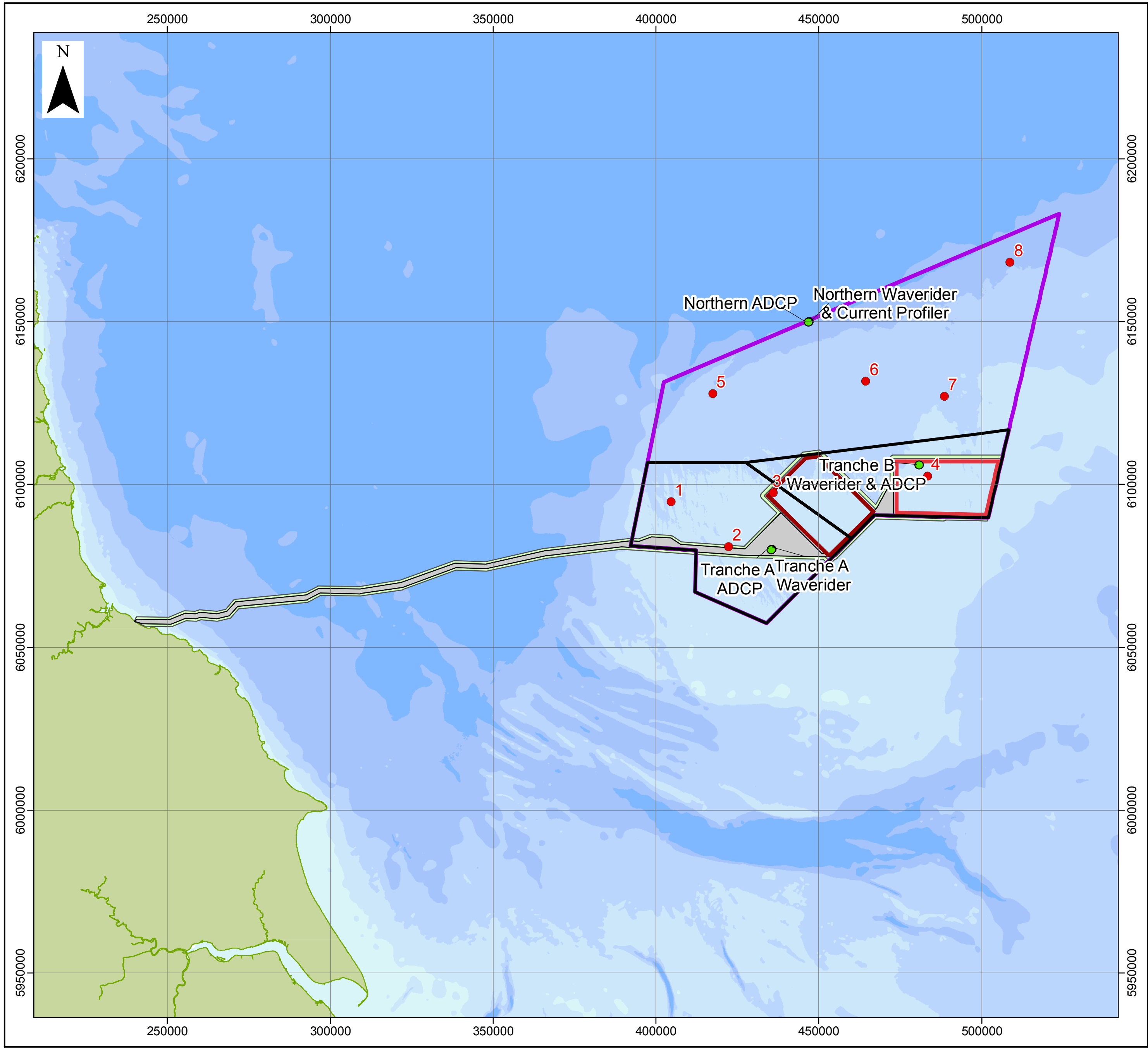

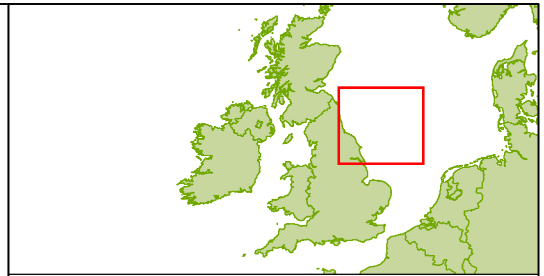

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 3.3 Metocean data points in the Dogger Bank Zone

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

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SCALE	PLOT SIZE	DATUM	PROJECTION
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3.3 Assessment of effects – methodology

Effects and impacts

3.3.1 The assessment methodology adopted to understand changes to the physical environment caused by Dogger Bank Teesside A & B is different to those adopted in other chapters of this ES. This is because the development will have effects on the hydrodynamic and sedimentary processes, but these effects in themselves are not considered to be impacts. The impacts will manifest upon other receptors such as marine ecology, fish and shellfish resources, marine water and sediment quality, and the historic environment. Hence, the assessment in this chapter focuses on describing the changes/effects against the existing environment, rather than defining the impact. Where an effect is identified, the assessment considers the magnitude of the degree of change relative to baseline conditions.

3.3.2 Potential impacts on receptors caused by changes in the physical environment are described in **Chapter 10 Marine Water and Sediment Quality**, **Chapter 12 Marine and Intertidal Ecology**, **Chapter 13 Fish and Shellfish Ecology** and **Chapter 18 Marine and Coastal Archaeology**. The assessments presented in these chapters draw on the outputs of the marine physical processes studies.

Modelling techniques

3.3.3 Effects on prevailing marine physical processes are predicted by comparing the existing environmental conditions with the conditions created by the construction, operation and decommissioning of Dogger Bank Teesside A & B. Several numerical modelling tools and conceptual techniques have been used to support the assessment of existing conditions and the potential effects of the construction, operation and decommissioning of the proposed wind farm and cables on marine physical processes.

Tidal current (hydrodynamic modelling)

3.3.4 The hydrodynamic regime is defined as the behaviour of bulk water movements driven by the action of tides. In order to investigate tidal current flows across the central North Sea and provide a baseline for prediction of changes due to the development, a project-specific hydrodynamic model was developed and run.

3.3.5 Tidal current simulations were carried out using DHI's fully calibrated and developed regional MIKE3-FM hydrodynamic (HD) model, which covers the entire North Sea and is forced by tide, atmospheric pressure and wind stresses. It is a flexible grid model with triangular and quadrilateral cells. The size of the computational cell varies over the model domain, and the model has been refined in and around the Dogger Bank Zone to provide a detailed representation of the flow in the developable area.

3.3.6 Open boundary conditions to the model consist of water levels and currents obtained from DHI's 3D North Sea Model (covering the seas around the UK and in the North Sea), which in turn uses open boundary conditions from DHI's larger 2D North Atlantic model.

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Wave modelling

3.3.7 The existing wave regime is defined as the combination of swell waves moving into and propagating through the area, and more locally generated wind waves. In order to investigate waves and provide a baseline for prediction of changes due to the development, a wave model was run.

3.3.8 Wave conditions were simulated using the spectral model MIKE21-SW (Spectral Waves), which describes the wave conditions by the directional frequency spectrum. The model includes effects like wave generation due to wind, energy dissipation due to bed friction, white-capping and depth induced wave breaking, depth and current refraction, reflection and diffraction. The model uses a flexible computational mesh, so a fine mesh can be applied to the areas where the locations of the wind turbines are proposed.

3.3.9 The wave model has been successfully calibrated against the three largest events that were recorded by the two Forewind waveriders, one deployed in Tranche A and one in the north of the Dogger Bank Zone (**Figure 3.3**) (Gardline 2011c). The data used in the model was captured up to the end of October 2011. Any additional data collected since October 2011 would not substantively change the conclusions reached based upon the wave sample used in the models.

Dispersion modelling

3.3.10 The simulation of the release and spreading of fine sediments (mud to fine sand) as a result of foundation and cable installation activities and operation of the wind farm has been modelled using the 3D model MIKE3-FM Mud Transport (MT). MIKE3-FM MT is integrated with MIKE3-FM HD, which has been used to predict tidal current changes, and takes into account:

- The actual release of sediments as a function of time, location and sediment characteristics;
- Advection and dispersion of the suspended sediment in the water column as a function of the 3D flow field predicted by MIKE3-FM HD;
- Settling and deposition of the dispersed sediment; and
- Re-suspension of the deposited sediment, predominantly by bed shear stresses from surface waves.

3.3.11 Particle size inputs to the dispersion models were calculated from two sources:

- For surface sediment as an average from analyses of the seabed sediment samples collected across Tranche B and the Dogger Bank Teesside A & B Export Cable Corridor; and
- For sub-surface sediments as an estimate from borehole data collected across Tranche B.

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Conceptual modelling

3.3.12 Expert geomorphological assessment, using the landfall conceptual model (Appendix C of **Appendix 9A**) as a basis, has been used to assess the effects of the landfall works on existing physical processes and future evolution of the coastline. The landfall conceptual model provides a baseline understanding of the physical and sedimentary processes operating along Redcar/Marske-by-the-Sea coast and, more specifically, in the vicinity of the landfall. The conceptual model was compiled almost entirely from existing data including wave conditions, sediment transport and coastal change. As long as due regard is taken of data origins and accuracy, predictions based on extrapolation of historical trends provide a reliable estimate of the most probable evolution of the coastline during construction and operation of landfall infrastructure.

3.3.13 Expert geomorphological assessment has also been used to assess the fate of the coarser sand that is not suspended during the foundation installation activities.

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4 Existing Environment

4.1 Bathymetry

4.1.1 The Dogger Bank is a large and isolated positive bathymetric feature which is approximately 300km long and elongate in an east-north east to west-south west direction. Within the Dogger Bank Zone, water depths range from approximately 78m below lowest astronomical tide (LAT) along the northern edge to just less than 20m below LAT in the south west (Tranche A).

4.1.2 A proportion (about one third) of the Dogger Bank Teesside B project area is located within the north eastern part of Tranche A and falls within the 20-30m bathymetry zone. The remaining two thirds is located in the western part of Tranche B. All of Dogger Bank Teesside A is located in Tranche B.

4.1.3 Gardline (2013a) and GEMS (2011) mapped the bathymetry of Tranche B and north east Tranche A, respectively, in more detail than the Dogger Bank Zone (**Figure 4.1**). Tranche B was divided into three main zones:

- Areas less than 25m below LAT; predominantly in the form of a plateau in the south east of Tranche B;
- Areas between 25 and 35m below LAT; these depths dominate most of Tranche B; the seabed here is generally low relief, with gradients of less than three degrees; and
- Areas greater than 35m below LAT; these depths occur in the north of Tranche B in the form of north west to south east elongated gullies up to 6m deep with gradients up to six degrees along their sides.

4.1.4 The part of Tranche A occupied by Dogger Bank Teesside B comprises an area between 20m and 30m below LAT; these depths dominate much of Tranche A where the seabed is generally low relief compared to deeper areas.

4.1.5 Gardline (2013b) mapped the bathymetry of the Dogger Bank Teesside A & B Export Cable Corridor (**Figure 4.1**). Water depths range from just above LAT near the coast to approximately 80m below LAT with the deepest point about 90km offshore.

4.1.6 At the landfall site, the seabed can be separated into two zones; a nearshore zone that extends 2.5km from the coast to 20m depth with a mean gradient of 0.4^{o} and an offshore zone that extends from 2.5km to 4km offshore, characterised by a mean gradient of 0.1^{o}.

