Hornsea Project Three
Offshore Wind Farm

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Offshore Wind Farm

Preliminary Environmental Information Report:
Chapter 2 – Benthic Subtidal and Intertidal Ecology

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 2

Chapter 2 – Benthic Subtidal and Intertidal Ecology

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Table of Contents

2. Benthic Ecology 1
2.1 Introduction 1
2.2 Purpose of this chapter 1
2.3 Benthic ecology study areas 1
2.4 Planning policy context 3
2.5 Consultation 6
2.6 Methodology to inform the baseline 9
2.7 Baseline environment 14
2.8 Key parameters for assessment 25
2.9 Impact assessment criteria 33
2.10 Measures adopted as part of Hornsea Thee 34
2.11 Assessment of significance 35
2.12 Cumulative Effect Assessment methodology 58
2.13 Cumulative Effect Assessment 66
2.14 Transboundary effects 74
2.15 Inter-related effects 75
2.16 Conclusion and summary 75
2.17 Next Steps 75
2.18 References 78

List of Tables

Table 2.1: Summary of NPS EN-3 provisions relevant to this chapter. 3
Table 2.2: Summary of NPS EN-1 provisions relevant to this chapter. 4
Table 2.3: Summary of NPS EN-3 policy on decision making relevant to this chapter. 5
Table 2.4: East Marine Plan Policies of relevance to this chapter. 5
Table 2.5: Summary of the Marine Strategy Framework Directive's (MSFD) high level descriptors of Good Environmental Status (GES) relevant to benthic ecology and consideration in the Hornsea Three assessment. 6
Table 2.6: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to benthic ecology. 7
Table 2.7: Summary of key desktop reports. 10
Table 2.8: Summary of benthic ecology surveys undertaken and proposed. 11
Table 2.9: Benthic infaunal and epifaunal biotopes identified in the Hornsea Three benthic ecology study area, including geographic locations (see Figure 2.5). 17
Table 2.10: Intertidal biotopes identified during the intertidal walkover survey and from intertidal core samples taken from the Hornsea Three offshore cable corridor landfall site, within the Hornsea Three benthic ecology study area (Figure 2.6). 20
Table 2.11: Criteria used to inform the valuation of ecological receptors in the Hornsea Three benthic ecology study area. 22
Table 2.12: Criteria Valued ecological receptors (VERs) within the Hornsea Three benthic ecology study area, their conservation status and importance. 23
Table 2.13: Maximum design scenario considered for the assessment of potential impacts on benthic ecology. 26
Table 2.14: Definition of terms relating to the sensitivity of the receptor. 33
Table 2.15: Definition of terms relating to the magnitude of an impact. 34
Table 2.16: Matrix used for the assessment of the significance of the effect. 34
Table 2.17: Designed-in measures adopted as part of Hornsea Three. 35
Table 2.18: Maximum long term habitat loss for VERs within Hornsea Three. 46
Table 2.19: Maximum long term habitat loss of VERs qualifying as features of protected areas within Hornsea Three. 46
Table 2.20: List of other projects and plans considered within the CEA. 60
Table 2.21: Maximum design scenario considered for the assessment of potential cumulative impacts on benthic ecology. 64
Table 2.22: Cumulative temporary habitat loss for Hornsea Three and other plans/projects/activities in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three. 67
Table 2.23: Cumulative long term habitat loss for Hornsea Three and other plans/projects in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three. 70
Table 2.24: Cumulative habitat creation for Hornsea Three and offshore wind farms in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three. 72
Table 2.25: Summary of potential environmental effects, mitigation and monitoring. 76

List of Figures

Figure 2.1: Location of Hornsea Three and the former Hornsea Zone, other offshore wind farm sites and nature conservation sites in the southern North Sea benthic ecology study area (i.e. the southern North Sea MNA). 2
Figure 2.2: Hornsea Project Three array area with existing (2010-2012) and Hornsea Three (2016) benthic ecology sampling locations (benthic grabs/DDV and trawls). Also shown are sampling sites within Markham's Triangle rMCZ (Defra, 2012 (note: third party survey data). 12
Figure 2.3: Hornsea Three offshore cable corridor with Hornsea Three (2016) benthic ecology sampling locations and benthic ecology sampling locations proposed for 2017 (benthic grabs, DDV and trawls). Note station labels are shown only for the sampled locations which are discussed in the text, all station labels are provided in volume 5, annex 2.1: Benthic Ecology Technical report. 13
Figure 2.4: Simplified Folk Sediment Classifications for each benthic grab sample location within the Hornsea Three benthic ecology study area. 15
Figure 2.5: Combined infaunal and epifaunal biotope map of the Hornsea Three benthic ecology study area (note nearshore habitat mapping is to be completed in final ES). 19
Figure 2.6: Intertidal biotopes at the Hornsea Three offshore cable corridor landfall site area at Weybourne and Salthouse, within the Hornsea Three benthic ecology study area. 21
Figure 2.7: Wide scale Subtidal Valued Ecological Receptors (VERs) in the Hornsea Three benthic ecology study area. Note: as detailed in Table 2.12, Habitats A (sand sediment), C (coarse sediment) and D (mixed sediment), where these occur within an MCZ or rMCZ are equivalent to Habitats H, G and I, respectively. 24
Figure 2.8: Offshore project/plans/activities screened into the Hornsea Three cumulative effect assessment for benthic ecology. 63

List of Annexes

Annex 2.1: Benthic Ecology Technical Report
Annex 2.2: Water Framework Directive Assessment
Annex 2.3: Marine Conservation Zone Assessment

Glossary

Term	Definition
Benthic ecology	Benthic ecology encompasses the study of the organisms living in and on the sea floor, the interactions between them and impacts on the surrounding environment.
Biomass	The total quantity of living organisms in a given area, expressed in terms of living or dry weight or energy value per unit area.
Biotope	The combination of physical environment (habitat) and its distinctive assemblage of conspicuous species.
Circalittoral	The subzone of the rocky sublittoral below that dominated by algae (i.e. the infralittoral), and dominated by animals.
Crustacean	An invertebrate belonging to the subphylum of Crustacea, of the phylum Arthropoda. Includes crabs, lobsters, shrimps, barnacles and sand hoppers.
Echinoderm	An invertebrate animal belonging to the phylum Echinodermata that includes sea stars, brittle stars, feather stars, sea urchins and sea cucumbers.
Epibenthic	Organisms living on the surface of the seabed.
Epifauna	Animals living on the surface of the seabed.
European site	A Special Area of Conservation (SAC) or candidate SAC, a Special Protection Area (SPA) or potential SPA, a site listed as a Site of Community importance (SCI) or a Ramsar site.
Hamon grab	A tool for sampling the benthic macro-infauna that is particularly effective for sampling from coarse substrata.
Infauna	The animals living in the sediments of the seabed.
Infralittoral	A subzone of the sublittoral in which upward-facing rocks are dominated by erect algae.
Intertidal	An area of a seashore that is covered at high tide and uncovered at low tide.
Mollusc	Invertebrate animal belonging to the phylum Mollusca that includes the snails, clams, chitons, tooth shells, and octopi.
Polychaete	A class of segmented worms often known as bristleworms.
Spat	The spawn or larvae of shellfish, especially oysters.
Sublittoral	Area extending seaward of low tide to the edge of the continental shelf.
Subtidal	Area extending from below low tide to the edge of the continental shelf.

Acronyms

Acronym	Description
AFDW	Ash-free dry weight
ASMS	Active Safety Management System
BAP	Biodiversity Action Plan
CBD	Convention on Biological Diversity
CEA	Cumulative Effects Assessment
CoCP	Code of Construction Practice
CPA	Coast Protection Act 1949
CTVs	Crew Transfer Vessels
DCO	Development Consent Order
DDV	Drop Down video
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DMRB	Design Manual for Roads and Bridges
DTI	Department of Trade and Industry
EA	Environment Agency
EcIA	Ecological Impact Assessment
EEA	European Economic Area
EIA	Environmental Impact Assessment
EMF	Electromagnetic Fields
EMODnet	European Marine Observation Data Network
EQS	Environmental Quality Standard
EWG	Expert Working Group
FEPA	Food and Environmental Protection Act 1985
FOCI	Feature of Conservation Interest
GBF	Gravity Base Foundations
GES	Good Environmental Status
HADA	Humber Aggregate Dredging Association
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Assessment
HSE MS	Health, Safety and Environmental Management System
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
ICES	International Council of the Exploration of the Sea
IMO	International Maritime Organization
INNS	Invasive Non-native Species
LWT	Lincolnshire Wildlife Trust
MALSF	Marine Aggregate Levy Sustainability Fund
MCZ/rMCZ	Marine Conservation Zone/recommended Marine Conservation Zone
MGN	Marine Guidance Note
MHWS	Mean High Water Springs
MLWS	Mean Low Water Springs
MNA	Marine Natural Area
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
NERC	Natural Environment and Rural Communities Act 2006
NPS	National Policy Statement
NSBP	North Sea Benthos Project
NSIP	Nationally Significant Infrastructure Project
O&M	Operation and Maintenance
OSPAR	Oslo-Paris Commission
OWEZ	Egmond aan Zee offshore Wind Farm
PEIR	Preliminary Environmental Information Report
PEMMP	Project Environmental Management and Monitoring Plan
PINS	Planning Inspectorate
PSA	Particle Size Analysis
REC	Regional Environmental Characterisation
RIAA	Report to Inform Appropriate Assessment

Acronym	Description
SCI	Site of Community Importance
SEA	Strategic Environmental Assessment
SPA/pSPA	Special Protection Area/possible Special Protection Area
SSC	Suspended Solids Concentrations
SSSI	Site of Special Scientific Interest
TBT	Tributyltin
UK	United Kingdom
UNEP	United Nations Environment Programme
VER	Valued Ecological Receptor
WFD	Water Framework Directive
YWT	Yorkshire Wildlife trust
ZoC	Zone of Characterisation
ZoI	Zone of Influence

Units

Unit	Description
%	Percent
cm	Centimetre
km	Kilometre
m	Metre
m^2	Metre squared
m^3	Metre Cubed
mg/kg	Milligrams per kilogram
mm	Millimetre

2. Benthic Ecology

2.1 Introduction

2.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the findings to date of the Environmental Impact Assessment (EIA) for the potential impacts of the Hornsea Project Three offshore wind farm (hereafter referred to as Hornsea Three) on benthic ecology. Specifically, this chapter considers the potential impact of Hornsea Three seaward of Mean High Water Springs (MHWS) during its construction, operation and maintenance, and decommissioning phases.

2.1.1.2 The detailed technical information which underpins the impact assessments presented in this chapter is contained within volume 5, annex 2.1: Benthic Ecology Technical Report. The technical report provides a detailed characterisation of the benthic ecology of Hornsea Three and the wider southern North Sea, based on existing literature sources, surveys of the former Hornsea Zone and specifically of Hornsea Three, and includes information on habitats and benthic species of ecological importance and of conservation value.

2.2 Purpose of this chapter

2.2.1.1 The primary purpose of the Environmental Statement is to support the Development Consent Order (DCO) application for Hornsea Three under the Planning Act 2008 (the 2008 Act). This PEIR constitutes the Preliminary Environmental Information for Hornsea Three and sets out the findings collected to date to enable consultees to understand the likely environmental effects of Hornsea Three and support pre-application consultation activities required under the 2008 Act. The EIA will be finalised following completion of pre-application consultation and the Environmental Statement will accompany the application to the Secretary of State for Development Consent.

2.2.1.2 The PEIR will form the basis for Phase 2 Consultation which will commence on 27 July and conclude on 20 September 2017. At this point, comments received on the PEIR will be reviewed and incorporated (where appropriate) into the Environmental Statement, which will be submitted in support of the application for Development Consent scheduled for the second quarter of 2018.This PEIR chapter:

- Presents the existing environmental baseline established from desk studies, and consultation;
- Presents the potential environmental effects on benthic ecology arising from Hornsea Three (for construction, operation, maintenance and decommissioning), based on the information gathered and the analysis and assessments undertaken to date;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and
- Highlight any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental effects identified in the EIA process.

2.3 Benthic ecology study areas

2.3.1.1 For the purposes of the Hornsea Three benthic subtidal and intertidal characterisation, two study areas were defined (see Figure 2.1):

- The Hornsea Three benthic ecology study area - this area encompasses Hornsea Three, which includes the Hornsea Three array area, offshore cable corridor temporary working area (i.e. encompassing subtidal benthic ecology), and landfall area (i.e. encompassing intertidal benthic ecology). The subtidal section of the Hornsea Three benthic ecology study area also incorporates the former Hornsea Zone plus a 5 km buffer around the former Hornsea Zone (where survey data is available). Surveys undertaken across the former Hornsea Zone, including those for Hornsea Project One and Hornsea Project Two have been used to inform this Benthic Ecology PEIR chapter. At the landfall area, the Hornsea Three benthic ecology study area considers habitats up to the MHWS; and
- The southern North Sea benthic ecology study area - this is the regional benthic ecology study area and was defined by the boundaries of the southern North Sea Marine Natural Area (MNA) (Jones *et al*., 2004). This southern North Sea benthic ecology study area is the area assessed through the desktop review, which includes the identification of designated sites (including those within other EEA waters which are within 1 tidal excursion of Hornsea Three), and provides wider context for the Hornsea Three data.