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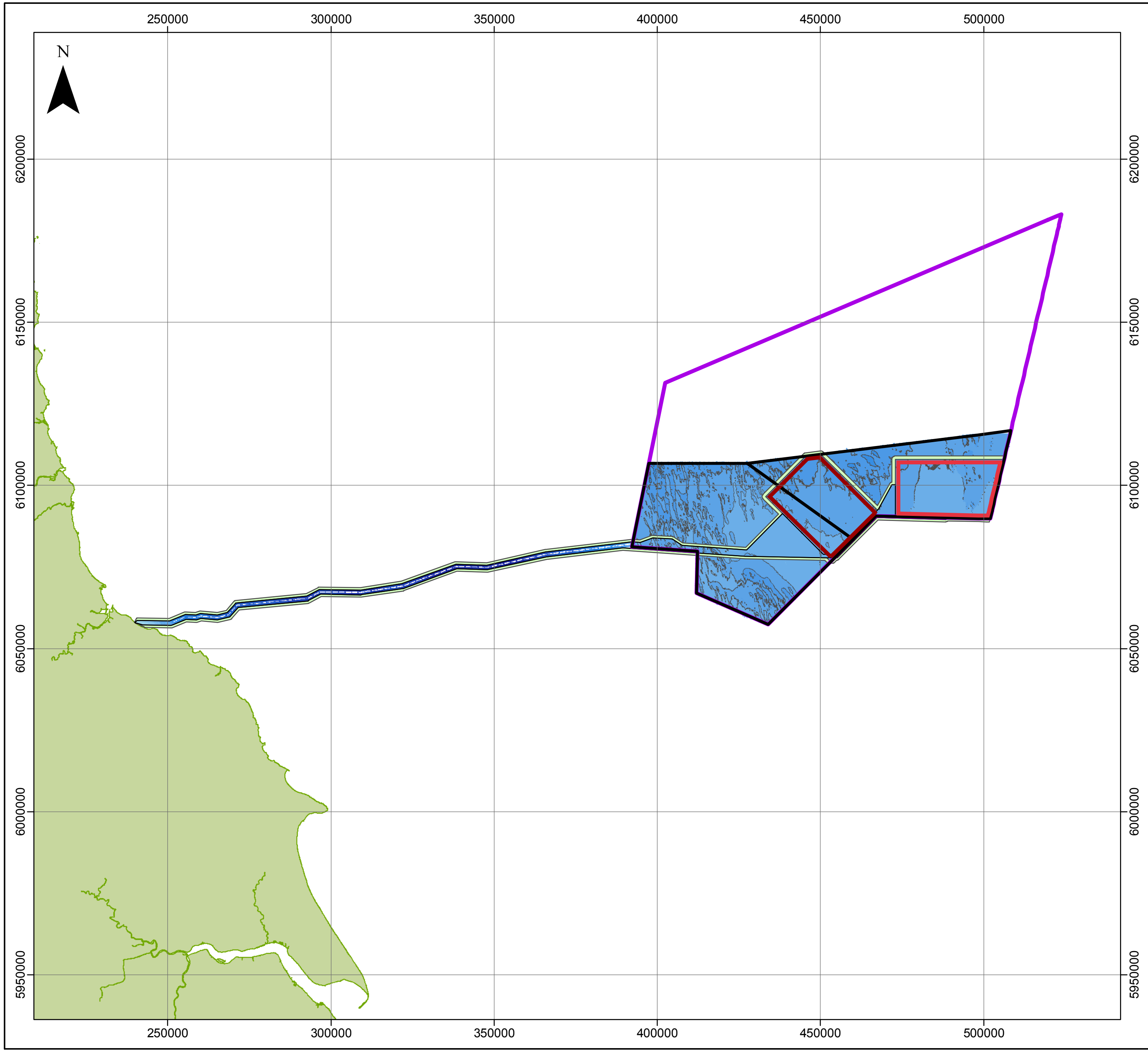

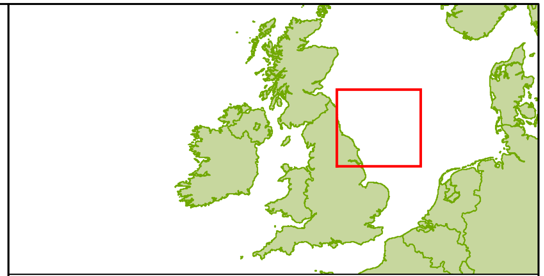

Data Source:
Tranche A bathymetry from GEMS (2010),
Tranche B bathymetry from Gardline (2011),
Cable corridor bathymetry from Gardline (2013),
Round 3 offshore wind farm boundary © Crown Copyright, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.1 Bathymetry of tranches A & B and the Dogger Bank Teesside A & B export cable corridor

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SCALE	1:1,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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4.2 Offshore geology

Pleistocene and older

4.2.1 The top 200m of the geology of Dogger Bank is dominated by sediments deposited during the Quaternary (Pleistocene followed by Holocene). The deeper Pleistocene formations preserved beneath tranches A & B of Dogger Bank comprise of a variety of sedimentary units including marine, non-marine and intertidal sediments and till (**Table 4.1**). Some units may be incised glacial sediments deposited in sub-glacial valleys. It is likely that some of these units approach within 50m of the seabed beneath tranches A & B.

Table 4.1 Stratigraphic summary of formations observed or believed to be present across tranches A and B

Age	Formation name	Composition / Sediment type	Environment
Holocene	Bligh Bank	Medium to fine sand	Marine
	Indefatigable Grounds	Gravelly sand and sandy gravel	Marine
	Nieuw Zeeland Gronden – Terschellinger Bank Member	Fine sand with shell fragments	Marine
	Well Hole	Fine sand and sandy mud	Shallow Marine
	Elbow	Peat followed by clay followed by muddy fine sand	Fluvial to Intertidal
	Transitional	Various	Sub-glacial to pro-glacial
	Botney Cut	Mud with cobble patches	Sub-glacial
Pleistocene	Dogger Bank	Clay diamicton	Sub-glacial and pro-glacial
	Eem	Shelly sand and muddy sand	Marine
	Tea Kettle Hole	Fine sand with organics	Periglacial and aeolian
	Cleaver Bank	Laminated clay and fine sand	Marine to pro-glacial
	Egmond Ground	Gravelly sand with interbeds of clay and silt	Marine
	Swarte Bank	Diamicton followed by mud then clay	Sub-glacial to pro-glacial
	Yarmouth Roads	Fine to medium sand	Fluvial to intertidal to shallow marine

4.2.2 The shallower Pleistocene units are dominated by the Dogger Bank Formation, which rests unconformably on the underlying formations. It comprises two main units; Older Dogger Bank and Younger Dogger Bank, both of which are clay-rich formations with multiple sand-rich layers of glacial origin (**Table 4.1**). The Dogger Bank Formation is present at or near the seabed, underlying Holocene sands, and in some areas underlying Botney Cut Formation channel infills.

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4.2.3 In Tranche B, the Older Dogger Bank unit comprises a series of pro-glacial morainic ridges in the west, oriented approximately northeast-southwest. The unit then thins across the central part of Tranche B before thickening again to the eastern side. The overlying Botney Cut Formation is composed of pro-glacial lake deposits that infill a basin in the Younger Dogger Bank unit. These sediments are thinly laminated clays with laminae of silts and fine sand.

4.2.4 To the south and west of Dogger Bank (and along the Dogger Bank Teesside A & B Export Cable Corridor), the Dogger Bank Formation passes laterally into the Bolders Bank Formation (Cameron et al., 1992). The Bolders Bank Formation is a sub-glacial to pro-glacial diamicton laid down during the late Pleistocene glaciation (Cameron et al., 1992).

Holocene

4.2.5 The Dogger Bank is formed mostly from a core of Pleistocene sediment, but is surrounded and covered by a veneer of Holocene sediments that reach 10m in thickness around its margins and greater than 25m thickness in infilled channels on Dogger Bank itself. The Bligh Bank and Indefatigable Grounds Formations and the Terschellinger Bank Member of the Nieuw Zeeland Gronden Formation (**Table 4.1**) are marine sands. There are also two older Holocene units (Well Hole and Elbow Formations) which were deposited in terrestrial tundra through to estuarine and intertidal environments.

4.2.6 The nature of the shallow geology (top 3m) along the Dogger Bank Teesside A & B Export Cable Corridor is mainly governed by the distribution and thickness of Holocene sands. The sand ranges in thickness from absent to greater than 20m at the eastern extent of the cable (Gardline 2013b). Where the sand is thin or absent, the outcrop at the seabed and in the shallow sub-seabed is composed predominantly of Pleistocene Bolders Bank Formation (Cameron *et al*. 1992; Stoker *et al*. 2011) or bedrock.

4.3 Coastal geology

4.3.1 The coastline between Redcar and Marske-by-the-Sea is backed by undefended and initially (Redcar) low, vegetated till cliffs rising to the higher coastal till slopes at Marske-by-the-Sea (**Figure 4.2**). The backshore and toe of the coastal slope is composed of a high, dry sandy backshore. Along some of the coastal slopes there are substantial shingle berms present at their toes.

4.3.2 The geological layers of interest for the construction of Dogger Bank Teesside A & B Export Cable and landfall are:

- Till slopes between Redcar and Marske-by-the-Sea;
- Sand beaches that front the slopes; and
- Occasional outcrops of underlying bedrock and patches of shingle berms at the toe of the slopes.

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PROJECT TITLE

DOGGER BANK TEESSIDE A & B

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Figure 4.2 Till cliffs and beach at Marske-by-the-Sea

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3	06/02/2014	DCO Submission	JE	DB

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SCALE	PLOT SIZE	DATUM	PROJECTION
Not to scale	A4		

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4.4 Wave climate

4.4.1 Gardline (2011c) presented wave roses for the Tranche A waverider buoy for time series between 23 September 2010 and 19 May 2011 and, for the northern buoy, between 6 November 2010 and 31 October 2011 (**Figure 4.3**). The results show that most waves approach the site from the northern sector. For the Tranche A buoy, the mean significant wave height for the time series period was 1.7m and the maximum value was 6.0m.

4.4.2 No new wave data has been collected along the Dogger Bank Teesside A & B Export Cable Corridor, and so the characterisation of the wave climate relies on existing information. At the offshore end of the Dogger Bank Teesside A & B Export Cable Corridor, BERR (2008) described annual mean significant wave heights of 1.75-2.0m, whereas close to the landfall site the annual mean significant wave height decreases to less than 1.0m. Across Dogger Bank, BERR (2008) described annual mean significant wave heights of 1.75-2.0m, which corresponds broadly to the mean significant wave height of 1.7m recorded from the Tranche A waverider buoy.

4.4.3 As offshore waves propagate towards the shore, they are influenced by the seabed and shoreline features and so wave transformation processes occur, resulting in a nearshore wave climate. Generally, nearshore waves approach the landfall from the north-north east and north east due to these transformation processes. The north-north east-approaching waves drive sediment transport to the south east along the Redcar/Marske-by-the-Sea coastline.

4.5 Astronomical tidal range

4.5.1 The tidal regime at the landfall site is semi-diurnal; the water level rises and falls twice a day. The tide levels for the landfall site have been estimated using the tide levels for the River Tees, obtained from 2013 Admiralty Tide Tables. **Table 4.2** shows that the tidal range, the difference between high and low water level, is 4.6m on a spring tide and 2.3m on a neap tide. These are astronomical levels and do not account for meteorological surges.

Table 4.2 Tidal levels at the River Tees (from the 2013 Admiralty Tide Tables)

Datum	m LAT	m ODN
Mean High Water Spring	5.5	2.65
Mean High Water Neap	4.3	1.45
Mean Sea Level	3.2	0.35
Mean Low Water Neap	2.0	-0.85
Mean Low Water Spring	0.9	-1.95

Note: Ordnance Datum Newlyn (ODN) is 2.85m above Lowest Astronomical Tide (LAT)

4.5.2 Mathiesen *et al*. (2011) showed that mean high water spring at Dogger Bank Teesside A is 0.65m above mean sea level (at Location 4, **Figure 3.3**) and 0.95m above mean sea level at Dogger Bank Teesside B (at Location 3, **Figure 3.3**) Mean low water spring tide was not presented in their analysis.

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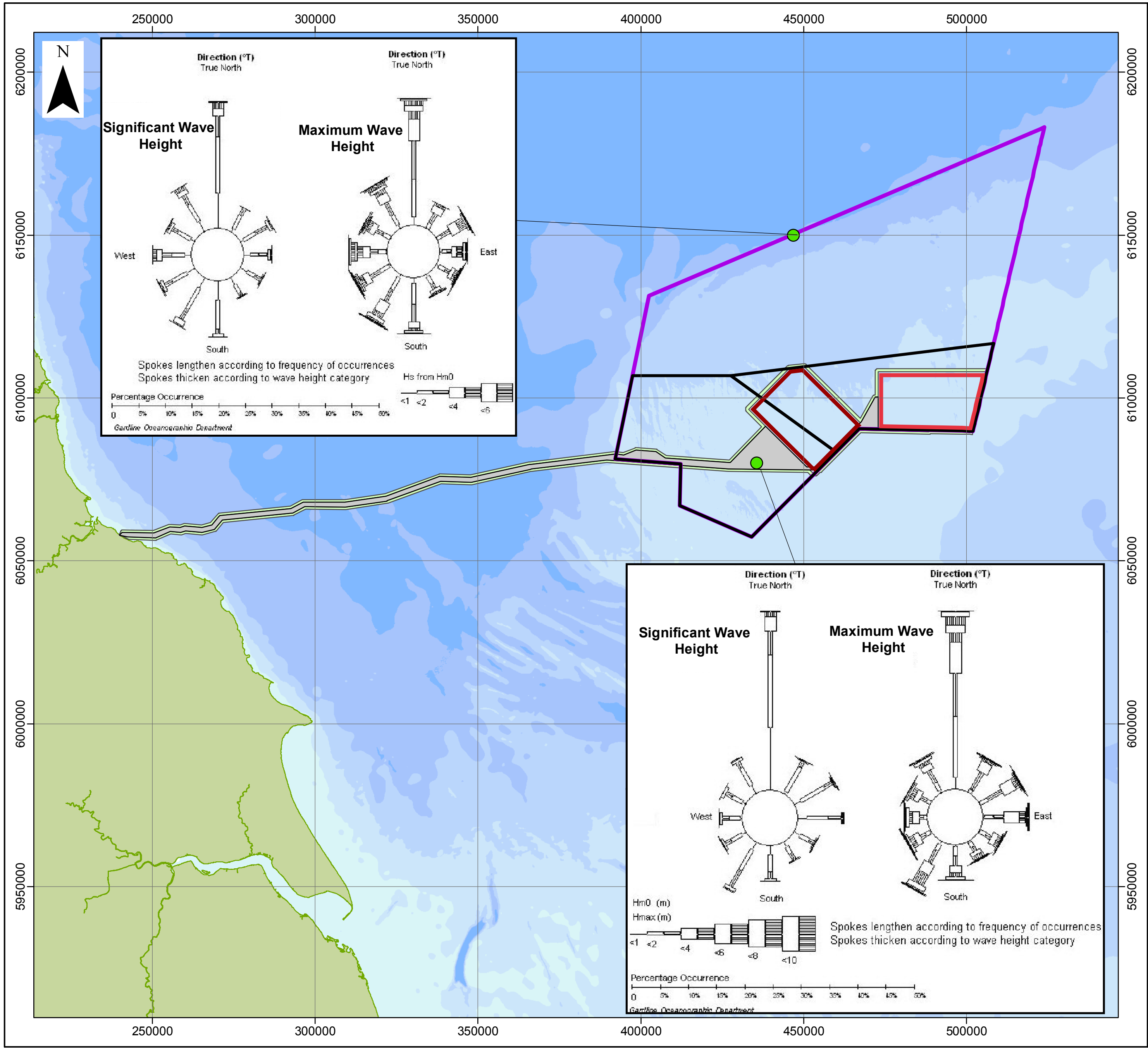