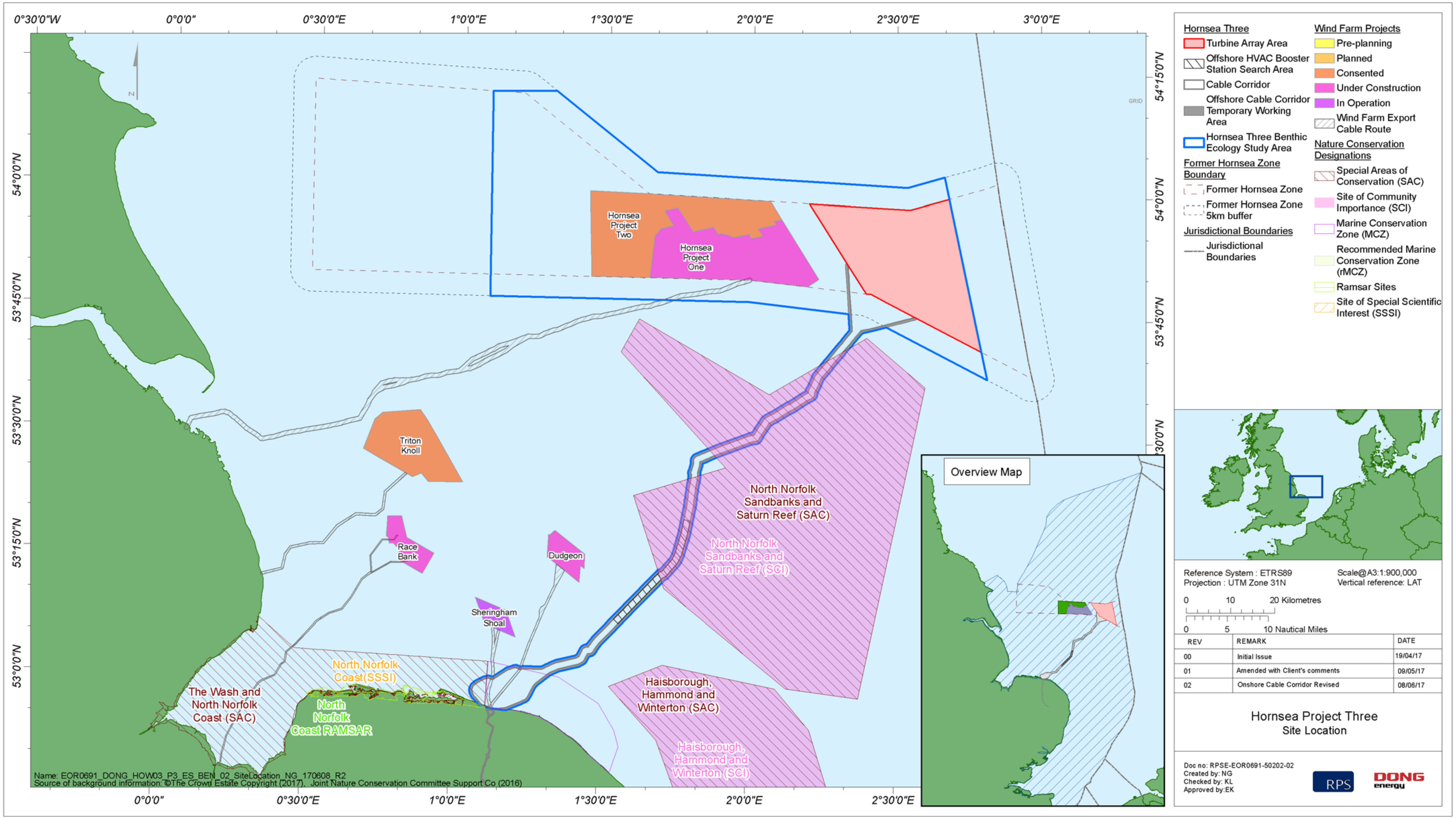

Figure 2.1: Location of Hornsea Three and the former Hornsea Zone, other offshore wind farm sites and nature conservation sites in the southern North Sea benthic ecology study area (i.e. the southern North Sea MNA).

2.4 Planning policy context

2.4.1.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to benthic ecology is contained in the Overarching National Policy Statement (NPS) for Energy (NPS EN-1; Department of Energy and Climate Change (DECC), 2011a), the NPS for Renewable Energy Infrastructure (NPS EN-3, DECC, 2011b) and the Marine Policy Statement (MPS). The MPS notes that marine planning authorities should be mindful of the high-level marine objectives set out by the UK to ensure due consideration of marine ecology and biodiversity interests. It also recognises the role of conservation of ecologically sensitive areas throughout the planning process and mitigation or compensatory actions where significant harm cannot be avoided (paragraph 2.6.1 of the MPS).

2.4.1.2 NPS EN-3 and NPS EN-1 include guidance on what matters are to be considered in the assessment. These are summarised in Table 2.1 and Table 2.2, respectively.

Table 2.1: Summary of NPS EN-3 provisions relevant to this chapter.

Summary of NPS EN-3 provision	How and where considered in the PEIR
Biodiversity	
Applicants should assess the effects on the offshore ecology and biodiversity for all stages of the lifespan of the proposed offshore wind farm (paragraph 2.6.64 of NPS EN-3).	Construction, operation and decommissioning phases of Hornsea Three have been assessed (see section 2.11).
Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate (paragraph 2.6.65 of NPS EN-3).	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of Hornsea Three (see Table 2.6).
Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational offshore wind farms should be referred to where appropriate (paragraph 2.6.66 of NPS EN-3).	Relevant data collected as part of post-construction monitoring from other offshore wind farm developments has informed the assessment of Hornsea Three (see paragraphs 2.11.1.25, 2.11.2.24 and 2.11.2.25).
Applicants should assess the potential for the scheme to have both positive and negative effects on marine ecology and biodiversity (paragraph 2.6.67 of NPS EN-3).	Both the positive and negative effects of Hornsea Three have been assessed (see section 2.11).
Benthic subtidal and intertidal ecology	
Applicants should assess the effects on the subtidal environment from habitat loss due to foundations and seabed preparation, predicted scour, scour protection and altered sedimentary processes (paragraph 2.6.113 of NPS EN-3) and effects on the intertidal zone (paragraph 2.6.81 of NPS EN-3).	The assessment has considered all phases of development on benthic subtidal and intertidal species and habitats in the vicinity of Hornsea Three. These assessments included likely effects from temporary and long term habitat loss (see paragraphs 2.11.1.3 *et seq*. and 2.11.2.3 *et seq.* respectively) and the effects of changes in physical processes (see paragraph 2.11.2.51 *et seq.*).
Applicants should include environmental appraisal of inter-array and cable routes and installation methods (paragraph 2.6.113 of NPS EN-3).	Effects of cable installation, including maximum adverse scenario for cable installation methodologies, on benthic ecology are assessed for all stages of the development (see paragraphs 2.11.1.3 *et seq*. for construction and paragraphs 2.11.3.3 *et seq*. for decommissioning).
Applicants should assess the effects of subtidal habitat disturbance from extendible legs and anchors of construction vessels (paragraph 2.6.113 of NPS EN-3) and habitat disturbance in the intertidal zone during cable installation and removal (decommissioning) (paragraph 2.6.81 of NPS EN-3).	The Hornsea Three assessment has considered the effects of subtidal and intertidal disturbances throughout all stages of the development (see paragraphs 2.11.1.3 *et seq*. for construction and paragraphs 2.11.3.3 *et seq*. for decommissioning)
Applicants should assess the effects of increased suspended sediment loads during construction on subtidal habitats (paragraph 2.6.113 of NPS EN-3) and intertidal habitats (paragraph 2.6.81 of NPS EN-3).	Specific effects of increased suspended sediment and associated deposition on benthic ecology have been assessed for both subtidal and intertidal habitats/species during the construction phase (see paragraph 2.11.1.42 *et seq.)* and decommissioning phase (see paragraph 2.11.3.20 *et seq*.).
Applicants should assess the predicted rates for subtidal habitat recovery (paragraph 2.6.113 of NPS EN-3) and intertidal zone recovery from temporary disturbance effects (paragraph 2.6.81 of NPS EN-3).	The likely rates of recovery of benthic subtidal and intertidal species/habitats have been assessed for each impact discussed, and have been used to inform each assessment of the significance of the effect (see section 2.11).
If it is proposed to install offshore cables to a depth of at least 1.5 m below the sea bed, the Applicant should not have to assess the effect of the cables on intertidal and subtidal habitat during the operational phase of the offshore wind farm (paragraphs 2.6.82 and 2.6.114 of NPS EN-3).	Typically the cable will be buried between 1 – 2 m. A Cable Burial Risk Assessment (CBRA) will inform cable burial depth which will depend on ground conditions. This assessment will be undertaken post-consent. As such, effects of electromagnetic fields (EMF) on benthic receptors are not assessed.

Table 2.2: Summary of NPS EN-1 provisions relevant to this chapter.

Summary of NPS EN-1 provision	How and where considered in the PEIR
Biodiversity (Section 5.3 of NPS EN-1)	
Where the development is subject to EIA the applicant should ensure that the ES clearly sets out any effects on internationally, nationally and locally designated sites of ecological or geological conservation importance, on protected species and on habitats and other species identified as being of principal importance for the conservation of biodiversity. The applicant should provide environmental information proportionate to the infrastructure where EIA is not required to help the IPC consider thoroughly the potential effects of a proposed project.	Effects on benthic features, including habitats and species of conservation importance, including those listed as features of designated sites, are fully considered in sections 2.11.1 (construction phase), 2.11.2 (operation and maintenance phase) and 2.11.3 (decommissioning phase). Baseline information on these receptors is presented in section 2.7, with valuation of these receptors in the context of their conservation importance considered in section 2.7.4.
The most important sites for biodiversity are those identified through international conventions and European Directives. The Habitats Regulations provide statutory protection for these sites but do not provide statutory protection for potential Special Protection Areas (pSPAs) before they have been classified as a Special Protection Area. For the purposes of considering development proposals affecting them, as a matter of policy the Government wishes pSPAs to be considered in the same way as if they had already been classified. Listed Ramsar sites should, also as a matter of policy, receive the same protection	Effects on benthic features of designated sites are fully considered in sections 2.11.1 (construction phase 2.11.2 (operation and maintenance phase) and 2.11.3 (decommissioning phase). These effects have also been assessed within the draft RIAA for Natura 2000 sites.
Many Sites of Special Scientific Interest (SSSI) are also designated as sites of international importance; those that are not, should be given a high degree of protection (paragraph 5.3.10 of NPS EN-1). Where a proposed development within or outside an SSSI is likely to have an adverse effect on an SSSI (either individually or together with other developments), development consent should not normally be granted. Where an adverse effect, after mitigation, on the site's notified special interest features is likely, an exception should only be made where the benefits (including need) of the development at this site clearly outweigh both the impacts on site features and on the broader network of SSSIs. The Secretary of State should use requirements and/or planning obligations to mitigate the harmful aspects of the development, and where possible, ensure the conservation and enhancement of the site's biodiversity or geological interest (paragraph 5.3.11 of NPS EN-1).	For SSSIs, where these are within Natura 2000 sites, these have been considered as part of that site in this environmental assessment. Any not included in a Natura 2000 have been considered under their own merit.
Marine Conservation Zones (MCZs) introduced under the Marine and Coastal Access Act (MCAA) 2009 are areas that have been designated for the purpose of conserving marine flora and fauna, marine habitat or features of geological or geomorphological interest. The Secretary of State is bound by the duties in relation to MCZs imposed by sections 125 and 126 of the MCAA 2009 (paragraph 5.3.12 in NPS EN-1).	Cromer Shoal Chalk Beds MCZ, which lies within the Hornsea Three benthic ecology study area, has been considered within the assessment (see section 2.11). For the two rMCZs identified within the Hornsea Three benthic ecology study area (Figure 2.1), the habitats and species of conservation priority within these sites have been considered in the assessment of valued ecological receptors (see Table 2.12).
Development proposals provide many opportunities for building-in beneficial biodiversity or geological features as part of good design. When considering proposals, the IPC should maximise such opportunities in and around developments, using requirements or planning obligations where appropriate.	Designed-in measures to be adopted as part of the Hornsea Three project are presented in section 2.10.
Other species and habitats have been identified as being of principal importance for the conservation of biodiversity in England and Wales and thereby requiring conservation action. The IPC (now PINS) should ensure that these species and habitats are protected from the adverse effects of development by using requirements or planning obligations.	All species and habitat receptors, including those of principal importance for the conservation of biodiversity in England are considered in section 2.7, with valuation of these receptors in the context of their conservation importance considered in section 2.7.4.
The applicant should include appropriate mitigation measures as an integral part of the proposed development. In particular, the applicant should demonstrate that: • during construction, they will seek to ensure that activities will be confined to the minimum areas required for the works; • during construction and operation best practice will be followed to ensure that risk of disturbance or damage to species or habitats is minimised, including as a consequence of transport access arrangements; • habitats will, where practicable, be restored after construction works have finished; and opportunities will be taken to enhance existing habitats and, where practicable, to create new habitats of value within the site landscaping proposals.	Mitigation measures proposed for Hornsea Three are presented in section 2.10.
Coastal Change (Section 5.5 of NPS EN-1)	
The ES (see Section 4.2) should include an assessment of the effects on the coast. In particular, applicants should assess the effects of the proposed project on marine ecology, biodiversity and protected sites (paragraph 5.5.7 of NPS EN-1).	Effects of physical changes on benthic ecology receptors are fully considered in sections 2.11.1 (construction phase), 2.11.2 (operation and maintenance phase) and 2.11.3 (decommissioning phase).
The applicant should be particularly careful to identify any effects of physical changes on the integrity and special features of MCZs, candidate marine SACs, coastal SACs and candidate coastal SACs, coastal SPAs and potential coastal SPAs, Ramsar sites, Sites of Community Importance (SCIs) and potential SCIs and SSSIs (paragraph 5.5.9 of NPS EN-1).	Effects of physical changes on benthic features of designated sites is fully considered in sections 2.11.1 (construction phase), 2.11.2 (operation and maintenance phase) and 2.11.3 (decommissioning phase). These effects have also been assessed within the draft RIAA (for Natura 2000 sites) and within volume 5: annex 2.3: MCZ Assessment (for MCZs and recommended MCZs).

2.4.1.3 NPS EN-3 also highlights a number of factors relating to the determination of an application and in relation to mitigation. These are summarised in Table 2.3 below.

Table 2.3: Summary of NPS EN-3 policy on decision making relevant to this chapter.

Summary of NPS EN-3 policy on decision making (and mitigation)	How and where considered in the PEIR
Biodiversity	
The Secretary of State should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it (paragraph 2.6.68 of NPS EN-3).	This has been described and considered within the assessment of Hornsea Three (see section 2.11).
The designation of an area as a European site does not necessarily restrict the construction or operation of offshore wind farms in or near that area (paragraph 2.6.69 of NPS EN-3).	European sites have been considered during the assessment (see section 2.6.3).
Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed (paragraph 2.6.70 of NPS EN-3).	Mitigation has been not been deemed necessary during the Hornsea Three assessment
Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact so that, where appropriate, adverse effects can then be mitigated and to enable further useful information to be published relevant to future projects (paragraph 2.6.71 of NPS EN-3).	The requirement for benthic ecology monitoring has been considered within the impact assessment, the relevant designed in measures are considered sufficient (i.e. pre-construction surveys).
Subtidal and Intertidal Ecology	
The conservation status of intertidal habitat (paragraph 2.6.84) and subtidal habitat (paragraph 2.6.115) is of relevance to the Secretary of State.	The conservation status of benthic receptors has been considered throughout the assessment (see Table 2.12).
The Secretary of State should be satisfied that activities have been designed taking into account sensitive subtidal environmental aspects (paragraph 2.6.116) and intertidal habitat (paragraph 2.6.85).	The assessment has identified potential impacts on sensitive subtidal habitats including potential Annex I reefs, and intertidal habitats and, where appropriate, designed suitable mitigation (see impact assessment in Section 2.11).
Where adverse effects are predicted, in coming to a judgement, the Secretary of State should consider the extent to which the effects are temporary or reversible (paragraph 2.6.117), this includes the installation and decommissioning of cables (paragraph 2.6.86).	The duration and reversibility of effects have been considered within the assessment of the significance of effects (see Table 2.13 and section 2.11).
Where it is proposed that the offshore export cables are armoured and buried at a sufficient depth to minimise heat effects the effects of heat on sensitive species from cable infrastructure during operation are unlikely to be a reason for the Secretary of State to refuse to grant consent for a development (paragraph 2.6.118).	The nature and installation of export cables has been considered in the assessment (see Table 2.13).

2.4.1.4 The assessment of potential changes to benthic ecology has also been made with consideration to the specific policies set out in the East Inshore and East Offshore Coast Marine Plans (MMO, 2014). Key provisions are set out in Table 2.4 along with details as to how these have been addressed within the assessment.

Table 2.4: East Marine Plan Policies of relevance to this chapter.

Policy	Key provisions	How and where considered in the PEIR
East Inshore and East Offshore Marine Plans – ECO1	Cumulative impacts affecting the ecosystem of the East marine plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation.	Cumulative effects are considered within section 2.13.
East Inshore and East Offshore Marine Plans – MPA1	Any impacts on the overall marine protected area (MPA) network must be taken account of in strategic level measures and assessments, with due regard given to any current agreed advice on an ecologically coherent network.	Designated nature conservation sites within the Hornsea Three and CEA benthic ecology study area have been described in section 2.7.3. The predicted changes to benthic ecology have been considered in sections 2.11 and 2.13.

2.4.1.5 Guidance provided within the Marine Strategy Framework Directive (MSFD), adopted in July 2008, has also been considered in the Hornsea Three assessment for benthic ecology. The relevance of the MSFD to Hornsea Three is described in full in volume 1, chapter 2: Policy and Legislation.

2.4.1.6 The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. Those descriptors relevant to the benthic subtidal and intertidal ecology assessment for Hornsea Three are listed in Table 2.5, including a brief description of how and where these have been addressed in the Hornsea Three assessment.

2.4.1.7 Further advice in relation specifically to the Hornsea Three development, has been sought through consultation with the statutory authorities and from the PINS scoping opinion (PINS, 2016) (section 2.5 and Table 2.5).

Table 2.5: Summary of the Marine Strategy Framework Directive's (MSFD) high level descriptors of Good Environmental Status (GES) relevant to benthic ecology and consideration in the Hornsea Three assessment.

Summary of MSFD high level descriptors of GES relevant to benthic ecology	How and where considered in the PEIR
Descriptor 1: Biological diversity: Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions.	The effects on biological diversity has been described and considered within the assessment for Hornsea Three alone and the cumulative effects assessment (CEA) (see section 2.11 and 2.12, respectively).
Descriptor 2: Non-indigenous species: Non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystems.	The effects of non-indigenous species on ecology within the Hornsea Three benthic ecology study area has been assessed in paragraphs 2.11.2.35 *et seq*.
Descriptor 4: Elements of marine food webs: All elements of the marine food webs, to the extent that they are known, occur at normal abundance and diversity and levels capable of ensuring the long term abundance of the species and the retention of their full reproductive capacity.	The effects on benthic subtidal and intertidal ecology has been described and considered within the assessment for Hornsea Three alone and the CEA (see section 2.11 and 2.12, respectively).
Descriptor 6: Sea floor integrity: Seafloor integrity is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected.	The effects on benthic subtidal and intertidal ecology has been described and considered within the assessment for Hornsea Three alone and the CEA (see section 2.11 and 2.12, respectively).
Descriptor 7: Alteration of hydrographical conditions: Permanent alteration of hydrographical conditions does not adversely affect marine ecosystems.	The effects of potentially altered hydrographical conditions are assessed in paragraph 2.11.2.51 *et seq*., and chapter 1: Marine Processes.
Descriptor 8: Contaminants: Concentrations of contaminants are at levels not giving rise to pollution effects.	The effects of contaminants on benthic species and habitats have been assessed in paragraphs 2.11.1.58 *et seq*., 2.11.1.59 *et seq*. and 2.11.3.41 *et seq*.
Descriptor 10: Marine litter: Properties and quantities of marine litter do not cause harm to the coastal and marine environment.	A Code of Construction Practice (CoCP) will be developed and implemented to cover the construction phase and an appropriate Project Environmental Management and Monitoring Plan (PEMMP) will be produced and followed to cover the operation and maintenance phase of Hornsea Three. The latter will include planning for accidental spills, address all potential contaminant releases and include key emergency contact details (e.g. Environment Agency (EA), Natural England and Maritime and Coastguard Agency (MCA)). A Decommissioning Programme will be developed to cover the decommissioning phase (see Table 2.17).

2.5 Consultation

2.5.1.1 A summary of the key issues raised during consultation specific to benthic ecology is outlined below, together with how these issues have been considered in the production of this PEIR. A summary of consultation specific to benthic ecology undertaken for Hornsea Project One and Hornsea Project Two, which are applicable to Hornsea Three, are also set out below.

2.5.2 Hornsea Project One and Hornsea Project Two consultation

2.5.2.1 Hornsea Three has similarities, both in terms of the nature of the development and its location, to Hornsea Project One and Hornsea Project Two. The matters relevant to Hornsea Three, which were raised by consultees during the pre-application and examination phases of Hornsea Project One and Hornsea Project Two, on benthic subtidal and intertidal ecology, are set out in volume 4, annex 1.1: Hornsea Project One and Hornsea Project Two Consultation of Relevance to Hornsea Three.

2.5.3 Hornsea Three consultation

2.5.3.1 Table 2.6 below summarises the issues raised relevant to benthic ecology, which have been identified during consultation activities undertaken to date. Table 2.6 also indicates either how these issues have been addressed within this PEIR or how the Applicant has had regard to them.

2.5.4 Evidence Plan

2.5.4.1 The Evidence Plan process has been set out in the Hornsea Project Three Offshore Wind Farm – Draft Evidence Plan (DONG Energy, 2017), the purpose of which is to agree the information Hornsea Three needs to supply to PINS, as part of a DCO application for Hornsea Three. The Draft Evidence Plan seeks to ensure compliance with the Habitat Regulations Assessment (HRA).

2.5.4.2 As part of the Evidence Plan process, the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology Expert Working Group (EWG) was established with representatives from the key regulatory bodies and their advisors and statutory nature conservation bodies, including the MMO, Cefas and Natural England. Representatives from the Wildlife Trust (TWT), who were not part of the EWG at the start, joined the EWG from February 2017. Between June 2016 and publication of this PEIR, a number of EWG meetings were held that included discussion of key issues with regard to the marine processes elements of Hornsea Three, including characterisation of the baseline environment and the impacts to be considered within the impact assessment. The identification of key issues was informed by consultation on Hornsea Project One and Project Two, where appropriate. Matters raised during EWG meetings have been included in Table 2.6 below.

Table 2.6: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to benthic ecology.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
21 June 2016	Benthic and Fish Ecology and Marine Processes Expert Working Group (EWG) meeting	Agreement with stakeholders that there is no requirement to carry out any additional beam trawls and no requirement to carry out additional sampling of sediment chemistry within the Hornsea Three array.	Sampling strategy of site-specific survey along the Hornsea Three offshore cable corridor and within the Hornsea Three array area, as agreed with the stakeholders, is detailed in chapter 5, annex 2.1: Benthic Ecology Technical Report.
06 December 2016	PINS/ Natural England - scoping opinion	Point raised on the scoping out of the impact 'remobilisation of contaminated sediments during construction and decommissioning' given the elevated levels of arsenic recorded for Hornsea Project One and Project Two. It was advised that evidence should be included within the Environmental Statement to demonstrate that these elevated levels are due to the presence of natural sources.	Contaminant data summarised in paragraph 2.7.1.4 and discussed in further detail chapter 5, annex 2.1: Benthic Ecology Technical Report. The impact 'seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology' has been scoped in for the offshore cable corridor (paragraph 2.11.1.58), while the potential for such an impact has been scoped out for the Hornsea Three array
06 December 2016	PINS - scoping opinion	A recommendation to review the Cefas 2012 Southern North Sea Synthesis Hamon grab data, which partly covers both the array area and offshore cable corridor, to maximise the site characterisation.	Awaiting provision of final report, information is to be incorporated into the baseline of the Environmental Statement chapter and the accompanying benthic ecology technical report.
06 December 2016	PINS - scoping opinion	Advised to use to most up-to- date, relevant impact assessment methodologies for their Environmental Statement.	Most up-to-date and relevant methodologies used (CIEEM, 2016; IEEM, 2010).
25 November 2016	MMO - scoping opinion	Point raised on whether there will be sufficient information for the purpose of the EIA, including adequate information to characterise the benthic ecology receptors likely to be affected by the proposed development. Concern over the possible gaps in the existing survey data for the eastern portion of the Hornsea Three array area, together with potential concerns regarding the sampling sample spacing queried, and the potential need to have a requirement for sufficient data to inform any potential impacts on the Markham's Triangle rMCZ.	A geophysical and benthic sampling survey has been undertaken at the Hornsea Three array area and extra sampling stations are proposed for the site-specific survey planned for Quarter Two 2017, as agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG (see paragraph 2.6.4.3 and chapter 5, annex 2.1: Benthic Ecology Technical Report).
25 November 2016	MMO - scoping opinion	It was recommended that the Environmental Statement include an assessment of smothering effects on sensitive benthic receptors. A need to consider potential impacts associated with the disposal of sediment during construction (arising from drilling for monopod foundations, seabed levelling for gravity-based foundations, and sandwave clearance), which may result in temporary or permanent loss of benthic habitat.	Smothering effects, including disposal of sediment during construction, which may lead to temporary or permanent loss of benthic habitat, have been considered in the assessment. See paragraph 2.11.1.42 *et seq.*
25 November 2016	MMO/Natural England - scoping opinion	A need to consider the potential for long-term, permanent impacts on the Cromer Shoal Chalk Beds MCZ, if the chalk within the MCZ is cut during the cable installation.	The potential for direct impacts on subtidal chalk are considered in paragraph 2.11.1.3 *et seq.*.
25 November 2016	MMO/Natural England - scoping opinion	Advised to assess the potential impact of the spread of non-native species as a separate impact.	Non-native species have been assessed as a separate potential impact; see paragraph 2.11.2.35 *et seq.*
25 November 2016	MMO - scoping opinion	Transboundary effects on benthic ecology should be screened in to the EIA process given the proximity to Klaverbank Site of Community Interest (SCI).	See paragraph 2.14.1.2.
25 November 2016	MMO - scoping opinion	Point raised on whether the potential impacts of re-suspended contaminated sediment in the Hornsea Three offshore cable corridor should be screened out of the EIA process.	The potential impacts of re-suspended contaminated sediment in the Hornsea Three offshore cable corridor has been included in the assessment; see paragraph in (paragraph 2.11.1.58).
25 November 2016	Natural England - scoping opinion	The North Norfolk Coast Special Protection Area (SPA) and the Greater Wash possible Special Protection Area (pSPA) should be included in the table. Impacts on benthic and intertidal ecology may have direct consequences for the SPA features.	To be considered in the draft Report to Inform Appropriate Assessment .
25 November 2016	Natural England - scoping opinion	Operation and Maintenance Activities: it is advised that thorough consideration is given in the EIA to the likely occurrence, types and duration of operation and maintenance (O&M) activities and the potential implications for recoverability of the interest features of designated sites.	Likely occurrence, types and duration of operation and maintenance (O&M) activities and recoverability of habitats have been considered, see section 2.11.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
25 November 2016	Natural England - scoping opinion	Request to use the available data or any additional modelling and assess any impacts on stratification and in particular the Flamborough Front.	The Flamborough Front has been assessed in chapter 1: Marine Processes and chapter 3: Fish and Shellfish.
01 February 2017	Benthic and Fish Ecology and Marine Processes EWG meeting	Agreement with stakeholders that the proposed sampling locations of the Hornsea Three specific survey planned for 2017 are appropriate for the purpose of characterising the Hornsea Three offshore cable corridor. It was also agreed that extra sampling would be carried out within the vicinity of Markham's Hole in the Hornsea Three array area. The extra sampling will provide a similar level of sampling density within Markham's Hole as the rest of the Hornsea Three array area. With this extra sampling it was agreed that there is sufficient data and proposed sampling to characterise the Hornsea Three array area.	The proposed sampling strategy is summarised in paragraph 2.6.4.3, and further detailed in chapter 5, annex 2.1: Benthic Ecology Technical Report.