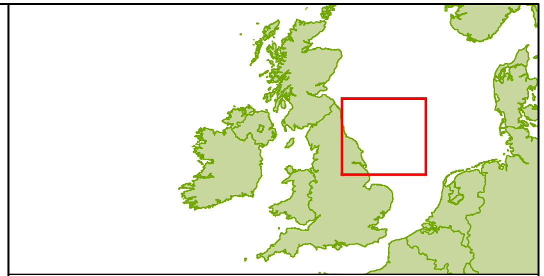

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area
- Forewind operating buoy

0 20 40
Kilometres

Data Source:
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from TCarta data © 2009
Buoys and wave roses data from Gardline Environmental Limited, MetOcean Operations Report (2013)

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.3 Wave roses at the Tranche A Waverider and the Northern Waverider

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1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: F-OFL-MA-415

SCALE	PLOT SIZE	DATUM	PROJECTION
1:1,800,000	A4	WGS84	UTM31N

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4.6 Extreme water levels

4.6.1 Water levels on the east coast are strongly influenced by tidal surges, which are driven by low pressure weather systems moving down the North Sea. These have the effect of raising extreme water surfaces above levels that would be caused by astronomical effects alone. The resulting water levels have been quantified, for different return periods, in the River Tyne to Flamborough Head Shoreline Management Plan (Royal Haskoning, 2007), and the results for the River Tees are shown in **Table 4.3**. The 50-year extreme water level is 3.68m ODN; an increase above the predicted astronomical spring tide level of about 1m.

Table 4.3 Extreme water levels at the River Tees (Royal Haskoning 2007)

Return period (years)	Water level (m ODN)
1	3.20
10	3.48
50	3.68
100	3.80
200	3.87

4.7 Sea-level rise

4.7.1 Global sea level is primarily controlled by three factors; thermal expansion of the ocean, melting of glaciers and change in the volume of the ice caps of Antarctica and Greenland. The Intergovernmental Panel on Climate Change (IPCC 2007) estimated a global average sea-level rise over the 20th century of 1.2-2.2mm/yr. with an average value of 1.7mm/yr. From 1961 to 2003, the rate was estimated at 1.8mm/yr. (1.3-2.3mm/yr.) rising to 3.1mm/yr. (2.4-3.8mm/yr.) between 1993 and 2003.

4.7.2 Woodworth *et al.* (2002) undertook an analysis of measured tide gauge data for UK sites with more than 15 years data record. The gauge at North Shields provides the longest available record of historic sea levels at a location relatively close to the envelope of the two cable landfall corridors. Between the years 1901 and 1996, relative sea level rise was measured to be 1.86mmyr^{-1}.

4.7.3 For Redcar to Marske-by-the-Sea, UKCP09 projected a 0.20m rise in sea level by 2050 ('most likely' value under the medium greenhouse gas emissions scenario) (UKCIP 2009). For the longer term, UKCP09 provides lower and upper bounds projections by 2100 of between 0.18m (low emissions) and 0.86m (high emissions), respectively. Since these potential changes in sea level will occur over the expected life time of Dogger Bank Teesside A & B, it is necessary to anticipate these increased water depths.

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4.8 Storm surges

4.8.1 The occurrence of storm surge events may be altered in the future by changes in storminess (the number, location or strength of storms), though there is no scientific consensus on this at present. UKCIP (2009) indicated that the projected future trends in 50-year storm surges are less than 40mm above current average storm surge levels by 2050, not including sea-level rise. This magnitude of change is within what might be expected through existing natural variation.

4.9 Tidal currents

4.9.1 Gardline (2011c) provided summary statistics of the data series for the Forewind current profiler at the northern limit of the Dogger Bank Zone (**Figure 3.3**) for its first (7 November 2010 to 21 January 2011) and third (31 July 2011 to 24 October 2011) periods of operation. Gardline (2011c) provided surface current roses for the two periods which are shown in **Figure 4.4**. Dominant tidal current directions over this period are from a broad range of directions from the north east sector through the south east sector to the south west sector. Current velocities are mainly less than 0.4m/s.

4.9.2 No new tidal current data has been collected along the Dogger Bank Teesside A & B Export Cable Corridor, and so the characterisation of the tidal currents relies on existing information. BERR (2008) modeled mid-depth peak flows for mean spring tides of approximately 0.4m/s at the offshore end of the Dogger Bank Teesside A & B Export Cable Corridor to between 0.20m/s and 0.60m/s off the coast at Redcar. The corresponding mid-depth peak flows for mean neap tides are about 0.2m/s and between 0.10m/s and 0.30m/s for the offshore and nearshore, respectively.

4.9.3 Mathiesen and Nygaard (2010) estimated extreme tidal current velocities at eight locations across Dogger Bank (**Figure 3.3**). The maximum extreme velocities for return periods of one, ten and 100 years were 0.88m/s, 0.98m/s and 1.11m/s, respectively. More details of extreme flows are provided in Appendix A of **Appendix 9A**.

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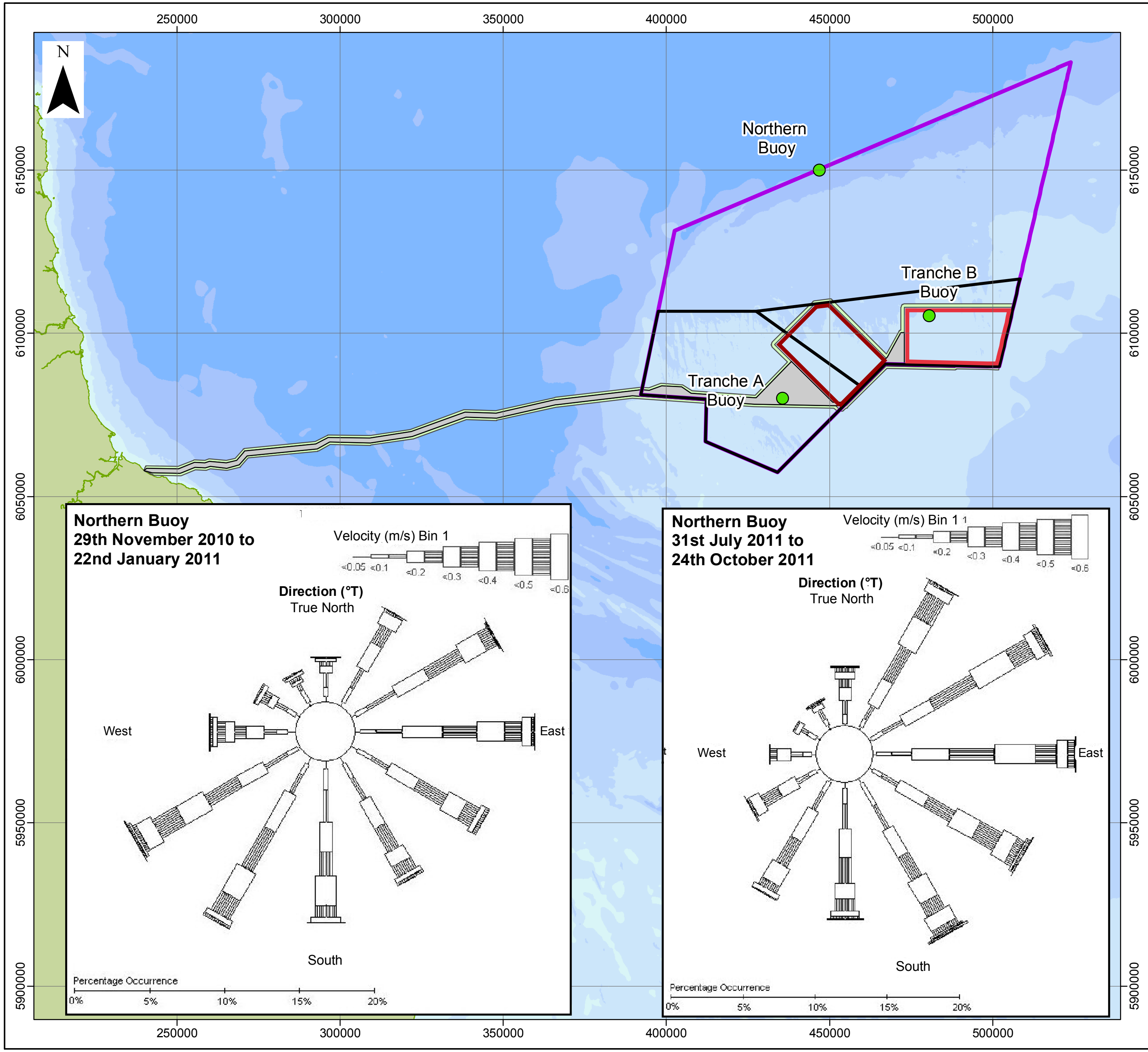

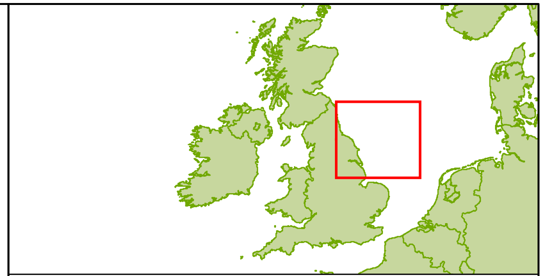

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area
- Forewind operating buoy

0 20 40
Kilometres

Data Source:
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from TCarta data © 2009
Buoys and wave roses data from Gardline Environmental Limited, MetOcean Operations Report (2013)

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.4 Surface Current Roses at the Northern Buoy

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1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-416**

SCALE	1:1,800,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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4.10 Seabed sediment distribution

4.10.1 GEMS (2011) and Gardline (2013a), using geophysical data, showed that the majority of seabed sediments across Tranche B and north east Tranche A are sandy (on the Udden-Wentworth scale) (**Figure 4.5**). Particle size analyses (Gardline 2011b; 2012) show that the medium particle diameter (d_{50}) for tranches A and B fall predominantly between 0.15mm and 0.22mm (fine sand) and 0.16mm and 0.19mm (fine sand), respectively, with a few samples in the medium to coarse sand categories. Most of the seabed sand samples contain less than 5% gravel and less than 5% mud, and can be categorised as slightly gravelly sand. Details of the particle size distributions of the seabed sand (and gravel) samples are provided in Appendix A of **Appendix 9A**.

4.10.2 Gardline (2013a) showed that patches of gravel occur across the east and south east of Tranche B (**Figure 4.5**). Median particle diameters (d_{50}) range from 1.8mm to 10.5mm, with gravel percentages between 49% and 93%. The mud content of the gravel areas is predominantly less than 5%. Seabed gravel is rare across north east Tranche A (Dogger Bank Teesside B) (GEMS 2011).

4.10.3 Along the Dogger Bank Teesside A & B Export Cable Corridor, the seabed is dominated by sand (Gardline 2013b) **(Figure 4.6**). However, patches of gravel occur between 60km and 110km offshore along the Dogger Bank Teesside A & B Export Cable Corridor and where it connects to Tranche A. Along the in-zone cable corridor, the seabed is also mainly sand with patches of gravel, mixed sediment and outcrop along its western half (**Figure 4.5**). Between approximately 5km and 25km offshore, the Dogger Bank Teesside A & B Export Cable Corridor passes through mudstone with pockets of till at seabed (Gardline 2013b). Where bedrock or till are near the seabed, cobbles and boulders are present.

4.10.4 Particle size analyses of samples from the Dogger Bank Teesside A & B Export Cable Corridor (Gardline 2013b) show that the medium particle diameter (d_{50}) falls predominantly between 0.15mm and 0.30mm (mainly fine sand with some occasional medium sand). Most of the seabed sand samples contain less than 1.5% gravel and less than 5% mud, and can be categorised as slightly gravelly sand. Several samples contain between 7% and 65% gravel. A breakdown of the particle size distributions of the Dogger Bank Teesside A & B Export Cable Corridor seabed samples is provided in Appendix B of **Appendix 9A**.

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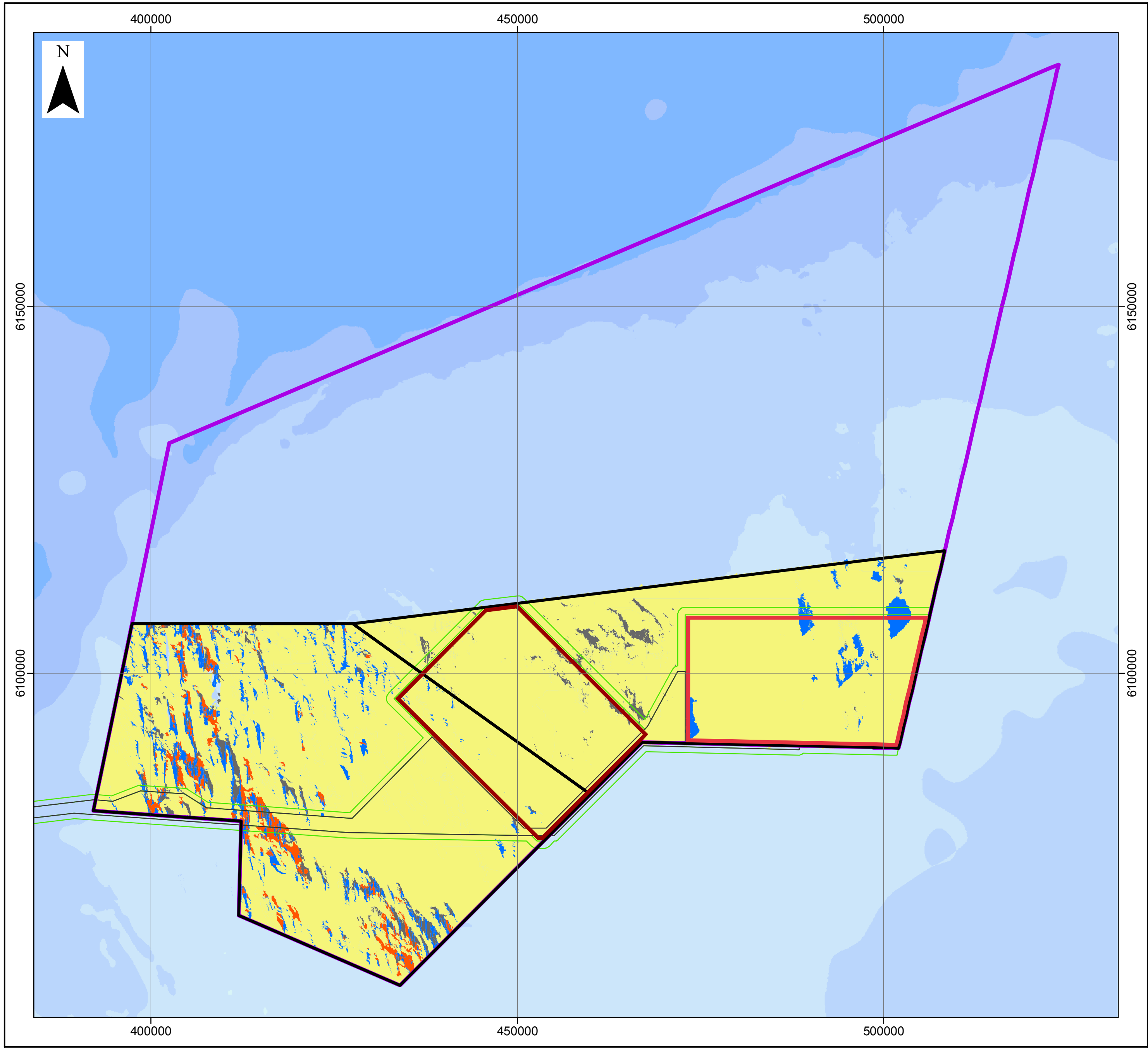

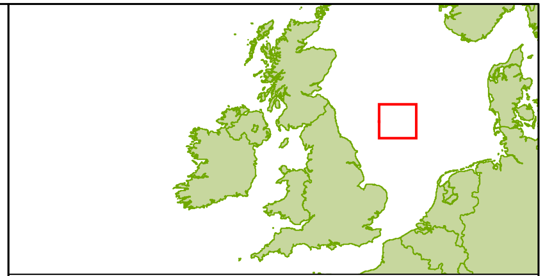

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area
- Sand
- Gravel
- Mixed sediment
- Outcrop

0 10 20
Kilometres

Data Source:
Tranche A sediment data from GEMS (2010),
Tranche B sediment data from Gardline (2011),
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.5 Distribution of seabed sediment across tranches A & B

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1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

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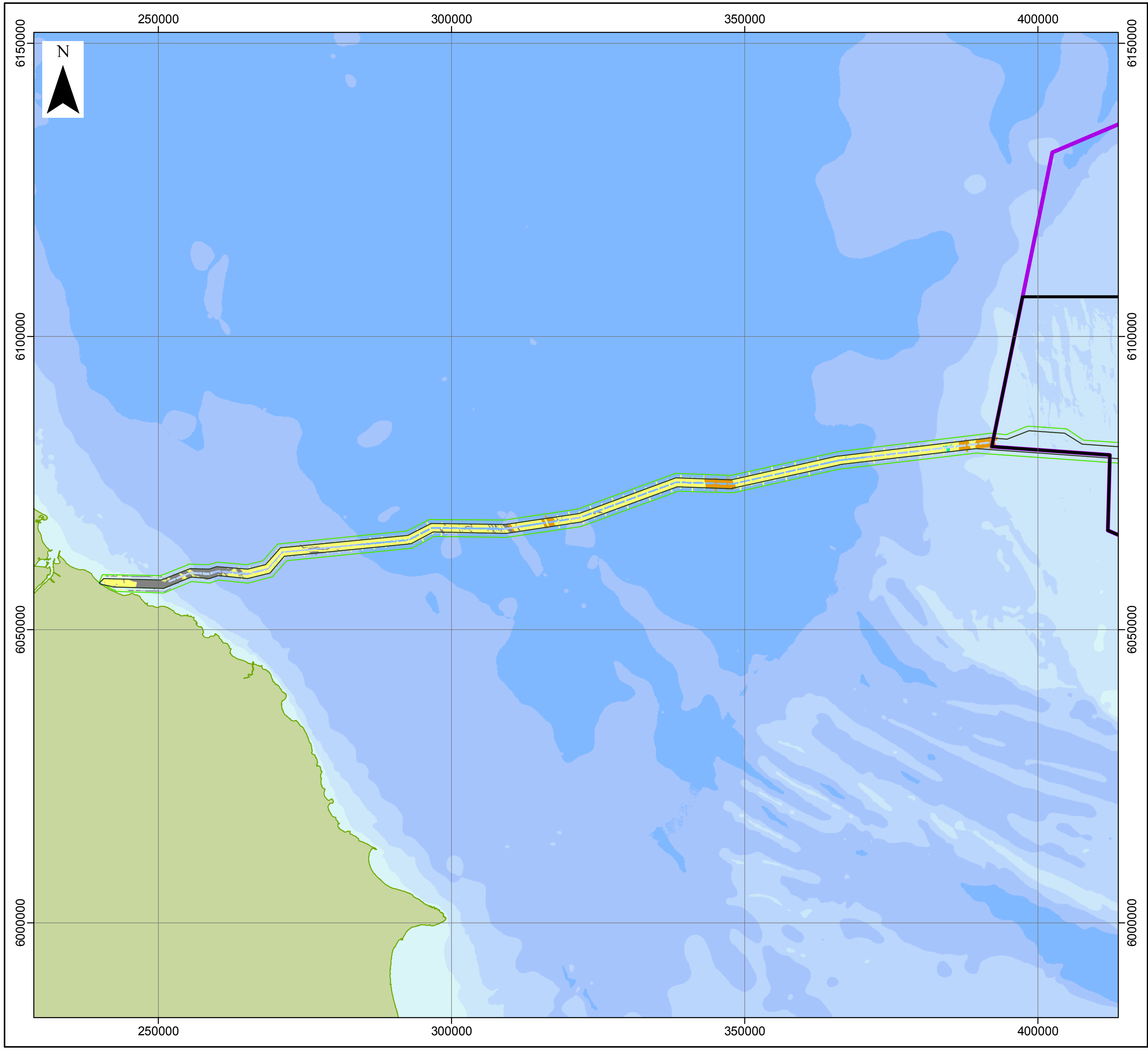

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Seabed sediment type

- Gravel
- Sand
- Rock
- Till

0 10 20
Kilometres

Data Source:
Seabed sediments data from Gardline (2012),
Round 3 offshore wind farm boundary © Crown Copyright, 2013
Background bathymetry image derived in part from TCarta data © 2009

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DOGGER BANK TEESSIDE A & B

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Figure 4.6 Dogger Bank Teesside A & B export cable corridor seabed sediment distribution

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1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

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SCALE	1:1,000,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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4.11 Bedforms and sediment movement

4.11.1 The Dogger Bank Zone seabed is largely benign and featureless because tidal current velocities are relatively weak at less than 0.4m/s. However, megaripples (wavelengths between 0.5 and 25m) sculpted into both gravel and sand substrates are present in patches across Dogger Bank Teesside A & B.

4.11.2 Gardline (2013a) observed megaripples within the gravelly sand areas of Dogger Bank Teesside A. The crests of the megaripples are aligned north-north west to south-south east and north to south, with amplitudes varying from 1.4m to 2.2m. Only limited bedforms occur in the north eastern part of Tranche A (Dogger Bank Teesside B) (GEMS 2011). Details of the bedforms are provided in Appendix A of **Appendix 9A**.

4.11.3 Although there is widespread occurrence of Holocene sands along the Dogger Bank Teesside A & B Export Cable Corridor, there is only limited development of megaripples and sand waves. Both are present along a short section of the Dogger Bank Teesside A & B Export Cable Corridor, at approximately 25-35km offshore. The largest sand wave is up to 3m high and the bedform crests are generally aligned north east to south west. The megaripples and sand waves are predominantly asymmetric with their steeper sides facing to the south east indicating that they are migrating to the south east.

4.12 Suspended sediment

4.12.1 Eisma (1981) showed that the general distribution of suspended sediment in the southern North Sea is characterised by values lower than 2mg/l across Dogger Bank and along the Dogger Bank Teesside A & B Export Cable Corridor. Eisma and Kalf (1987) carried out a water sampling programme in January 1980 and differentiated general surface concentrations from bottom concentrations. They showed that across Dogger Bank, the concentrations were similar at both elevations, ranging from 1mg/l across south Dogger Bank to 2mg/l across north Dogger Bank (**Figure 4.7**). Data along the Dogger Bank Teesside A & B Export Cable Corridor is limited, but appears to show concentrations less than 2mg/l.