2.6 Methodology to inform the baseline

2.6.1 Evidence-based Approach

2.6.1.1 The approach proposed by Hornsea Three for the purposes of characterising the benthic ecology within the two benthic ecology study areas defined in paragraph 2.3.1.1, was an evidence based approach to the EIA, which involves utilising existing data and information from sufficiently similar or analogous studies to inform the baseline understanding and/or impact assessments for a new proposed development. In this way, the evidence based approach does not necessarily require new data to be collected, or new modelling studies to be undertaken, to characterise potential impacts with sufficient confidence for the purposes of EIA (see volume 1, chapter 5: Environmental Impact Assessment Methodology).

2.6.1.2 The Hornsea Three array area is located within the former Hornsea Zone, for which extensive data and knowledge regarding benthic ecology is already available. This data/knowledge has been acquired through zonal studies and from the surveys and characterisations undertaken for Hornsea Project One and Hornsea Project Two. It was therefore proposed that the Hornsea Three benthic ecology characterisation of the Hornsea Three array be completed using a combination of desktop data and information sources, and historic survey data collected as part of the characterisations of the Hornsea Project One and Hornsea Project Two offshore wind farms and the former Hornsea Zone. Over the series of EWG meetings conducted between June 2016 and publication of this PEIR, it was agreed that this approach (further detailed in the sections below) was largely appropriate and sufficient for the purposes of characterising the benthic ecology of Hornsea Three. However, it was agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish EWG that further sampling would be undertaken in 2017 in an area of finer sediment in Markham's Hole, within the Hornsea Three array area, to augment the existing data and ensure sufficient coverage of the eastern extent of the Hornsea Three array area (see paragraph 2.6.4.3).

2.6.1.3 The Hornsea Three offshore cable corridor is unique to Hornsea Three. As such, the existing data and knowledge of the baseline environment along the offshore cable corridor for Hornsea Project One and Hornsea Project Two is relevant only in part to the Hornsea Three offshore cable corridor and the evidence-based approach described above cannot be applied. Therefore the baseline characterisation of the Hornsea Three offshore cable corridor within this PEIR has primarily drawn upon the site-specific survey completed in 2016 and desktop information from third-party surveys, including surveys targeting areas within and in close proximity to areas designated for nature conservation. A further site-specific survey of the Hornsea Three offshore cable corridor is planned for Quarter Two 2017. This survey has been designed to address further data requirements identified from analysis of benthic data acquired during the sampling campaigns of the geophysical surveys described in paragraph 2.6.4.1. Together with the existing data (i.e. geophysical ground-truthing samples retained for benthic analysis, habitat assessment data of offshore cable corridor and historic survey data), this survey will be used to establish a robust and up-to-date characterisation of the baseline environment in the Hornsea Three offshore cable corridor. This site-specific Hornsea Three offshore cable corridor survey has been discussed and agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish EWG. The results will be used to update the Hornsea Three benthic ecology baseline characterisation in the Environmental Statement (see section 2.6.4 below).

2.6.1.4 A geotechnical survey is also planned to be undertaken in 2017, to further investigate the inshore approach to the landfall location of the offshore cable corridor. DDV sampling will be performed as part of this surveys, with the resulting data providing further information on habitats close to shore within the offshore cable corridor and may subsequently contribute to the biotope maps in the final EIA report.

2.6.2 Desktop study

2.6.2.1 Information on benthic ecology within the southern North Sea study area was collected through a detailed desktop review of existing studies and datasets. The key data sources are summarised in Table 2.7, although this should not be considered an exhaustive list of references. Further detail is presented within volume 5, annex 2.1: Benthic Ecology Technical Report.

2.6.3 Designated sites

2.6.3.1 All designated sites within the southern North Sea benthic ecology study area that could be affected by the construction, operation and maintenance, and decommissioning of Hornsea Three for benthic ecology, were identified using the three step process described below:

2.6.3.2 Designated sites within close proximity to Hornsea Three and therefore most likely to be potentially affected by activities associated with it, are described here and discussed in full in volume 5, annex 2.1: Benthic Ecology Technical Report. Designated sites that are considered to fall within the potential Zone of Influence (ZoI) of Hornsea Three comprise the following:

- Sites with relevant benthic ecology features which overlap with Hornsea Three;
- Sites with relevant benthic ecology features which are located within one tidal excursion (approximately 12 km) of the Hornsea Three array area and /or offshore cable corridor.

2.6.3.3 This ensures that the benthic ecology features of all sites potentially affected by changes in water quality (e.g. increased suspended sediment concentrations) within a tidal excursion and potential changes to the hydrodynamic regime are included in the EIA assessment.

Table 2.7: Summary of key desktop reports.

Title	Source	Year	Author
Humber Regional Environmental Characterisation (REC)	Marine Aggregate Levy Sustainability Fund (MALSF)	2011	Tappin *et al*.
Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region	Humber Aggregate Dredging Association (HADA)	2012	Environmental Resources Management (ERM)
European Marine Observation Data Network (EMODnet) Seabed Habitats Project	EUSeaMap 2016: www.emodnet-seabedhabitats.eu/	2016	EUSeaMap 2016
UK Benthos Database	Oil and Gas UK: http://oilandgasuk.co.uk/product/ukbenthos/	2015	Oil and Gas UK
North Sea Benthos Project (NSBP) 2000	North Sea Benthos Project 2000: www.vliz.be/vmdcdata/nsbp/	2001	International Council of the Exploration of the Sea (ICES)
Technical reports for the Offshore Oil and Gas Strategic Environmental Assessment (SEA) Areas 2 and 3	UK Government, Department of Energy and Climate Change (DECC).	2001	Department of Trade and Industry (DTI)
Cromer Shoal Chalk Beds rMCZ Post-survey Site Report.	Department for Environment, Food and Rural Affairs (Defra)	2015	Defra
North Norfolk Sandbanks and Saturn Reef SCI management investigation report.	Joint Nature Conservation Committee (JNCC), Cefas	2015	Jenkins *et al*.
Benthic survey of Inner Dowsing, Race Bank and North Ridge cSAC, and of Haisborough, Hammond and Winterton cSAC.	Cefas	2013	Barrio Froján *et al*.
Sheringham Shoal Offshore Wind Farm Environmental Statement and pre-construction survey data.	Scira Offshore Energy	2006 2009	Scira Offshore Energy; Brown and May
Dudgeon Offshore Wind Farm Environmental Statement	Dudgeon Offshore Wind Limited	2009	Royal Haskoning Warwick Energy

2.6.4 Site specific surveys

2.6.4.1 Data from the following surveys have been used to inform the baseline characterisation, as agreed with the Marine Processes, Benthic Ecology and Fish and Shellfish EWG (see section 2.6.1, Figure 2.2 and Figure 2.3):

- Intertidal walkover survey of the landfall site in 2016;
- Faunal and particle size analysis (PSA) on benthic samples retained during ground-truthing campaigns in 2016 in support of geophysical surveys in the Hornsea Three array area and Hornsea Three offshore cable corridor;
- Benthic sampling and drop-down video (DDV) habitat assessment survey by Benthic Solutions Limited along the Hornsea Three offshore cable corridor in 2016;
- Historic benthic ecology surveys from the former Hornsea Zone between 2010 and 2012; and
- Benthic survey carried out at Markham's Triangle rMCZ by Defra in 2012.

2.6.4.2 See volume 5, annex 2.1: Benthic Ecology Technical Report for further information on each of the site specific surveys. Note that the temporary working area of the offshore cable corridor has not been directly surveyed (Figure 2.3), however there is high confidence that the working area will not differ substantially from the adjacent mapped sections of the corridor. Also, where sensitive habitats are identified in the offshore cable corridor the project will consider mitigating impacts on these habitats by avoiding them; this will extend out to the temporary working area.

2.6.4.3 As outlined in paragraphs 2.6.1.3 and 2.6.1.4, two further site-specific surveys are planned for Quarter Two 2017: a benthic ecology survey of the Hornsea Three offshore cable corridor (and targeting Markham's Hole within the Hornsea Three array area) (Figure 2.3) and a geotechnical survey to further investigate the inshore approach to the landfall location of the offshore cable corridor. A summary of the surveys undertaken to date, together with the Hornsea Three surveys planned for 2017, is outlined in Table 2.8 below. Note that surveys were only undertaken within the Hornsea Three benthic ecology study area. The southern North Sea benthic ecology study area relates to the desktop study, not survey data, as outlined in paragraph 2.3.1.1.

Table 2.8: Summary of benthic ecology surveys undertaken and proposed.

Title	Extent of survey	Overview of survey	Survey contractor	Year	Reference to further information
Historic survey data within the Hornsea Three benthic ecology study area					
Zone characterisation (ZoC) benthic sampling survey	Former Hornsea Zone	122 combined DDV and Hamon grab sampling stations, plus 40 epibenthic beam trawl stations	EMU Ltd	2010	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Project One benthic sampling survey	Former Hornsea Zone	161 combined DDV and Hamon grab sampling stations, of which 40 stations were sampled for sediment chemistry, plus 41 epibenthic beam trawl stations	EMU Ltd	2010 to 2011	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Project Two benthic infill survey	Former Hornsea Zone	51 combined DDV and Hamon grab sampling stations, of which 8 stations were sampled for sediment chemistry, plus 21 epibenthic beam trawl stations	EMU Ltd	2012	Volume 5, annex 2.1: Benthic Ecology Technical Report
Markham's Triangle rMCZ survey [a]	Markham's Triangle rMCZ	21 combined DDV and Hamon grab sampling stations and 29 stations sampled by Hamon grab only	Cefas	2012	Volume 5, annex 2.1: Benthic Ecology Technical Report
Site specific surveys within the Hornsea Three benthic ecology study area					
Hornsea Three array area geophysical and benthic sampling survey	Hornsea Three array area	Geophysical survey consisting of dual frequency side scan sonar and multibeam echosounder and 20 ground truthing Hamon grab samples for PSA and infaunal analysis	EGS International Ltd (EGSi)	2016	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Three offshore cable corridor geophysical and benthic sampling survey	Hornsea Three offshore cable corridor	Geophysical survey consisting of dual frequency side scan sonar and multibeam echosounder and 19 combined DDV and Hamon grab sampling stations plus one DDV sampling station	Bibby HydroMap Limited and Benthic Solutions	2016	Volume 5, annex 2.1: Benthic Ecology Technical Report
Hornsea Three intertidal survey of the landfall area	Hornsea Three landfall area (mean low water spring (MLWS) to MHWS)	Phase I walkover habitat survey habitat with 0.1 m^2 dig-over sampling	RPS Energy	2016	Volume 5, annex 2.1: Benthic Ecology Technical Report
Proposed site specific surveys within the Hornsea Three benthic ecology study area					
Hornsea Three benthic sampling survey	Hornsea Three offshore cable corridor and three sampling stations in Markham's Hole within the Hornsea Three array area	5 epibenthic beam trawl stations, 16 combined DDV and Hamon grab sampling stations, plus 5 stations for Day grab sampling only, and 15 stations for DDV transects only	Gardline	Proposed for 2017	Volume 5, annex 2.1: Benthic Ecology Technical Report (for proposed sampling strategy only)
Hornsea Three offshore cable corridor inshore geotechnical survey	Up to 12 sampling locations within 1 km of offshore cable corridor landfall.	Spot DDV sampling to be undertaken at each of the 12 borehole locations.	TBC	2017	TBC

[a] PSA data from the Markham's Triangle rMCZ designation survey has been obtained for the purposes of characterising the Hornsea Three array area. This survey was undertaken by Cefas (Defra, 2014) and has no connection with the Hornsea Three development.

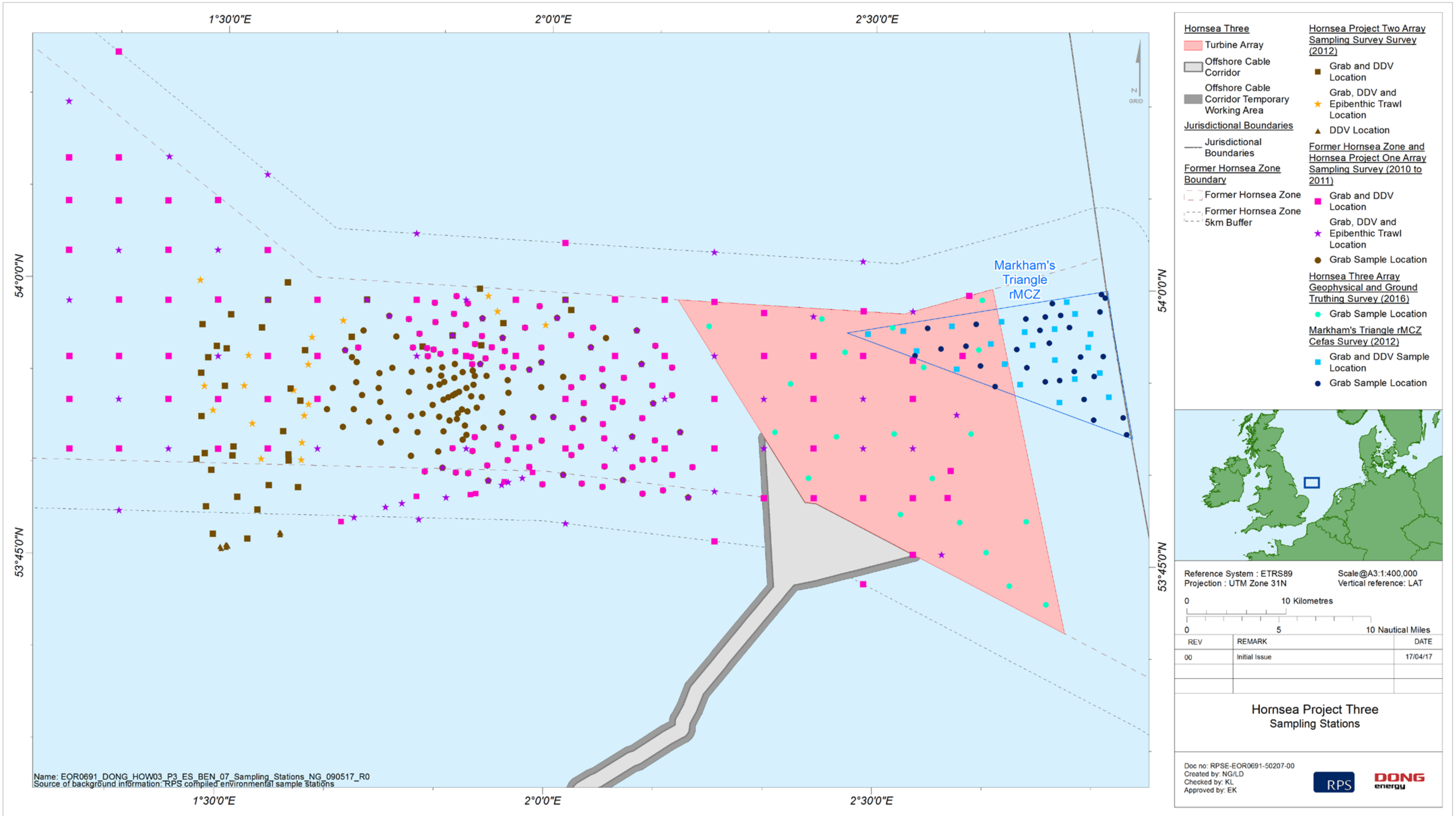

Figure 2.2: Hornsea Project Three array area with existing (2010-2012) and Hornsea Three (2016) benthic ecology sampling locations (benthic grabs/DDV and trawls). Also shown are sampling sites within Markham's Triangle rMCZ (Defra, 2012 (note: third party survey data).