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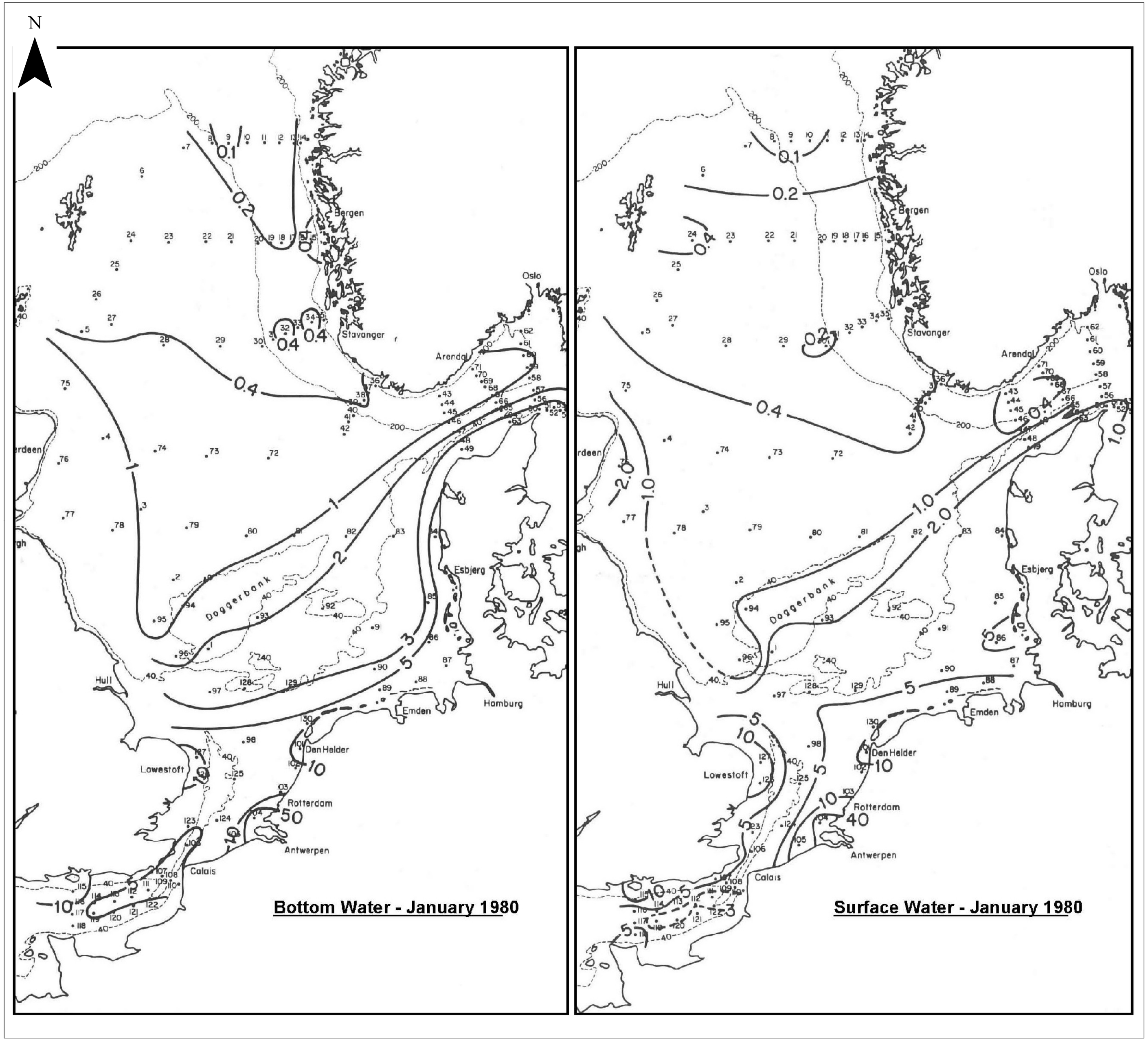

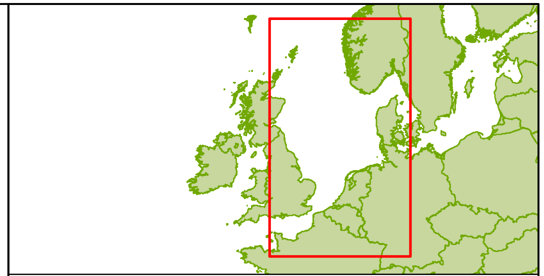

LEGEND

—2.0— Suspended sediment concentration (mg/l)

Data Source:
Eisma and Kalf (1987)

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.7 Concentration of suspended sediment in the North Sea

VER	DATE	REMARKS	Drawn	Checked
1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	14/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-419**

SCALE: Not to scale | PLOT SIZE: A4 | DATUM | PROJECTION

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4.12.2 The main driving force for suspended sediment dynamics in the North Sea is turbulence induced by tidal currents and waves (Stanev *et al*. 2008). The fundamental mechanism controlling sediment re-suspension from the seabed is bed shear stress. Across Dogger Bank, Stanev *et al*. (2008) showed that during storm conditions, no clear correlation exists between Dogger Bank bed shear stress and suspended sediment concentrations. They concluded that the availability of re-suspendable sediment at the bed across Dogger Bank is limited.

4.12.3 Site measurements of suspended sediment were not undertaken at Dogger Bank because the data from previous studies (Eisma, 1981; Eisma and Kalf, 1987) were deemed to be robust enough as a baseline. The concentrations are low (2mg/l) meaning that the effects compared to this baseline will be very conservative.

4.13 Coastal sediment sources, transport and sinks

4.13.1 The coastline of the landfall site, between Redcar and Saltburn-by-the-Sea comprises a wide (300-400m) sand beach held in place by Saltburn Scar (a rock headland) to the east. Along its western end the beach is backed by a rock revetment built on to the face of a narrow strip of sand dune fronting a till hinterland (British Geological Survey 1998). Here the beach is controlled by groynes. The eastern half is mainly undefended and the beach is backed by a narrow strip of dunes in front of till slopes, apart from a stretch of sea wall in front of Saltburn-by-the-Sea at the eastern extremity. Prior to defences, the dunes and till cliffs appear to have been eroding at a fairly constant rate to form a gently curving bay between Redcar and Saltburn Scar.

4.13.2 The dunes are in poor health and are actively eroding, forming a 'veneer' in front of the till hinterland. In places, the dunes are absent and till is exposed at the coast. In front of the till, the beach is composite with pebbles forming an upper storm beach with a wide sandy lower beach. This structure indicates that the pebbles are supplied locally through erosion of the till. In front of the dunes, the upper pebble beach breaks down and there are patches of shingle sometimes shaped into cusps on the beach surface, which is mainly sand.

4.13.3 Net longshore sediment transport is to the east (Babtie 1997; 1999) but only small sediment build-up on the west side of the Redcar groynes indicates that actual longshore sediment transport is low in this area. In addition, the presence of Saltburn Scar does not allow much loss of sediment to the east.

4.13.4 Not all of the alongshore transport of sediment occurs in the intertidal zone. Sediment transport occurs throughout what is termed the 'active' beach profile, which extends offshore from the high water mark to a nearshore point below low water, which is determined by the 'closure depth' of the beach profile (a parameter defined by the wave height and period in the nearshore zone). This could be described as the water depth offshore from which sediment is not disturbed during fair weather (wave) conditions. Whilst the predominant transport is from north west to south east, onshore to offshore movement occurs during storms.

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4.13.5 Houston (1995) provided a simple formula based on a mean annual significant wave height ($\dot{H}_s$):

$$h_{in} = 6.75\ \dot{H}_s$$

where (h_{in}) is the seaward limit of the active zone or closure depth.

4.13.6 The mean annual wave climate towards the western end of the Dogger Bank Teesside A & B Export Cable Corridor is approximately 1.0–1.5m (Appendix B of **Appendix 9A**). Taking the higher value as a conservative approach, the Houston formula yields a closure depth in about 10m water depth, which is approximately 2km offshore from mean low water spring.

4.13.7 Babtie (1999) showed that over the long-term (1858-1990), the mean high water and mean low water marks have retreated by up to 0.8myr^{-1}) but with local accretion at Marske-by-the-Sea (0.01myr^{-1}). Overall, Babtie (1999) estimated that the erosion rate for undefended land has been 0.4myr^{-1} with localised erosion of 0.6-0.7myr^{-1} closer to Redcar.

4.13.8 Since 2008, Redcar and Cleveland Borough Council has been monitoring beach morphological change as part of the wider Cell 1 (North East) Regional Coastal Monitoring Programme (Cooper *et al*. 2009). Beach profile RC7 is located within the envelope of the two cable landfall corridors. **Figure 4.8** shows the variations in beach and coastal slope profile over time between November 2008 and April 2011. The profiles describe changes to foreshore levels of up to 0.6m over this short period.

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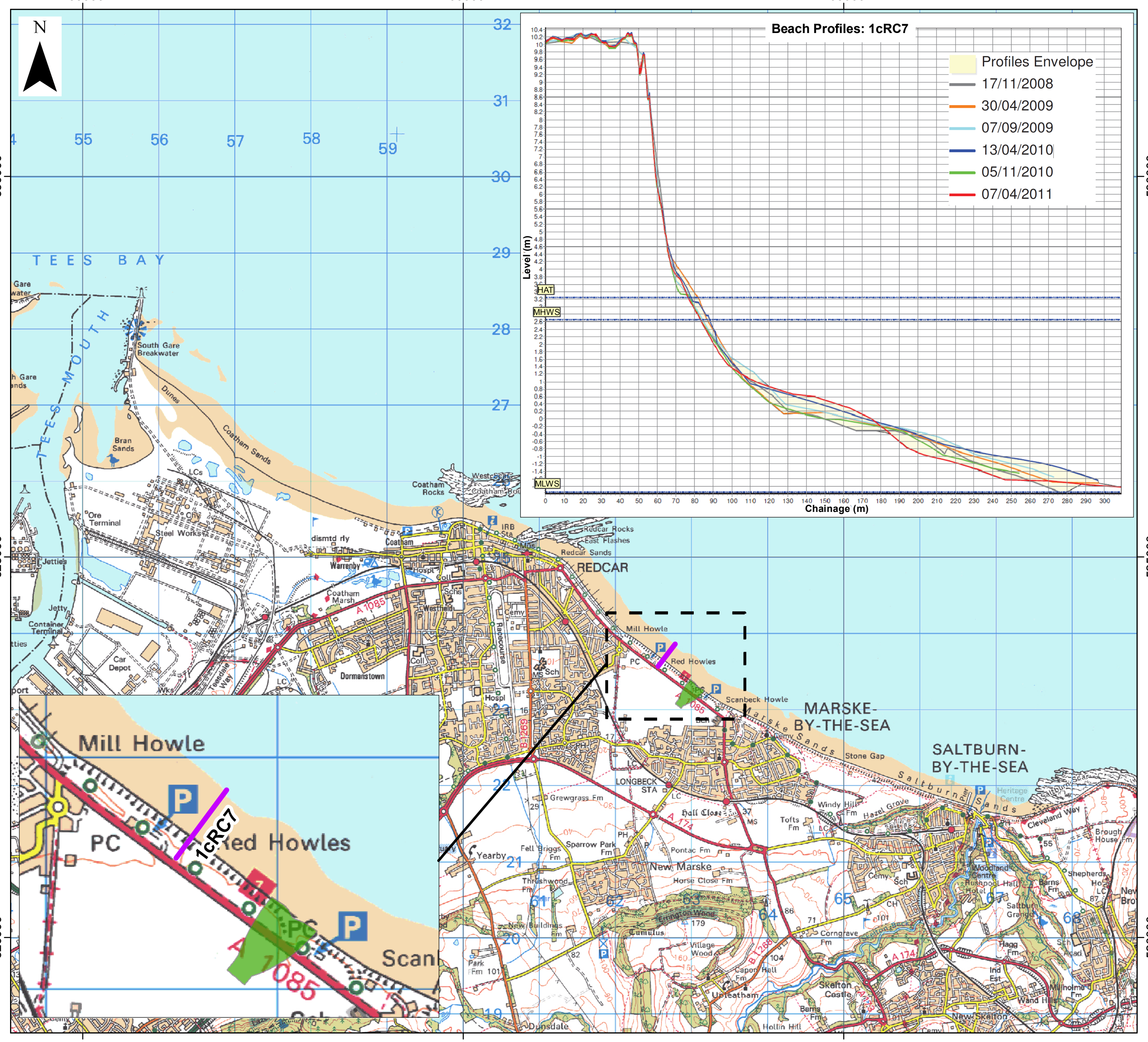

LEGEND

Dogger Bank Teesside A & B cable landfall envelope

Bi-annual topographic profile

0 1 2

Kilometres

Data Source:
North East Coastal Observatory
Ordnance Survey data © Crown Copyright 2013. All rights reserved,2013. License number 100020449

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 4.8 Location of beach profile RC7 (Cell 1 Regional Coastal Monitoring Programme)

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1	25/06/2013	Draft	FK	DB
2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

DRAWING NUMBER: **F-OFL-MA-420**

SCALE	1:80,000	PLOT SIZE	A4	DATUM	OSGB36	PROJECTION	BNG

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5 Assessment of Effects – Worst Case Definition

5.1 General

5.1.1 This section establishes the realistic worst case scenario for each category of effect as a basis for the subsequent impact assessment. For the assessment, this involves both a consideration of the construction scenarios (i.e. the manner in which Dogger Bank Teesside A & B will be built out), as well as the particular design details of each project (such as the maximum construction footprint at the landfall) that define the Rochdale[1] envelope.

5.1.2 Full details of the range of development options being considered by Forewind are provided within **Chapter 5 Project Description**. For the purpose of the marine physical processes assessment, the realistic worst case scenarios, taking these options into consideration, are set out in **Table 5.1**.

5.1.3 Only those design parameters with the potential to influence the level of effect are identified. Therefore, if the design parameter is not described, it is not considered to have a material bearing on the outcome of the assessment.

5.1.4 The realistic worst case scenarios identified here are also applied to the cumulative assessment. When the worst case scenarios for the project in isolation do not result in the worst case for the cumulative assessment, this is addressed within the cumulative section of this chapter (see Section 10) and summarised in **Chapter 33 Cumulative Impact Assessment**.