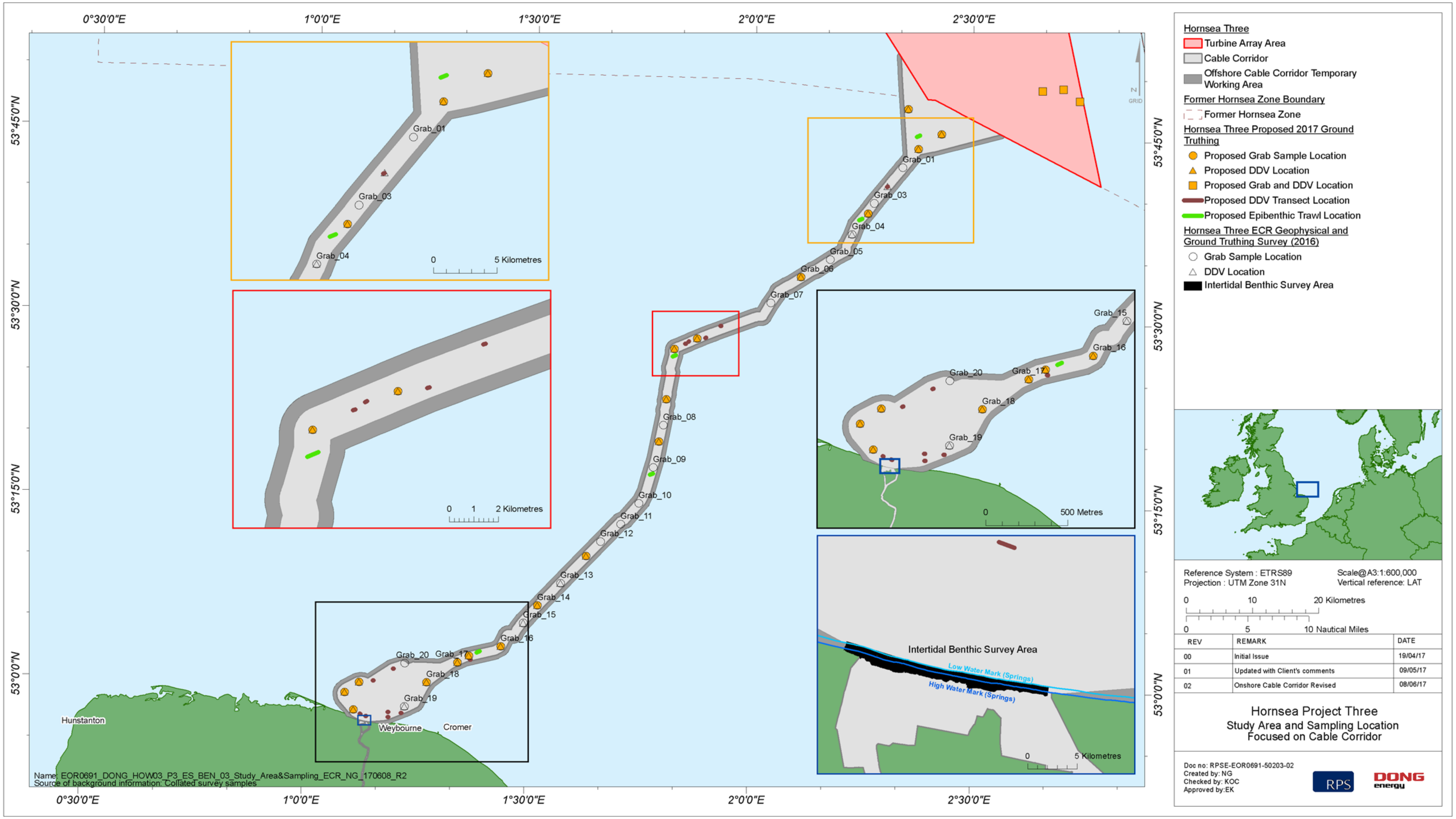

Figure 2.3: Hornsea Three offshore cable corridor with Hornsea Three (2016) benthic ecology sampling locations and benthic ecology sampling locations proposed for 2017 (benthic grabs, DDV and trawls). Note station labels are shown only for the sampled locations which are discussed in the text, all station labels are provided in volume 5, annex 2.1: Benthic Ecology Technical report.

2.7 Baseline environment

2.7.1 Subtidal

Sediment composition

2.7.1.1 The benthic subtidal sediments of all samples (geophysical ground-truthing samples retained for benthic analysis, habitat assessment data of the offshore cable corridor and historic survey data) within the Hornsea Three benthic ecology study area were classified according to the Simplified Folk Classification (Long, 2006) into three main sediment types: sand and muddy sand (SS.SSA: Sublittoral Sands and Muddy Sands), coarse sediments (SS.SCS: Sublittoral Coarse Sediment) and mixed sediments (SS.SMX: Sublittoral Mixed Sediment). Sand and muddy sand sediments were found throughout the Hornsea Three benthic ecology study area (Figure 2.4).

2.7.1.2 These sediments dominated much of the central swathe of the Hornsea Three array area, the central section of the Hornsea Three offshore cable corridor and most the wider Hornsea Three benthic ecology study area, particularly the area in the west of the former Hornsea Zone (Figure 2.4). Coarse sediments were distributed throughout the southern and northern sections of the Hornsea Three array area, particularly the area corresponding with the western edge of Markham's Triangle rMCZ. The areas of coarse material within the Hornsea Three array area were separated by the sand and muddy sand sediments in the centre of the Hornsea Three array area. Patches of coarse material were present in the central former Hornsea Zone, while a large area of coarse sediment dominated the southwestern region of the former Hornsea Zone (Figure 2.4). Isolated patches of mixed sediments were recorded primarily in the centre and in the northeast of the Hornsea Three array area, again where the array and Markham's Triangle rMCZ overlap. Mixed sediments were also found in the area coinciding with the central area of the former Hornsea Zone and to the southeast of this.

2.7.1.3 Sediments along the Hornsea Three offshore cable corridor were dominated by infralittoral/circalittoral coarse sediments, with some areas comprising circalittoral/infralittoral fine sands. An area of bedrock, primarily moderate energy infralittoral rock with small regions of high energy infralittoral rock and moderate energy circalittoral rock, was evident just offshore of North Norfolk, within the Hornsea Three offshore cable corridor, in the EUSeaMap data. This characterisation corresponds with subtidal chalk beds which is a protected habitat feature for the Cromer Shoal Chalk Beds MCZ.

Sediment contamination

2.7.1.4 The results of the heavy metals analysis for the subtidal samples revealed that, except for arsenic, cadmium and nickel, concentrations of all metals within sediments were below both the Cefas AL1 and the more stringent Canadian TEL, and therefore were at levels below which biological effects in benthic organisms could be expected.

2.7.1.5 Arsenic was found to exceed the Canadian TEL at all but five sites within the Hornsea Three benthic ecology study area, and of the sites with elevated levels of arsenic, five recorded concentrations above the Canadian PEL at levels where a toxicity effect would be evident. Although levels of arsenic in sediments exceeded the Cefas AL1 of 20 mg/kg at 26 sites, concentrations at all sites were well below the Cefas AL2 of 100 mg/kg. Historically the Humber has been subjected to a large point discharge of arsenic from industrial sources and samples collected during various North Sea surveys between 1991 and 1995 have identified numerous areas with high raw arsenic concentrations, particularly off north Yorkshire and the Humber Estuary (Whalley *et al*., 1999). However, Whalley *et al*. (1999) demonstrated that after normalisation against iron, the levels of arsenic in historical samples were much reduced in significance. Whalley *et al.* (1999) proposed that the low residual values might be explained by dilution into the Humber Estuary's high suspension load, or by particulate transport away from the region. Also, the Humber Estuary receives large amounts of iron waste (Millward and Glegg, 1997) to which arsenic may sorb (Cefas, 2000). The arsenic concentrations within sediments in the Hornsea Three benthic ecology study area are similar to those reported by Whalley *et al.* (1999); therefore, they are considered unlikely to represent excessive levels for the region. As such, only impacts by remobilisation of contaminated sediments within the Hornsea Three offshore cable corridor will be assessed; this impact will not be considered within the Hornsea Three array area.

2.7.1.6 The level of cadmium marginally exceeded the Canadian TEL and Cefas AL1 at one site in the centre of the former Hornsea Zone but was well within the Cefas AL2 and the Canadian PEL. The concentration of nickel marginally exceeded the Canadian TEL (15.9 mg/kg) at one site but was below the Cefas AL1 (20 mg/kg) at all sites.

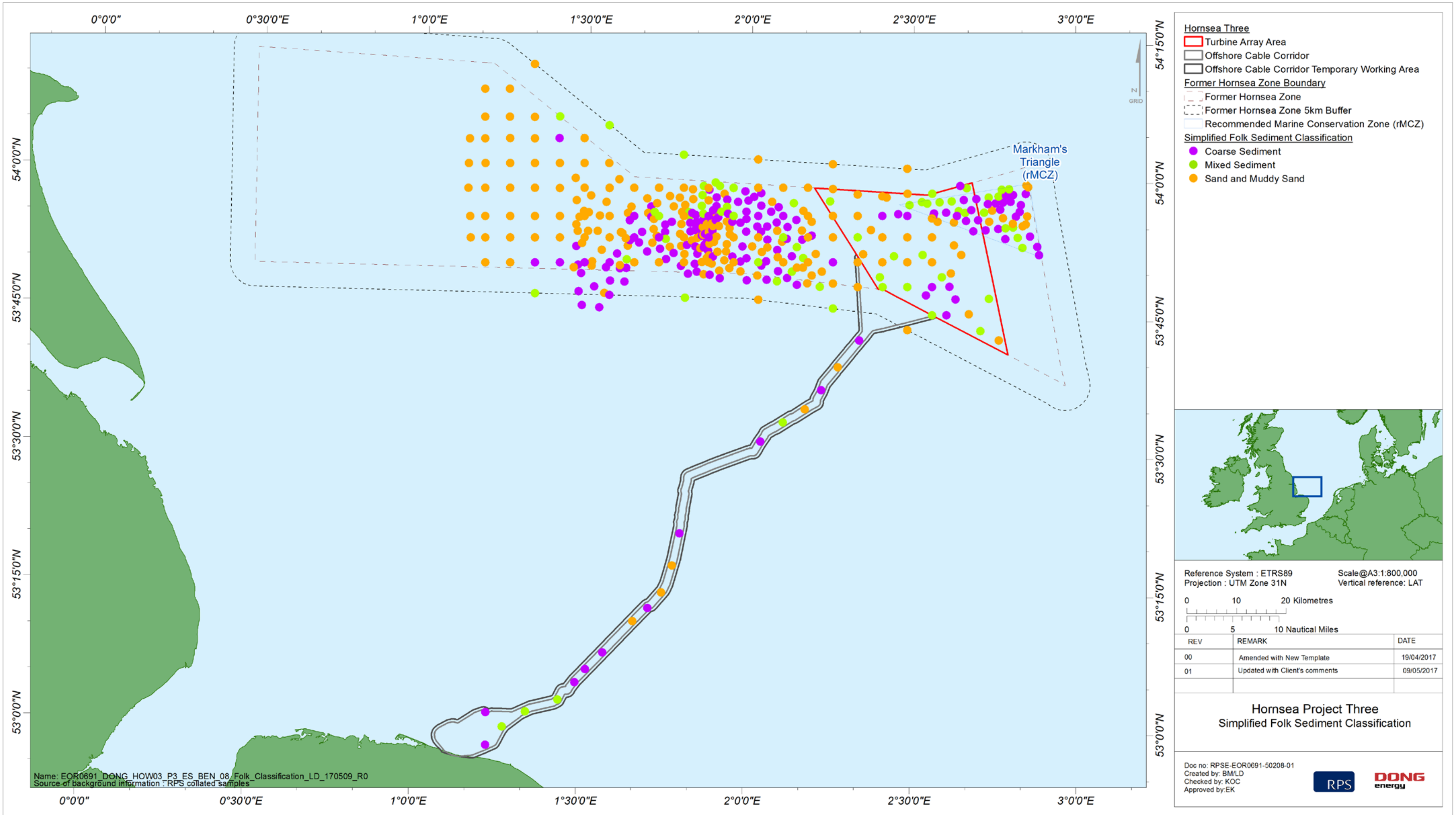

Figure 2.4: Simplified Folk Sediment Classifications for each benthic grab sample location within the Hornsea Three benthic ecology study area.