5.2 Construction scenarios

5.2.1 There are a number of key principles relating to how the projects will be built, and that form the basis of the Rochdale Envelope (see **Chapter 5**). These are:

- The two projects may be constructed at the same time, or at different times;
- If built at different times, either project could be built first;
- Offshore construction will commence no sooner than 18 months post consent, but must start within seven years of consent (as an anticipated condition of the development consent order); and
- Assuming a maximum construction period per project of six years, and taking the above into account, the maximum construction period over which the construction of Dogger Bank Teesside A & B could take place is 11 years and six months.

[1]As described in **Chapter 5** the term 'Rochdale Envelope' refers to case law (R.V. Rochdale MBC Ex Part C Tew 1999 "the Rochdale case"). The 'Rochdale Envelope' for a project outlines the realistic worst case scenario or option for each individual impact, so that it can be safely assumed that all lesser options will have less impact.

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5.2.2 As explained in Section 3.3, the marine physical processes assessment focuses on describing the changes/effects in hydrodynamic and sedimentary processes against the existing environment. In order to do this, a variety of numerical modelling tools and conceptual techniques have been used. The spatial and temporal scale at which these tools and techniques have been implemented has been used to ensure that the Rochdale Envelope incorporates all of the possible construction scenarios as outlined in **Chapter 5** (details provided in **Table 5.1** below).

5.3 Operation scenarios

5.3.1 **Chapter 5** provides details of the operation scenarios for Dogger Bank Teesside A & B. Flexibility is required to allow for the following three scenarios:

- Dogger Bank Teesside A to operate on its own;
- Dogger Bank Teesside B to operate on its own, and
- For the two projects to operate concurrently.

5.3.2 As above, the numerical modelling tools and conceptual techniques used in this assessment have been implemented at a spatial and temporal scale to ensure that the worst case of all three operation scenarios has been assessed (details provided in **Table 5.1** below).

5.4 Decommissioning scenarios

5.4.1 **Chapter 5** provides details of the decommissioning scenarios for Dogger Bank Teesside A & B. Exact decommissioning arrangements will be detailed in a Decommissioning Plan (which will be drawn up and agreed with DECC prior to construction); however, for the purpose of this assessment it is assumed that decommissioning of Dogger Bank Teesside A & B could be conducted separately, or at the same time.

5.5 Realistic worst case scenarios

5.5.1 **Table 5.1** identifies the key design parameters for the assessment of effects. In order to identify the realistic worst case scenarios, a detailed iterative process was carried out (described in **Appendix 9A**), including consultation with stakeholders.

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Table 5.1 Key design parameters forming the realistic worst case scenarios for the assessment of effects on marine physical processes

Effect	Realistic worst case scenario	Rationale
Construction		
Offshore Increase in suspended sediment concentrations due to installation of foundations and cables	The worst case installation process for effects on sediment transport that was modelled is 24 12m-diameter drilled monopole foundations, a set of inter-array cables connecting them and one export cable (within and outside the Dogger Bank Zone) installed together over a 30-day period. The worst case installation sequencing is: • Foundations installed on a daily basis; • After each daily installation of the first eight foundations, the drill arisings are dispersed by typical wave and tidal current conditions; • After installation of the eighth foundation, a one-year storm event takes place and equilibrium scour is reached at each foundation releasing the full sediment load through scour; • At day 25, no more foundations are installed; • Each foundation is connected to an adjacent foundation by an inter-array cable after all 24 foundations have been installed; and • Excavation of the export cable is assumed continuous over the 30-day period and takes place simultaneously with the installation of the 24 foundations. The worst-case scenario assumes that all sediment with a particle size less than 0.18mm is suspended in a plume	An installation process was developed that would be realistic, but that would also be very conservative in terms of numbers of foundations and installation over a relatively short period.
	A worst case drill arisings volume of 6,220m^3 is applied for installation of a 12m piled foundation, the widest diameter needed to support a 12m-diameter monopole to hold a 10MW wind turbine.	Forewind calculated this volume based on a pile diameter of 12m and an average drill penetration depth of 55m. The depth of drill penetration is above the level of the top of the chalk and so particles from the chalk do not contribute to the sediment in the arisings
	The worst case equilibrium scour volume for 12m	The scour volumes for the monopole foundation were predicted using

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Effect	Realistic worst case scenario	Rationale
	monopole foundations is estimated to range from 365m^3 to 756m^3 depending on applied wave climate and water depth.	empirical methods from existing literature and knowledge using the following criteria (details can be found in Appendix E of **Appendix 9A**): • The equilibrium scour volumes for sand were derived in various water depths defined by the location of the foundations; • They were calculated for the combined action of waves and tidal currents during a one-year storm event; and • They conservatively assume maximum equilibrium scour depths because there is the potential for any one set of 24 foundations to be located where the sand thickness is greater than the equilibrium scour depth.
	The inter-array cables will release approximately 3,750m^3 of sediment per km length excavated.	The inter-array cable volume released is based on cables that are excavated up to 3m deep and 1.5m wide in an approximate 'U' shape.
	The export cable will produce 971,000m^3 of sediment over its 216km length or approximately 4,500m^3 per km or 1,344m^3 for every hour of trenching.	The export cable volume released is based on a cable that will be placed in a trench 1.5m wide with a maximum depth of 3m (in an approximate 'U' shape) over a length that can be excavated of 216km (the assumed cable length from landfall to project). An excavation rate of 298.6m/hour was used (total time to complete excavation would be 30 days).
	The worst case location for the 24 drilled monopole foundations is in the western corner of Dogger Bank Teesside B.	The foundations have been located near to the habitats most sensitive to increases in suspended sediment concentration. Sandeels are considered the most sensitive, and the highest densities (proxy data from Danish satellite vessel monitoring system) occur in the western corner of Dogger Bank Teesside B and outside and adjacent to its northern and western boundaries.
Offshore Fate of sediment that is not suspended during foundation installation	The worst case scenario is for 12m-diameter drilled monopole foundations and assumes that all sediment with a particle size greater than 0.18mm falls to the seabed and does not enter the plume.	An installation process was developed that would be realistic in terms of particle size distribution released into the water column
Landfall Interruption of sediment transport due to construction activities	The worst case landfall construction would be in the intertidal zone. The worst case scenario for interruption to sediment transport is two large cofferdams measuring 15m long by 10m wide by 3m deep installed over a 14-week period.	A landfall construction in the intertidal zone (at the location of low tide) will have the greatest effect on sediment transport processes of any cross-shore position as this is where the majority of sediment transport is likely to take place. Installation of four small cofferdams and two large cofferdams were

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Effect	Realistic worst case scenario	Rationale
		compared. Given their identical construction period, the large cofferdams would provide a longer (15m cross-shore) barrier to sediment transport than a shorter 10m cofferdam.
Operation		
Offshore Changes in waves and tidal currents due to operation	Conical gravity base is the worst case foundation for effects on tidal currents.	This was quantified using a tidal current model which predicts the reduction in tidal flow around each foundation. The characteristics of the worst case conical gravity base foundation were selected from a range of six alternative conical gravity base designs which were interrogated using the tidal current model.
	Conical gravity base is the worst case foundation for effects on waves.	This was quantified using the WAMIT model which calculates reflection factors for different wave periods which are then integrated with the average wave spectrum to predict the overall wave reflection ('blockage') induced by each foundation. The characteristics of the worst case conical gravity base foundation were selected from a range of six alternative conical gravity base designs which were interrogated using the WAMIT model.
	An array of 400 6MW conical GBS#1 foundations across Dogger Bank Teesside A & B, spaced 750m apart around their perimeters with a wider internal spacing, is the worst case layout for effects on tidal currents An array of 400 6MW conical GBS#1 foundations across Dogger Bank Teesside A & B, spaced 750m apart around their perimeters with a wider internal spacing, is the worst case layout for effects on waves	The worst case scenario layout is considered to be a grid of foundations that fills each project, with the minimum spacing around the perimeter, providing the maximum potential for interaction of tidal current and wave processes between foundations in areas of sensitive habitat. Two scenarios were tested to reach this conclusion: • Grid of 6MW foundations across Dogger Bank Teesside A & B; and • Grid of 10MW foundations across Dogger Bank Teesside A & B
Offshore Increase in suspended sediment concentrations due to operation	An array of 400 6MW conical gravity base foundations across each project is the worst case operational foundation layout for effects on sediment transport. The worst case layout comprises a perimeter of foundations at their minimum spacing (750m) with a wider spaced grid of foundations across the bulk of each project. The foundations would be installed over a (minimum) two	The worst case scenario layout is considered to be a grid of foundations that fills each project area providing the maximum potential for creation of high suspended sediment plumes: • A 'perimeter plus grid' layout is considered to be a realistic potential project layout; • A closer spaced perimeter would increase the intensity of the sediment dispersion close to the most sensitive habitat, relative to an equally spaced grid throughout each project;

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Effect	Realistic worst case scenario	Rationale
	year construction period. The worst case length of inter-array cables is 1,900km (across both projects), of which up to 364km may need remedial protection. The worst case length of inter-platform cables is 640km (across both projects), of which up to 131.2km may need remedial protection.	• The perimeter encompasses the full area available to the project and the central grid fills this perimeter, ensuring the sediment dispersion is maximised over the widest possible area; • After one year of installation, a one-year storm takes place and equilibrium scour is reached at 200 foundations (half of the total number of foundations to be installed). The storm releases the full sediment load through scour; and • At the end of year two, after all 400 foundations have been installed, both projects are subject to a 50-year storm and the storm releases the full sediment load through scour.
	The worst case operational scour volumes for the conical gravity base foundations are: • 0-21m^3 for typical conditions; • 0-709m^3 for a one-year storm; and • 0-2,843m^3 for a 50-year storm The worst case operational scour plan areas (including the base plate area itself) for the conical gravity base foundations are: • 1,964-2,073m^2 for typical conditions; • 1,964-2,625m^2 for a one-year storm; and • 1,964-3,350m^2 for a 50-year storm The worst case operational scour depths for the conical gravity base foundations are: • 0-0.39m for typical conditions; • 0-2.2m for a one-year storm; and • 0-4.3m for a 50-year storm	The worst case scour volumes, plan areas and depths were estimated using a combination of empirical methods in three stages: • Stage 1: predict scour volumes, areas and depths using various empirical formulae devised for granular sand under waves and tidal currents; • Stage 2: take account of the strength of the sub-seabed Holocene sediments and their ability to resist scour; and • Stage 3: take account of the scour-resistant clay layer that directly underlies the sand at various depths across Dogger Bank Teesside A & B.
Offshore Interruption of sediment	• No remedial cable protection will be necessary from the cliffs to 750m seaward of the cliffs. The worst case offshore of 750m from the cliffs is a potential maximum	The worst case operational length and position of cable protection is based on potential geological conditions along the export cable.

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Effect	Realistic worst case scenario	Rationale
transport due to linear cable protection	of 84.2km of remedial protection per export cable for Teesside A and a maximum of 75.7km of remedial protection per export cable for Teesside B. The protection would be up to 15m wide and stand up to approximately 1.5m above the surrounding seabed.	
Decommissioning		
Offshore	Removal of foundations, export and inter-array cables and cable protection	Effects are expected to be less than construction because there will be no need for seabed preparation or pile drilling and there is a possibility that cables are left *in situ* with no consequential increase in suspended sediment concentration.
Landfall	Removal of cable from the cliff, beach and intertidal zone	If the cable is removed from the beach and intertidal area, there will be temporary local effects of a type and duration likely to be similar to the construction phase activities.

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6 Assessment of Effects during Construction

6.1 Introduction

6.1.1 The construction phases of Dogger Bank Teesside A & B have the potential to affect marine physical processes both in the near-field and far-field environments. Construction activities include installation of the foundations, laying of inter-array and export cables, and installation of landfall infrastructure, all of which may affect the tidal current regime, wave climate and sediment transport processes. Specific effects related to these processes are described below.

6.2 Increase in suspended sediment concentrations and sediment deposition as a result of combined drilled 12m monopole foundation and cable installation activities

6.2.1 Sediment dispersion modelling was undertaken using the MIKE3-FM MT model, integrated with the MIKE3-FM HD model (see Section 3.3). The modelling scenario used was as outlined in **Table 5.1**.

6.2.2 The results of the sediment dispersion modelling are presented as a series of maps showing suspended sediment concentration in the bottom layer (corresponding to the lower 5m of the water column) and sediment deposition on the seabed from the plume, using the following statistical measures:

- The maximum values of suspended sediment concentration above a background of 2mg/l and thickness of deposited sediment over the 30-day simulation period;
- The average values of suspended sediment concentration above a background of 2mg/l and thickness of deposited sediment over the 30-day simulation period; and
- The time over which suspended sediment concentration exceeds 2mg/l.