Infaunal and epifaunal biotopes

2.7.1.7 The subtidal biotopes identified in the Hornsea Three benthic ecology study area are described in this section, and presented in Figure 2.5 and Table 2.9 (see also volume 5, annex 2.1: Benthic Ecology Technical Report). The broad patterns in the infaunal and epifaunal biotopes identified across the Hornsea Three benthic ecology study area can be summarised as follows:

- Subtidal sandy sediments (biotope codes starting SS.SSa) in the western and central parts of the Hornsea Three benthic ecology study area and much of the Hornsea Three array area were characterised by the FfabMag, NcirBat and EpusOborApri biotopes with typically extremely sparse epibenthic communities. The EpusOborApri biotope was particularly prevalent in the northeast and southwest of the former Hornsea Zone where it was occasionally recorded in association with the ScupHyd epibenthic biotope;
- Muddy sand sediments (biotope codes starting SS.SMu) in deeper waters to the north of the Hornsea Three benthic ecology study area and in the Hornsea Three array area were characterised by the AfilMysAnit biotope with limited associated epifaunal communities, with the exception of brittlestars;
- Coarse sediments (biotope codes starting SS.SCS) with diverse infaunal communities characterised by the PoVen biotope in large swathes within the Hornsea Three array area, in the southwest of the former Hornsea Zone and patchily distributed in the central section of the former Hornsea Zone. The majority of these sediments had typically sparse epibenthic communities, however, some in the central former Hornsea Zone were associated with the FluHyd epibenthic overlay; and
- Three areas of mixed sediments ((biotope codes starting SS.SMX) along the Hornsea Three offshore cable corridor, characterised by the SspiMx infaunal biotope exhibited the FluHyd epifauna biotope.

Potential Annex I habitats and features of conservation interest

2.7.1.8 A *Sabellaria* biotope (SspiMx) was identified at ten sampling locations, largely using infaunal grab sample data, within the Hornsea Three offshore cable corridor and at a single site located in the centre of the former Hornsea Zone. Although Annex I *Sabellaria* reefs are associated with the SspiMx biotope, the occurrence of a *Sabellaria* biotope does not automatically indicate that a reef is present.

2.7.1.9 A full Annex I reef assessment was undertaken for sites ECR02 and ECR04 by Benthic Solutions Limited (see paragraph 2.6.4.1, Figure 2.3 and volume 5, annex 2.1: Benthic Ecology Technical Report), as these were the only locations where *S. spinulosa* aggregations were visible in the DDV footage. *Sabellaria* aggregations were generally recorded at station ECR04 in the form of domical mounds, while those at station ECR02 exhibited pavement formations. It was not possible to delineate the extent of *S. spinulosa* at station ECR04 due to the patchiness of the aggregations, therefore the area of the aggregations was not determined. Both the elevation and patchiness were assessed as being 'low reef' at ECR04 giving an overall reef structure of 'low reef'. As the reef structure at station ECR04 was determined to be 'low', this area could only achieve a low reefiness score irrespective of the total area of the aggregations.

2.7.1.10 At station ECR02, the *Sabellaria* aggregations were estimated to cover an area of approximately 0.084 km^2 ('medium reef'). The mean elevation at station ECR02 achieved a 'low reef' score in the assessment, while patchiness was determined to represent 'high reef', resulting in an overall reef structure score of 'low reef'. Both of the surveyed areas of *S. spinulosa* aggregations on the Hornsea Three offshore cable corridor were assigned low overall reefiness; therefore it is unlikely that these would be considered Annex I reef habitats.

2.7.1.11 The occurrence of *Sabellaria* biotopes throughout the Hornsea Three offshore cable corridor, together with other data such as the Humber REC data and the HADA MAREA data which indicates a wide distribution throughout this part of the southern North Sea benthic ecology study area, suggests that *S. spinulosa* reefs in this area are likely to be ephemeral and, although the specific locations may change, the propensity for the presence of reef in these areas and in the Hornsea Three offshore cable corridor is evident. It is therefore concluded that there is potential for reefs to occur within discrete parts of the Hornsea Three benthic ecology study area (namely the Hornsea Three offshore cable corridor) if suitable conditions prevail.

2.7.1.12 A benthic species of conservation importance, which was recorded within the Hornsea Three benthic ecology study area, was the ocean quahog *Arctica islandica.* This species is listed by Oslo-Paris Commission (OSPAR) as a threatened and/or declining species for the Greater Northern North Sea (OSPAR Region II), and was recorded from nine sites (from six sites as single specimens, and three site where two individuals were recorded) in the former Hornsea Zone. All records were of juvenile *A. islandica*, except for one which measured less than 10 mm, indicating it was a spat rather than a juvenile of the species (Witbaard and Bergman, 2003).

Table 2.9: Benthic infaunal and epifaunal biotopes identified in the Hornsea Three benthic ecology study area, including geographic locations (see Figure 2.5).

Biotope code	Hornsea Three Biotope Description	Geographic Location
Infaunal biotopes		
SS.SSa.IFiSa.NcirBat (NcirBat)	This biotope occurred in well sorted medium and fine sands and was characterised by the polychaetes *Nephtys cirrosa* and *Spiophanes bombyx*, the amphipod *Bathyporeia elegans* and the opossum shrimp *Gastrosaccus spinifer*.	This biotope was located in the central part of the former Hornsea Zone, the central part of the Hornsea Three array area and three areas along the Hornsea Three offshore cable corridor.
SS.SSa.CFiSa.ApriBatPo (ApriBatPo)	Occurring in circalittoral and offshore medium to fine sands with a community characterised by the bivalve *Abra prismatica*, the amphipod *Bathyporeia elegans* and polychaetes including *Scoloplos armiger*, *Spiophanes bombyx*, *Aonides paucibranchiata*, *Chaetozone setosa*, *Ophelia borealis* and *Nephtys longosetosa*. The brittlestar *Amphiura filiformis* was also common at some sites.	This biotope was located at limited discrete locations in the former Hornsea Zone and the central section of the Hornsea Three offshore cable corridor.
SS.SSa.CFiSa.EpusOborApri (EpusOborApri)	Offshore sediments dominated by medium to fine sands and characterised by the polychaetes *Ophelia borealis* and *Nephtys cirrosa*, high abundances of the pea urchin *Echinocyamus pusillus* and by the venerid bivalve *Abra prismatica*.	This biotope was recorded in the southwest and northwest of the former Hornsea Zone and in the west of the Hornsea Three array area.
SS.SSa.IMuSa.FfabMag (FfabMag)	In stable, fine, compacted and slightly muddy sands in the infralittoral and littoral fringe, this community was characterised by venerid bivalves such as *Tellina* (*Fabulina*) *fabula*, *Chamelea striatula* and *Abra prismata*, polychaetes including *Magelona johnstoni* and *Spiophanes bombyx* and the amphipods *Bathyporeia elegans*, *Bathyporeia tenuipes* and *Bathyporeia guilliamsoniana*.	The biotope was the predominant biotope throughout the west of the former Hornsea Zone and in the west of the Hornsea Three array area. It was also recorded in patches throughout the central section of the former Hornsea Zone.
SS.SMu.CSaMu.AfilMysAnit (AfilMysAnit)	Poorly sorted cohesive muddy sands in moderately deep water with an infaunal community dominated by high abundances of the echinoderm *Amphiura filiformis,* the bivalve *Kurtiella* (*Mysella*) *bidentata*, polychaetes and nemerteans.	This biotope was assigned to a swathe of sediment stretching the length of the northern former Hornsea Zone. It was also present in the deeper waters of the central part of the Hornsea Three array area.
SS.SCS.CCS.MedLumVen/ SS.SSa.CFiSa.EpusOborApri (MedLumVen/EpusOborApri)	A mosaic biotope with characteristics of both the circalittoral fine sand EpusOborApri biotope and the richer coarser sand MedLumVen biotope dominated by polychaetes and venerid bivalves. This biotope was characterised by the polychaetes *Nephtys cirrosa* and *Ophelia borealis*, the echinoderm *Echinocyamus pusillus*.	This mosaic biotope was recorded in patches within the central former Hornsea Zone, particularly in the south.
SS.SCS.ICS.MoeVen (MoeVen)	This biotope occurred in infralittoral medium to coarse sand which is subject to moderately strong water movement from tidal streams with communities characterised by high abundances of the venerid bivalve mollusc *Goodallia triangularis* and to a lesser extent *Timoclea ovata* and a relatively diverse assemblage of polychaetes including *Nephtys cirrosa* and *Ophelia borealis*.	This biotope was found in discrete patches in the central former Hornsea Zone and the shallower water of the nearshore section of the Hornsea Three offshore cable corridor.
SS.SCS.CCS.MedLumVen (MedLumVen)	Circalittoral gravels, coarse to medium sands, and shell gravels, sometimes with a small amount of silt characterised by polychaetes including *Spiophanes bombyx*, *Ophelia borealis*, *Mediomastus fragilis* and *Glycera lapidum* with the pea urchin *Echinocyamus pusillus*. Communities also including *Nemertea* spp. and venerid bivalves such as *Dosinia* sp. which although in low numbers are likely to have been under-sampled in the grab surveys.	This mosaic biotope was recorded in isolated patches of the central former Hornsea Zone.
SS.SMx.OMx.PoVen (PoVen)	In offshore gravelly sands an infaunal community characterised by a particularly rich community of polychaetes including Notomastus spp., *Pista cristata*, *Scalibregma inflatum* and *Protodorvillea kefersteini*, ribbon worms *Nemertea* spp., the pea urchin *Echinocyamus pusillus* and low numbers of venerid bivalves including *Timoclea ovata*.	This biotope was distributed extensively throughout the Hornsea Three array area, particularly to the south and northeast of the Hornsea Three array area. It was also found in the southwest and the central section of the former Hornsea Zone.
SS.SMx.CMx.MysThyMx (MysThyMx)	Moderately exposed or sheltered, circalittoral muddy sands and gravels characterised by communities of the bivalve *Mysella bidentata*, polychaetes such as *Glycera alba*, *Mediomastus fragilis* and *Goniada maculata*. The brittlestar *Amphiura filiformis* was also abundant at some sites.	This biotope was distributed as isolated patches throughout the central northern and eastern sections of the former Hornsea Zone, particularly within the Hornsea Three array area.
SS.SBR.PoR.SspiMx (SspiMx)	This biotope occurred on mixed sediments and was characterised by high abundances of the tube-building polychaete Sabellaria spinulosa and a diverse community of infaunal polychaetes including *Polycirrus* spp., *Scalibregma inflatum*, *Mediomastus fragilis* and *Pholoe baltica* together with the bivalve mollusc *Abra alba*.	This biotope was predominantly recorded along the Hornsea Three offshore cable corridor, particularly in the nearshore and most offshore sections.
SS.SSa.IFiSa.IMoSa (IMoSa)	Medium to fine sandy sediment in shallow water, often formed into dunes, on tide swept coasts containing very little fauna due to the mobility of the substratum. Characterised by low numbers of amphipods such as *Bathyporeia* spp., the mysid *Gastrosaccus spinifer* and the venerid bivalve *Ensis siliqua*.	This biotope was found in isolated areas in the central former Hornsea Zone.

Biotope code	Hornsea Three Biotope Description	Geographic Location
Epifaunal biotopes		
SS.SSa.IFiSa.IMoSa (IMoSa)	Medium to fine sandy sediment on exposed coasts that often contains very little epifauna due to the mobility of the substratum. Very few epifaunal species were recorded and, with the exception of the echinoderms including *Asterias rubens* and *Astropecten irregularis*, generally occurred at low abundances including flatfish and sandeels. In areas where localised cobbles and pebbles provided substrate for epifaunal species in an otherwise featureless habitat, hydroid turfs and bryozoan crusts were observed on the pebbles and cobbles.	This biotope was distributed extensively throughout the Hornsea Three benthic ecology study area, particularly the Hornsea Three offshore cable corridor and the central section of the Hornsea Three array area, as well as the area to the west of this.
SS.SSa.IFiSa.ScupHyd (ScupHyd)	Sand sediment with cobbles and pebbles, exposed to strong tidal stream, this biotope is characterised by the echinoderm *Asterias rubens*, conspicuous mixed hydroid and bryozoan turfs and the sand mason *Lanice conchilega* in the surrounding sand.	This biotope was recorded in the central section of the former Hornsea Zone.
SS.SMu (SMu)	Sublittoral mud and cohesive sandy mud found in offshore areas of deeper water. This biotope is characterised by epifaunal communities of brittlestars, echinoderms Asterias rubens and burrowing megafauna including *Nephrops norvegicus*.	This biotope was found in the deeper waters to the north, centre and southeast of the Hornsea Three array area.
SS.SCS.ICS.SSh (SSh)	Sublittoral clean shingle and pebbles with a lack of conspicuous fauna. Although the majority of the sites assigned to this biotope constituted predominantly coarse gravelly sand, rather than pebbles, the distinct lack of epifauna matched this biotope. This biotope was characterised by a lack of epifauna and the presence of similar epifauna to the IMoSa biotope in sandy sediment including the echinoderms *Asterias rubens*, *Astropecten irregularis*, sandeels and locally abundant hydroid turfs and soft coral *Alcyonium digitatum* on cobbles and pebbles.	This biotope was present in large swathes in the north and south of the Hornsea Three array area as well as the areas of coarser sediments to the west of the Hornsea Three array area.
SS.SMx.CMx.FluHyd (FluHyd)	This biotope is best considered as an epifaunal overlay on a substratum of boulder, cobbles or pebbles with gravel and sand. The epifaunal community was characterised by mixed turfs of hydroids and bryozoans including *Flustra foliacea*, barnacles *Balanus crenatus*, the ascidian *Dendrodoa grossularia*, keelworms *Pomatoceros* sp. and anemones including *Urticina* sp. on scattered pebbles and cobbles.	This biotope was found in two discrete locations to the northeast of the Hornsea Three array area, several areas along the Hornsea Three offshore cable corridor, and in the southwest of the Hornsea Three benthic ecology study area.

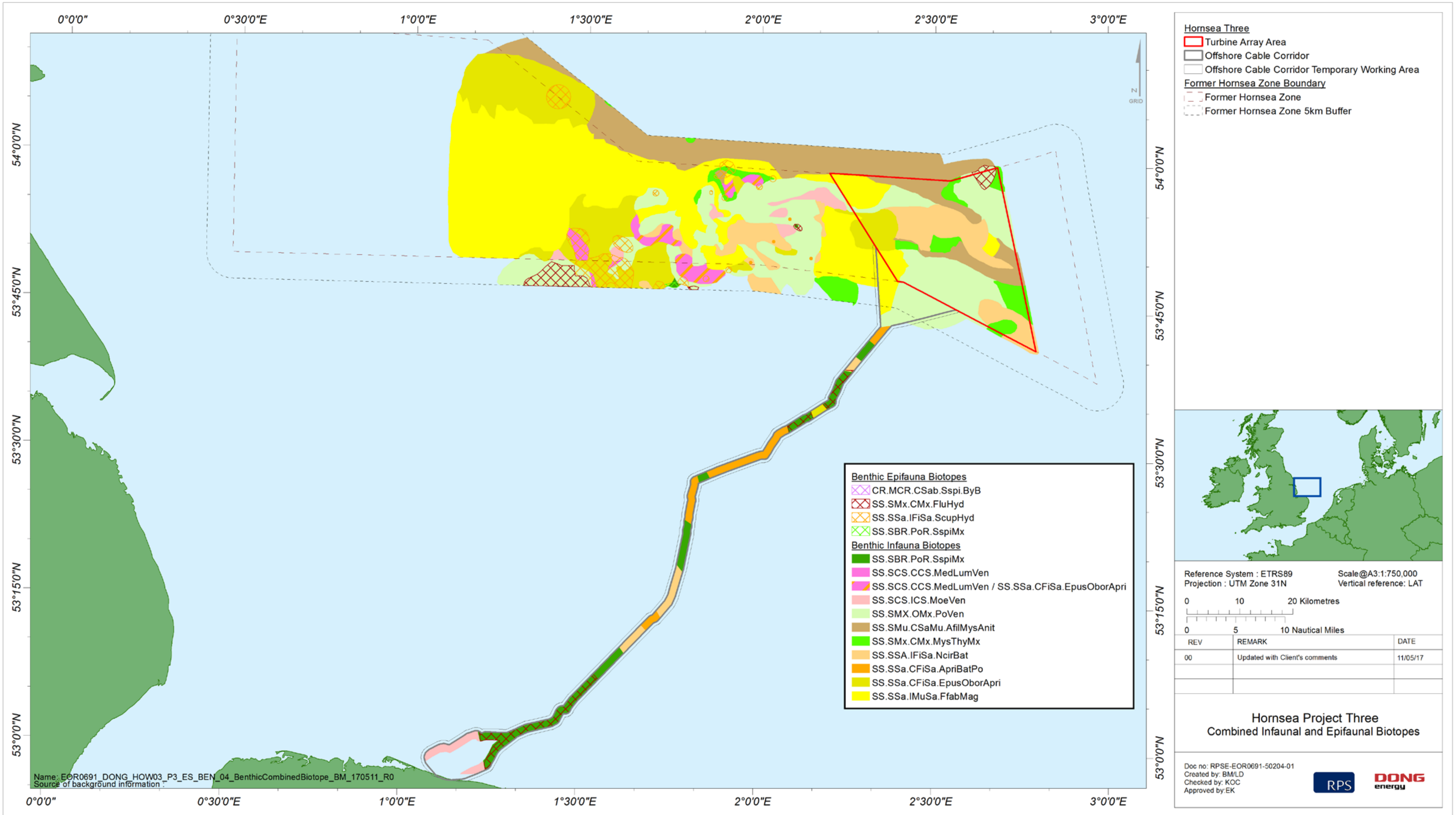

Figure 2.5: Combined infaunal and epifaunal biotope map of the Hornsea Three benthic ecology study area (note nearshore habitat mapping is to be completed in final ES).

2.7.2 Intertidal

2.7.2.1 The landfall site in the Hornsea Three benthic ecology study area at Weybourne was, on the whole, characterised by naturally species-poor intertidal benthic communities which are typical of dynamic shingle and sandy shore environments. A total of four intertidal biotopes were recorded at the landfall (see Table 2.10 and Figure 2.6). The intertidal zone between Weybourne and Salthouse and the wider intertidal area comprised a shingle beach dominated by barren pebbles and cobbles. The beach profile was steep, as expected for a shingle shore, with distinct ridges or berms across the face of the beach; this profile pattern and the sediment type was largely consistent for the full length of the landfall. Areas of fine sand with reduced shingle content were observed at the MLWS and in isolated patches on the lower shore throughout the landfall area.

2.7.2.2 No valued ecological receptors (VERs) were identified at the Hornsea Three landfall and, while the landfall area in general has been considered in the assessment, the sparse ecological communities at the landfall have not been assessed.

2.7.3 Designated sites

2.7.3.1 Designated sites within close proximity to Hornsea Three with benthic ecology features and therefore most likely to be potentially affected by activities associated with it, are described here and discussed in full in volume 5, annex 2.1: Benthic Ecology Technical Report. See section 2.6.3 for methods of screening in designated sites. The benthic ecology features of direct relevance to the Hornsea Three development for which the sites have been designated are also provided.

International Designations

Natura 2000 sites

2.7.3.2 Natura 2000 sites within the southern North Sea benthic ecology study area, and which lie within close proximity to Hornsea Three benthic ecology study area include:

- The Wash and North Norfolk Coast SAC (Annex I sandbanks and reefs);
- Haisborough, Hammond and Winterton SCI (Annex I sandbanks and reefs);
- North Norfolk Sandbanks and Saturn Reef SCI (Annex I sandbanks and reefs); and
- Klaverbank SCI (Annex I reefs).

Table 2.10: Intertidal biotopes identified during the intertidal walkover survey and from intertidal core samples taken from the Hornsea Three offshore cable corridor landfall site, within the Hornsea Three benthic ecology study area (Figure 2.6).

Biotope code	Biotope description	Geographic location
LS.LSa.St (St) Strandline	The driftline consisted of decomposing bryozoan colonies, brown seaweed (*Fucus* spp.), reeds, feathers and twigs. A community of sandhoppers (including talitrid amphipods) is often associated with driftline debris as it provides suitable cover and humidity. However sandhoppers were not observed on the shingle substrate at the Hornsea Three landfall area.	This biotope was recorded in the upper shore, between 3 and 30 m from the back of the beach.
LS.LCS.Sh.BarSh (BarSh) Barren littoral coarse shingle	This biotope extended over the whole shore at Weybourne, Salthouse and between these locations. Sediment comprised mostly shingle, of pebble or cobble dimension, according to the Wentworth classification system, with some gravel. Gravel was generally limited to the lower shore in association with cusp features and transitions to areas of fine sand. No faunal species were recorded within this biotope.	This biotope, which was present on the upper, mid and lower shore, dominated the landfall between the MHWS and MLWS.
LS.LSa.FiSa (FiSa) Polychaete / amphipod dominated fine sand shores	Sediments comprised clean, fine to medium sand. Fine sand shores usually support a range of species including amphipods and polychaetes; dig-over samples revealed gammarid amphipods with abundances of between 25 and 50 per m^2. No other fauna were recorded.	This biotope was generally located close to the MLWS in the east of the Hornsea Landfall area and as a mosaic with BarSh in beach cusp features in the west.
LH.HLR.MusB (MusB) Mussels and/or barnacle communities	Communities of this classification are typically dominated by mussels and/or barnacles comprising *Chthamalus* spp. and/or *Semibalanus balanoides*. This biotope was observed in association with an iron outfall pipe and support structure at Weybourne, in a 1.5 m high band of encrusting barnacle growth, in conjunction with green algae, Ulva spp., 1.5 m above the low water mark. No other faunal species were evident.	This minor biotope was associated with the outfall pipe in the mid to lower shore at Weybourne in the east of the Hornsea Three landfall area.

2.7.3.3 The only Natura 2000 site considered in the assessment is the North Norfolk Sandbanks and Saturn Reef SCI site. While the offshore cable corridor does coincide with a small section of the Wash and North Norfolk Coast SAC (see Figure 2.1), most of the qualifying features of this SAC (e.g. Mudflats and sandflats not covered by seawater at low tide, Salicornia and other annuals colonising mud and sand, Atlantic salt meadows) are intertidal habitats and occur within the Wash. Of those with the potential to occur in subtidal areas, e.g. reefs and sandbanks which are slightly covered by sea water at all time, these also occur closer to the Wash, with no evidence of these habitats occurring in site-specific surveys of the Hornsea Three offshore cable corridor to date. The other Natura 2000 sites are at least 10 km away and therefore, like the features of the Wash and North Norfolk Coasts SAC, are only likely to be affected by increased suspended sediments. However, as discussed in paragraph 2.11.1.45, the maximum predicted concentrations of suspended sediments are predicted to fall to near background levels within hundreds of metres/several kilometres, therefore Haisborough, Hammond and Winterton SCI site and Klaverbank SCI site are unlikely to be impacted by Hornsea Three. The Klaverbank SCI site is further discussed in section 2.14 in the context of transboundary effects.

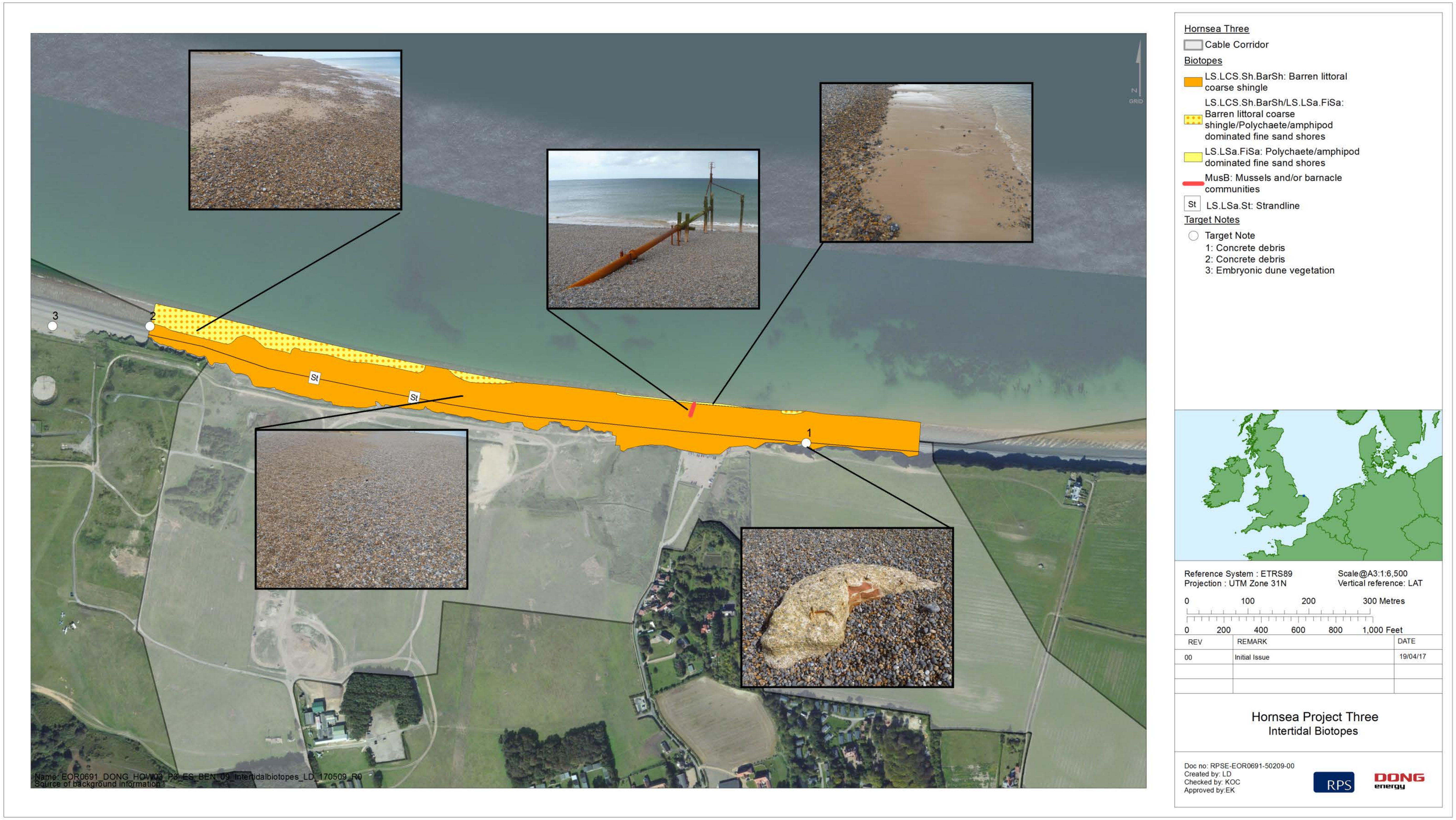

Figure 2.6: Intertidal biotopes at the Hornsea Three offshore cable corridor landfall site area at Weybourne and Salthouse, within the Hornsea Three benthic ecology study area.

National designations

2.7.3.4 The MCZ and proposed rMCZs in close proximity to Hornsea Three benthic ecology study area include:

- Cromer Shoal Chalk Beds MCZ (subtidal chalk, clay and peat exposures, subtidal coarse sediments, subtidal mixed sediments and subtidal sand);
- Markham's Triangle rMCZ (subtidal coarse and subtidal sand); and
- Wash Approach rMCZ (subtidal mixed sediments and subtidal sand).