6.2.3 These statistical measures are intended to support the assessment of ecological impact. The maps showing average values provide a basis for the assessment of long-term impact (over the construction period) and the maps with maximum values provide a basis for the assessment of peak impact. The exceedance map provides information on the probability of the predicted concentrations occurring (e.g. how frequently a given limit is exceeded).

Predicted suspended sediment concentrations in the bottom layer

6.2.4 **Figure 6.1** to **Figure 6.3** show maps of predicted suspended sediment concentration in the bottom layer. The concentrations are presented as excesses over the natural background concentration (2mg/l).

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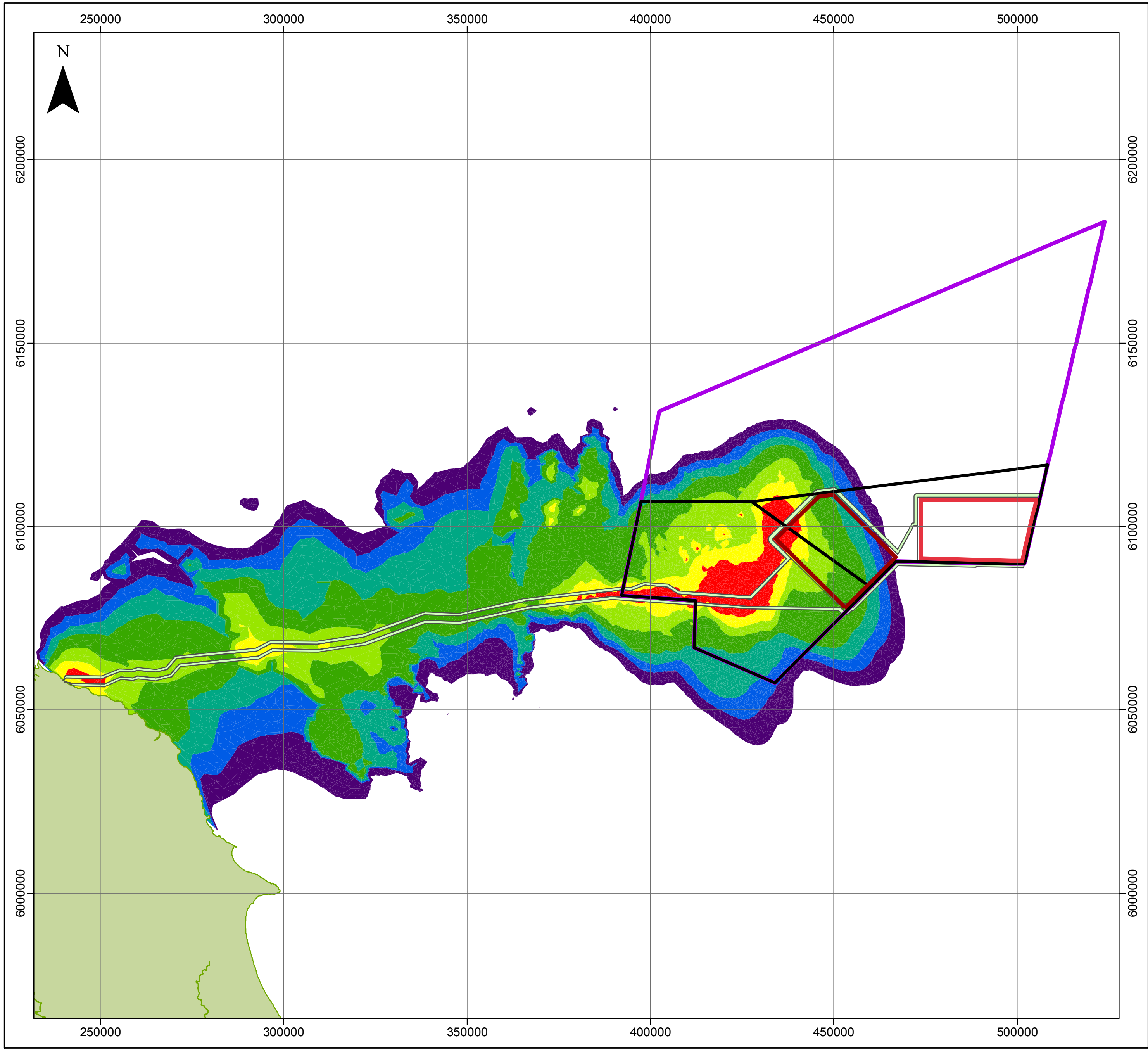

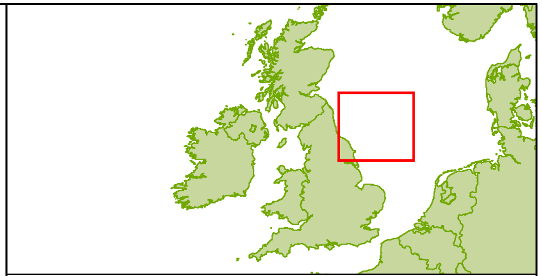

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 6.1 Maximum SSC in the bottom layer predicted over the simulation period for the construction phase for 12m monopoles using the re-suspension of fractions 1 and 2 method

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2	07/10/2013	PEI3	LW	DB
3	06/02/2014	DCO Submission	JE	DB

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SCALE	1:1,600,000	PLOT SIZE	A4	DATUM	WGS84	PROJECTION	UTM31N

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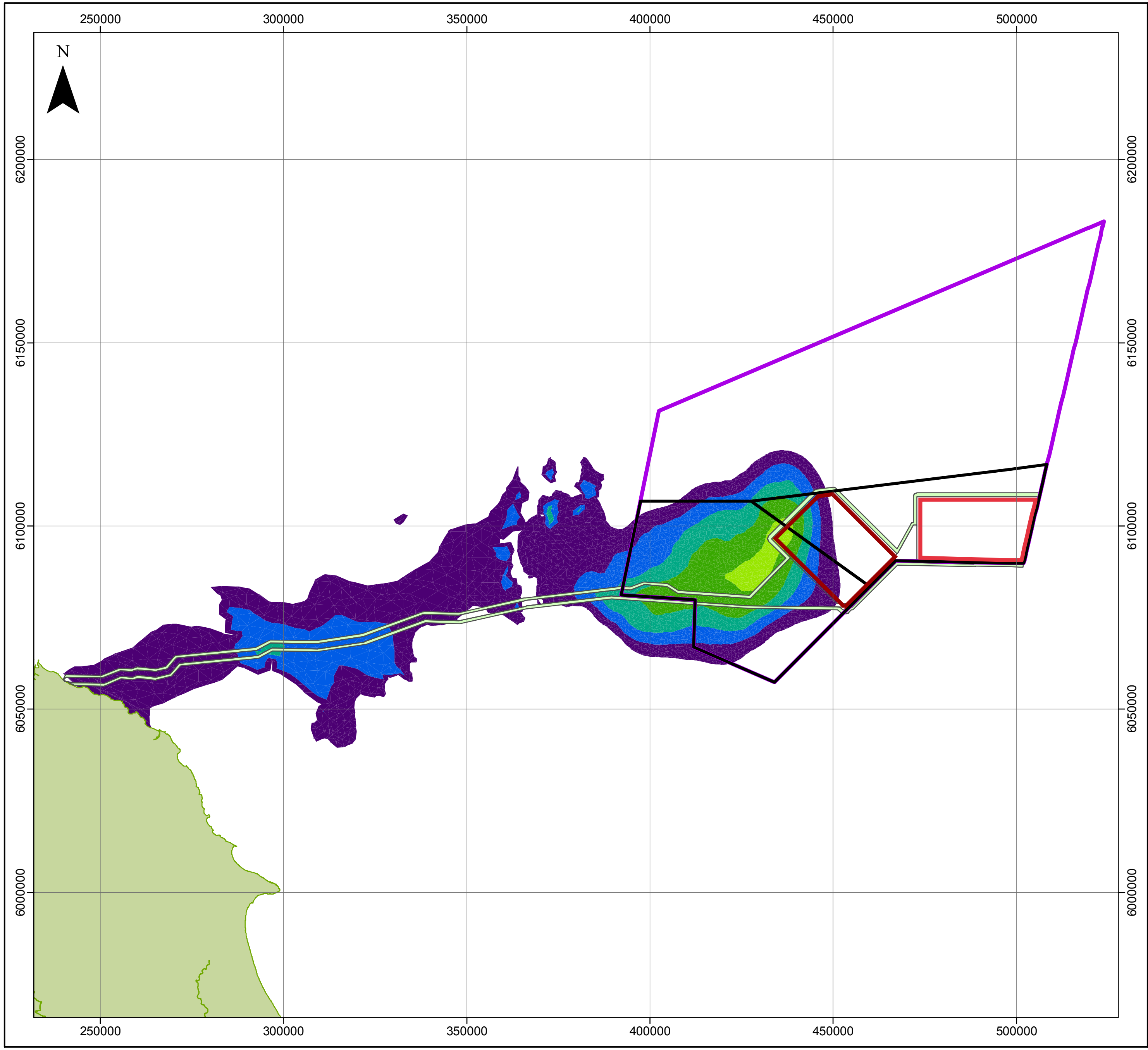

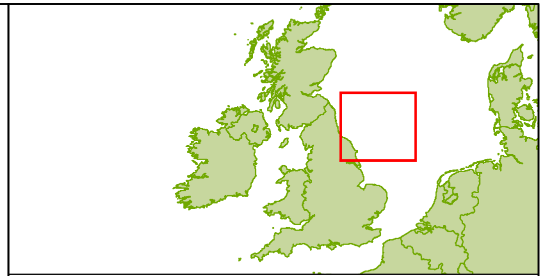

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Suspended sediment concentration kg/m³

- Above 0.200
- 0.100 - 0.200
- 0.050 - 0.100
- 0.020 - 0.050
- 0.010 - 0.020
- 0.005 - 0.010
- 0.002 - 0.005
- Below 0.002

0 10 20
Kilometres

Data Source:
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Figure 6.2 Average SSC in the bottom layer predicted over the simulation period for the construction phase for 12m monopoles using the re-suspension of fractions 1 and 2 method

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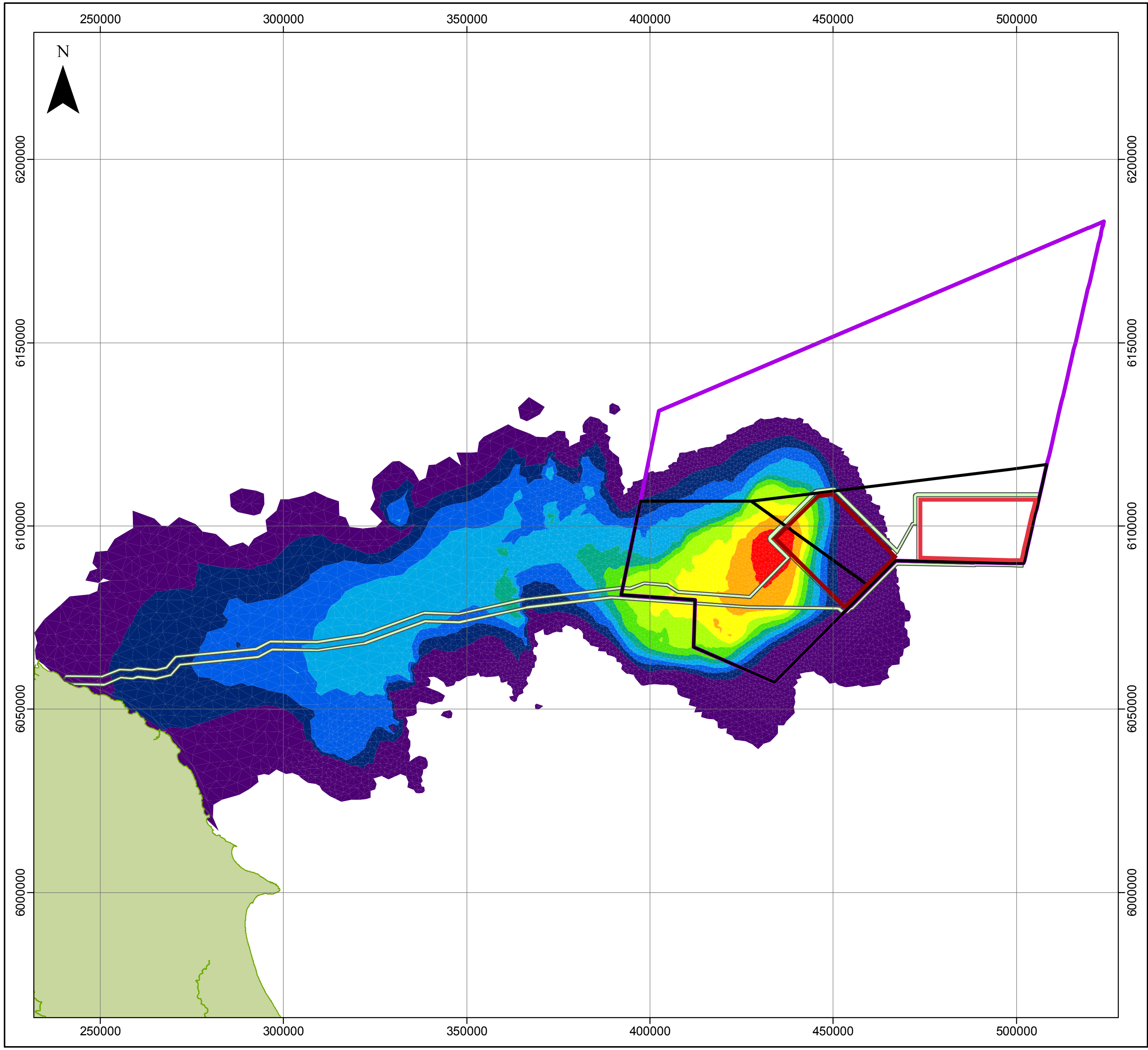

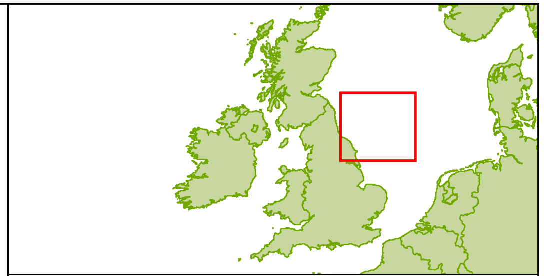

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Exceedance of 2 mg/l (%)

- Above 90
- 80 - 90
- 70 - 80
- 60 - 70
- 50 - 60
- 40 - 50
- 30- 40
- 20 - 30
- 10 - 20
- 0 - 10
- Below 0

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

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DOGGER BANK TEESSIDE A & B

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Figure 6.3 Percentage of time predicted over the simulation period where SSC of 2mg/l is exceeded in the bottom layer for the construction phase for 12m monopoles using the re-suspension of fractions 1 and 2 method

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6.2.5 **Figure 6.1** shows the maximum concentration predicted by the model at any time over the 30-day simulation period. Suspended sediment concentrations are increased in a band either side of the 24 foundations and Dogger Bank Teesside A & B Export Cable Corridor. A maximum suspended sediment concentration of greater than 200mg/l is predicted to occur within the confines of the 24 foundations and along the export cable route within the Dogger Bank Zone and between approximately 1km and 11km either side of the route. Maximum concentrations gradually reduce with distance from the foundations and the export cable route within the Dogger Bank Zone until they are at the background of 2mg/l, up to 40km to the north and up to 40km south.

6.2.6 Along the Dogger Bank Teesside A & B Export Cable Corridor outside the Dogger Bank Zone, the maximum predicted suspended sediment concentration is 100-200mg/l in two small patches, near the coast and about 50km offshore (**Figure 6.1**). However, concentrations are typically less than 100mg/l along large proportions of the Dogger Bank Teesside A & B Export Cable Corridor. Maximum concentrations gradually reduce with distance from the Dogger Bank Teesside A & B Export Cable Corridor until they are predicted to be at the background of 2mg/l, up to 50km to the north and up to 45km south of the corridor.

6.2.7 The average suspended sediment concentration in the bottom layer predicted over the simulation period is presented in **Figure 6.2**. The results show that within the confines of the 24 foundations and up to approximately 20km along the export cable route within the Dogger Bank Zone (a band up to 9km wide adjacent to and north of the route), the predicted suspended sediment concentration is between 50mg/l and 100mg/l. The average suspended sediment concentration reduces to the background of 2mg/l approximately 18km (south) to 32km (north) from the export cable route within the Dogger Bank Zone. Relatively small changes in average suspended sediment concentration of up to 10mg/l are predicted along the Dogger Bank Teesside A & B Export Cable Corridor outside the Dogger Bank Zone.

6.2.8 **Figure 6.3** presents the exceedance time during the simulation of the predicted suspended sediment concentration above the baseline of 2mg/l. The map shows that 2mg/l is exceeded over 90% of the 30-day simulation period up to 15km south west of the centre of the foundations, along the export cable route within the Dogger Bank Zone. Where suspended sediment concentrations are greater that 200mg/l close to the coast, the exceedance time for concentrations greater than 2mg/l is less than 10% of the simulation period. Analysis of the time series data at a point in the centre of the high suspended sediment coastal plume shows that 200mg/l is only exceeded for two hours of the 30-day simulation before returning to lower concentrations.

Predicted deposition and re-suspension of dispersed sediment

6.2.9 **Figure 6.4** shows the maximum change in deposition predicted at any time over the 30-day simulation period. The largest predicted change is a small patch within the confines of the foundation layout where the maximum deposition reaches 10-50mm. Away from the foundations and along the Dogger Bank Teesside A & B Export Cable Corridor, the maximum deposition decreases to

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less than 5mm. Predicted deposition reduces to 0.5mm up to approximately 35km north of the export cable route within the Dogger Bank Zone and 25km north of the Dogger Bank Teesside A & B Export Cable Corridor outside the Dogger Bank Zone.

6.2.10 **Figure 6.5** describes the predicted average deposition from the plume predicted over the 30-day simulation period. Average deposition of 1-5mm occurs within and 10km to the north of the foundations, and in small patches along the Dogger Bank Teesside A & B Export Cable Corridor. Predicted average deposition decreases to less than 0.5mm along the remainder of the Dogger Bank Teesside A & B Export Cable Corridor, and is effectively zero in places.

6.2.11 Analysis of the time series of predicted deposition from the plume over the 30-day simulation period at five selected points (Points P1 to P5 in **Figure 6.6**) describes the persistency of sediment thickness on the seabed. **Table 6.1** describes the maximum lengths of time that sediment maintains predicted thicknesses greater than 10mm, 7mm, 3mm and 1mm over the 30-day simulation period.

Table 6.1 Maximum persistency of sediment thickness over the 30-day simulation period for construction of a 12m monopole

Point	Maximum thickness (mm)	Maximum continuous time of sediment thickness (hours with days in brackets)				Thickness at end of simulation (mm)
		>10mm	>7mm	>3mm	>1mm	
P1	13.71	32 (1.33)	38 (1.58)	80 (3.33)	174 (7.25)	<0.1
P2	3.19	0	0	10	22	<0.1
P3	1.35	0	0	0	6	<0.1
P4	1.26	0	0	0	2	<0.1
P5	1.00	0	0	0	2	<0.1

6.2.12 **Table 6.1** demonstrates that within the foundation layout (Point P1), sediment thicknesses predicted to be greater than 10mm and 7mm persist for maximum continuous periods of 32 hours (1.33 days) and 38 hours (1.58 days), respectively. Thicknesses greater than 3mm and 1mm occur continuously for a maximum of 80 hours (3.33 days) and 174 hours (7.25 days), respectively. Approximately 20km west-south west of the foundation layout (Point P2, **Figure 6.6**), sediment thicknesses greater than 3mm only persist for a maximum continuous period of ten hours (0.42 days), whereas 1mm thick sediment persists for a maximum continuous period of 22 hours (0.92 days).

6.2.13 At Point P3, approximately 55km to the west of the foundation layout (and positioned outside the western boundary of the Dogger Bank Zone in the vicinity of a zone of sandeel habitat), the deposition at any one time rarely exceeds 1mm. At a point mid-way along the Dogger Bank Teesside A & B Export Cable Corridor (Point P4), predicted deposition never exceeds 1.3mm over the simulation period. The longest continuous period when it exceeds 1mm is two

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hours (0.08 days). At Point P5, about 20km from the coast, total deposition from the plume never exceeds 1mm.

6.2.14 **Table 6.1** shows that at the end of the simulation the predicted thickness of sediment resting on the seabed is mainly less than 0.1mm. This demonstrates that once the supply of sediment from foundation installation was stopped at day 25, then re-suspension of the deposited sediment was the dominant process to reduce the thickness to effectively negligible values.

6.2.15 There is no discernible difference in deposition caused by changing the construction sequence from one foundation per day to no foundation on a single day (day six) or two foundations on a single day (day three).

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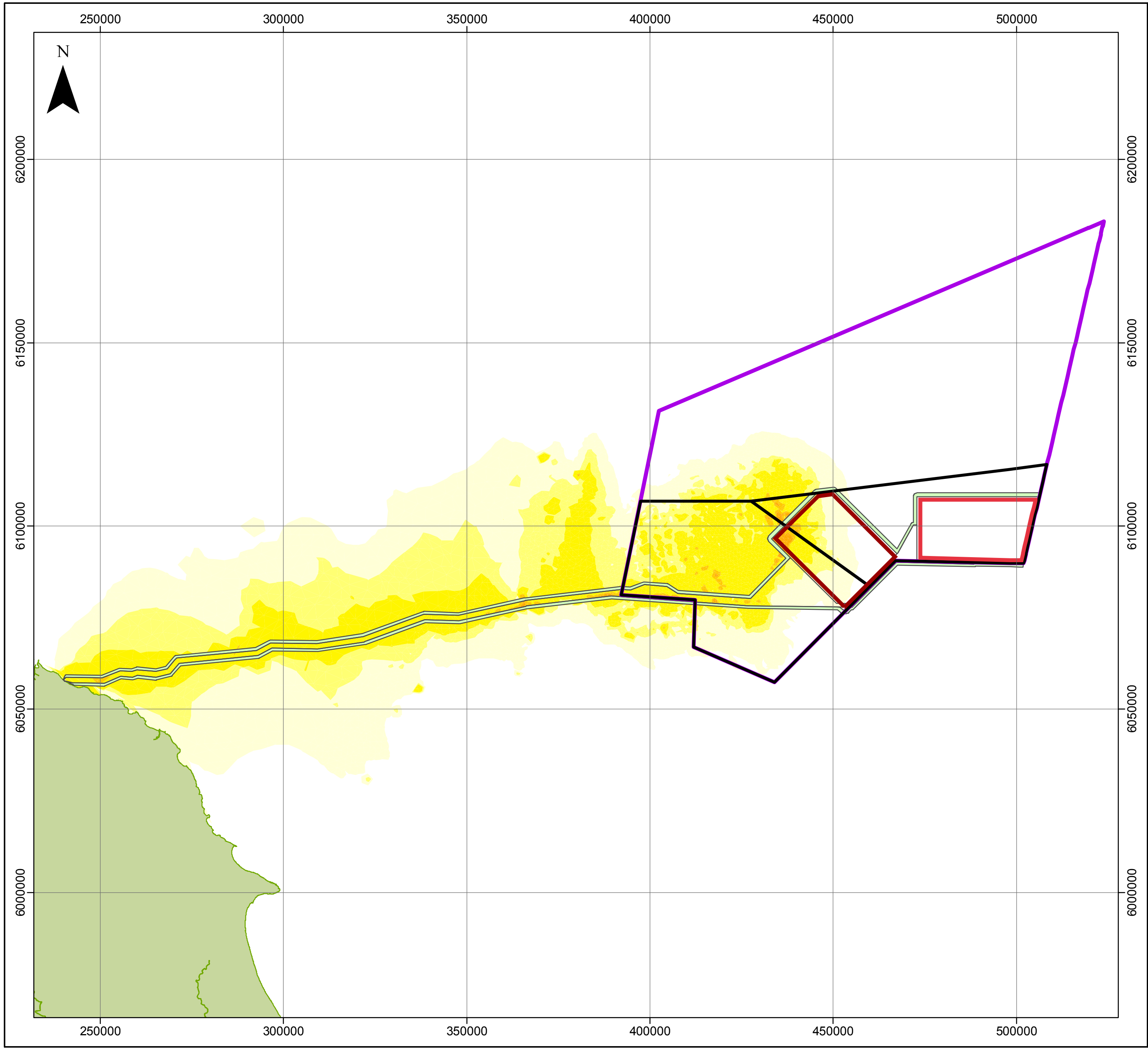

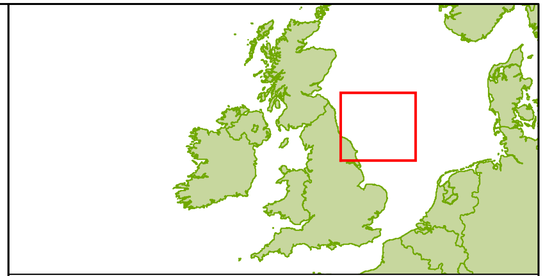

LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Sediment thickness (m)

- Above 0.1000
- 0.0500 - 0.1000
- 0.0100 - 0.0500
- 0.0050 - 0.0100
- 0.0010 - 0.0050
- 0.0005 - 0.0010
- 0.0001 - 0.0005
- Below 0.0001

0 10 20
Kilometres

Data Source:
Modelling © Danish Hydraulic Institute, 2013

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Figure 6.4 Maximum deposition predicted over the simulation period for the construction phase for 12m monopoles using the re-suspension of fractions 1 and 2 method

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