2.7.4 Valued Ecological Receptors

2.7.4.1 The value of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2016). The most straightforward context for assessing ecological value is to identify those species and habitats that have a specific biodiversity importance recognised through international or national legislation or through local, regional or national conservation plans (e.g. Annex I habitats under the EC Habitats Directive, BAP habitats and species, habitats/species of principal importance listed under the Natural Environment and Rural Communities (NERC) Act 2006 and habitats/species listed as features of existing or rMCZs). However, only a very small proportion of marine habitats and species are afforded protection under the existing legislative or policy framework and therefore evaluation must also assess value according to the functional role of the habitat or species. For example, some features may not have a specific conservation value in themselves, but may be functionally linked to a feature of high conservation value. The following table shows the criteria applied to determining the ecological value of VERs within the geographic frame of reference applicable to the Hornsea Three benthic ecology study area (Table 2.11).

2.7.4.2 For the purposes of conducting the EIA, the habitats present across the Hornsea Three benthic ecology study area (including biotopes and Annex I habitats) have been grouped into 11 broad habitat/community types. Together with the species of conservation interest, *A. islandica*, which was found within the Hornsea Three benthic ecology study area, these serve as the 12 VERs against which impacts associated with the construction, operation and maintenance and decommissioning of Hornsea Three have been assessed. As discussed in paragraph 2.7.2.2, no VERs were identified at the Hornsea Three landfall area. As such, no intertidal VERs have been considered in the assessment, instead, the Hornsea Three landfall area has been discussed in general, in relevant impacts within the assessment.

2.7.4.3 The biotopes have been grouped into broad habitat/community types according to the results of the statistical analyses described in volume 5, annex 2.1: Benthic Ecology Technical Report. Habitats with similar physical, biological characteristics (including species complement and richness/diversity) as well as conservation status/interest have been grouped together for the purposes of the EIA. Consideration was also given to the inherent sensitivities of different habitats in assigning the groupings presented in Table 2.12, such that habitats and species with similar vulnerability and recoverability, often as a result of similar broad sediment types and species complements, were grouped together. The overall value of each VER was then assessed using the criteria presented in Table 2.11.

Table 2.11: Criteria used to inform the valuation of ecological receptors in the Hornsea Three benthic ecology study area.

Value of VER	Criteria to define value
International	Internationally designated sites. Habitats and species protected under international law (i.e. Annex I habitats within an SAC boundary).
National	Nationally designated sites. Species protected under national law. Annex I habitats not within an SAC boundary. UK Biodiversity Action Plan (BAP) priority habitats and species, NERC habitats and species of principal importance in England, and Nationally Important Marine Species that have nationally important populations within Hornsea Three benthic ecology study area, particularly in the context of species/habitat that may be rare or threatened in the UK. Habitats and species that are listed as conservation priorities in MCZs and rMCZs.
Regional	UK BAP priority habitats, NERC habitats and species of principal importance in England, or Nationally Important Marine Species that have regionally important populations within the Hornsea Three benthic ecology study area (i.e. are locally widespread and/or abundant). Habitats or species that provide important prey items for other species of conservation or commercial value.
Local	LNRs. Habitats and species which are not protected under conservation legislation form a key component of the benthic ecology within the Hornsea Three benthic ecology study area.

2.7.4.4 Table 2.12 presents the VERs, their conservation status and importance within the Hornsea Three benthic ecology study area, which are presented geographically in Figure 2.7 for subtidal features. Note that the main habitats identified throughout the benthic ecology study area comprised four broad VERs (Habitats A, B, C and D), which are mapped in Figure 2.7, while Habitats E, F, G, H and I are features of conservation interest within the four broad habitat types. As such, impacts relating to areas of habitat loss discuss VERs A to D (unless otherwise specified) and within these areas VERs E to I are discussed in further detail where relevant. VERs J and K will be shown in Figure 2.7 in the final EIA once these features have been surveyed in the Hornsea Three offshore cable corridor within the Cromer Shoal Chalk Beds MCZ, in Quarter Two 2017. The VER extents are shown for the Hornsea Three benthic ecology study area, rather than just Hornsea Three, as this is considered to put the distribution of these habitats in to context. Figure 2.7 highlights that, while Hornsea Three will have impacts on the VERs in the Hornsea Three area, these habitats types are actually extensive in this part of the North Sea.

Table 2.12: Criteria Valued ecological receptors (VERs) within the Hornsea Three benthic ecology study area, their conservation status and importance.

VER	Representative infaunal and/or epifaunal biotopes	Protection status	Conservation Interest	Importance within Hornsea Three benthic ecology study area and justification
Habitat A: Sandy sediments with low infaunal diversity and sparse epibenthic communities (Figure 2.7).	IMoSa, IMuSa, NcirBat, FfabMag, EpusOborApri, ApriBatPo and ScupHyd (where present as an epifaunal overlay in small areas of the EpusOborApri biotope).	None	UK BAP priority habitat.	Regional – UK BAP with nationally important populations close to the Hornsea Three benthic ecology study area.
Habitat B: Brittlestar dominated communities in deep muddy sands (Figure 2.7).	AfilMysAnit	None	UK BAP priority habitat.	Regional – although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Habitat C: Coarse and mixed sediments with moderate to high infaunal diversity and scour tolerant epibenthic communities (Figure 2.7).	MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd, FluHyd.	None	UK BAP priority habitat. 'Subtidal sands and gravels' is a habitat Feature of Conservation Interest (FOCI) under the Nature Conservation part (Part 5) of the MACAA 2009.	Regional – although this habitat is representative of a nationally important marine habitat, the southern North Sea is not a key geographic area.
Habitat D: Mixed sediments with high infaunal and epifaunal diversity (Figure 2.7).	SspiMx, PKef, Sspi.ByB.	None	Not applicable	Regional - Habitats or species that provide important prey items for other species of conservation or commercial value.
Habitat E: Annex I 'Sandbanks' within an SAC (see Figure 3.5 in volume 5, annex 2.1: Benthic Ecology Technical Report).	N/A	Annex I Habitats Directive	Annex I 'Sandbanks which are slightly covered by seawater all the time' within an SAC. UK BAP priority habitat.	International – part of European designated sites (i.e. North Norfolk Sandbanks and Saturn Reef SCI, the Wash and North Norfolk Coast SAC and Haisborough, Hammond and Winterton SCI).
Habitat F: Annex I reefs within an SAC (see Figure 3.5 in volume 5, annex 2.1: Benthic Ecology Technical Report).	SspiMx, Sspi.ByB	Annex I Habitats Directive	Annex I reefs within an SAC. OSPAR habitat: Sabellaria spinulosa reefs. UK BAP priority habitat.	International – part of European designated sites (i.e. North Norfolk Sandbanks and Saturn Reef SCI, the Wash and North Norfolk Coast SAC and Haisborough, Hammond and Winterton SCI).
Habitat G: Subtidal coarse sediments within an MCZ or rMCZ (equivalent to Habitat C, but within an MCZ or rMCZ) (Figure 2.7).	MedLumVen/EpusOborApri, MedLumVen, MoeVen, MysThyMx, PoVen, ScupHyd, FluHyd.	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ. Also includes seafloor features for which Markham's Triangle rMCZ has been proposed for designation.
Habitat H: Subtidal sandy sediments within an MCZ or rMCZ (equivalent to Habitat A, but within an MCZ or rMCZ) (Figure 2.7).	IMoSa, IMuSa, NcirBat, FfabMag, EpusOborApri, ApriBatPo and ScupHyd (where present as an epifaunal overlay in small areas of the EpusOborApri biotope).	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ. Also includes seafloor features for which Markham's Triangle rMCZ has been proposed for designation.
Habitat I: Subtidal mixed sediments within an MCZ or rMCZ (equivalent to Habitat D, but within an MCZ or rMCZ) (Figure 2.7).	SspiMx, PKef, Sspi.ByB.	MCZ	Protected feature within the Cromer Shoal Chalk Beds MCZ.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Habitat J: Subtidal chalk (see Figure 3.3 in volume 5, annex 2.1: Benthic Ecology Technical Report).	N/A	Annex I Habitats Directive MCZ	Annex I 'Reefs'. UK BAP priority habitat. Protected feature within the Cromer Shoal Chalk Beds MCZ. 'Subtidal chalk' is a habitat FOCI under the Nature Conservation part (Part 5) of the MACAA 2009.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Habitat K: Peat and clay exposures (see Figure 3.3 in volume 5, annex 2.1: Benthic Ecology Technical Report).	N/A	MCZ	UK BAP priority habitat. Protected feature within the Cromer Shoal Chalk Beds MCZ.	National – included as a protected feature within the Cromer Shoal Chalk Beds MCZ.
Species L: Ocean quahog *Arctica islandica.*	N/A	None	OSPAR List of threatened and/or declining species for the Greater North Sea (OSPAR Region II). FOCI under the Nature Conservation part (Part 5) of the MACAA 2009.	National – UK BAP with nationally important populations close to the Hornsea Three benthic ecology study area.

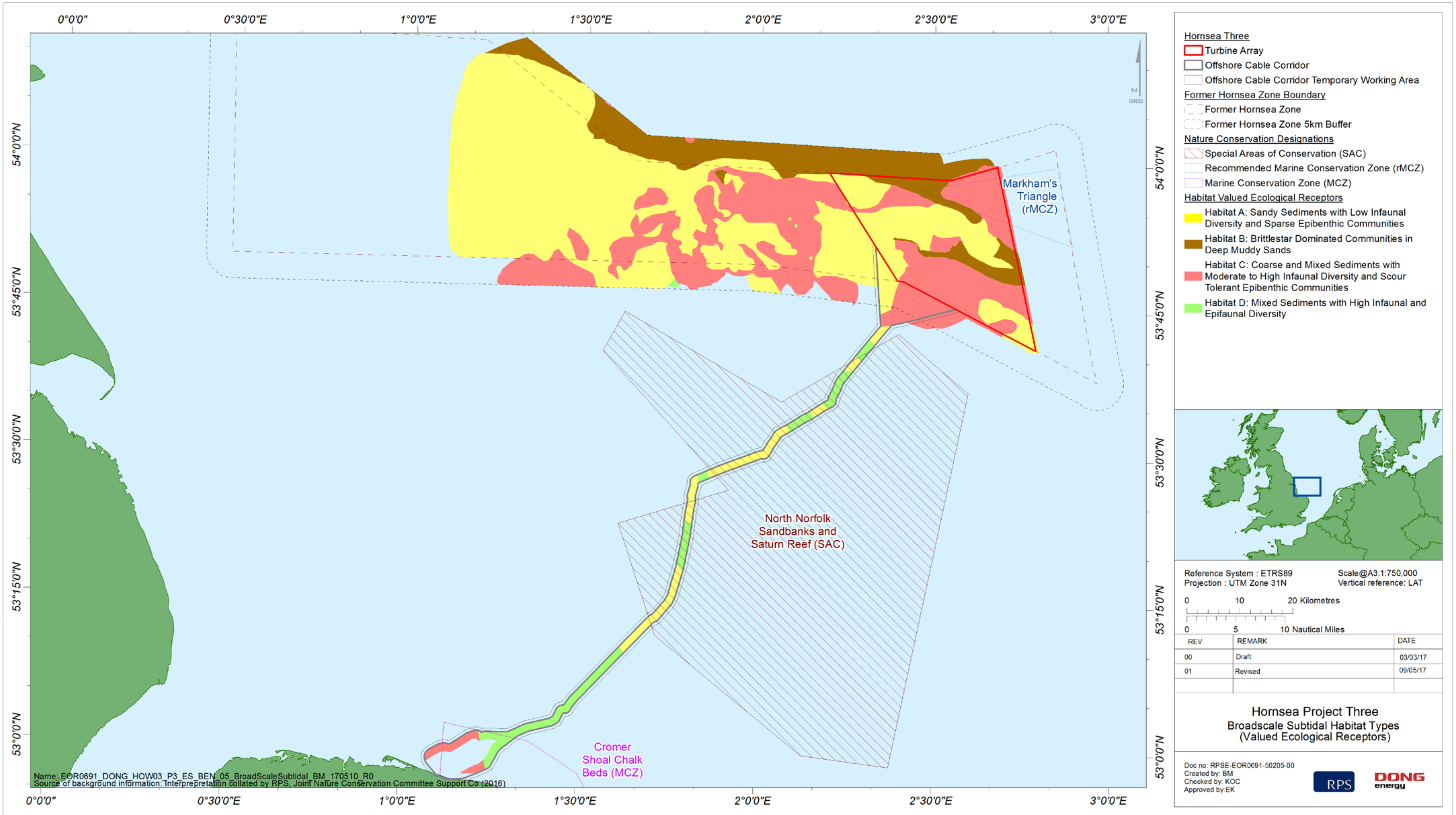

Figure 2.7: Wide scale Subtidal Valued Ecological Receptors (VERs) in the Hornsea Three benthic ecology study area. Note: as detailed in Table 2.12, Habitats A (sand sediment), C (coarse sediment) and D (mixed sediment), where these occur within an MCZ or rMCZ are equivalent to Habitats H, G and I, respectively.

2.7.5 Future baseline scenario

2.7.5.1 The baseline environment is not static and will exhibit some degree of natural change over time, with or without Hornsea Three in place, due to naturally occurring cycles and processes. Therefore, when undertaking impact assessments, it will be necessary to place any potential impacts in the context of the envelope of change that might occur naturally over the timescale of the project.

2.7.5.2 Further to potential change associated with existing cycles and processes, it is necessary to take account of potential effects of climate change on the marine environment. Variability and long-term changes on physical influences may bring direct and indirect changes to benthic habitats and communities in the mid to long term future (UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3), 2016). A strong base of evidence indicates that long-term changes in the benthic ecology may be related to long-term changes in the climate or in nutrients (OESEA3, 2016), with climatic process driving shifts in abundances and species composition of benthic communities (Marine Climate Change Impacts Partnership (MCCIP), 2015). Studies of the benthic ecology over the last three decades have shown that biomass has increased by at least 250 to 400%; opportunistic and short-lived species have increased; and long-living sessile animals have decreased (Krönke, 1995; Krönke, 2011). Modelling sea surface temperature in relation to climate change in the UK has shown that the rate of temperature increase over the previous 50 years has been greater in waters off the east coast of the UK compared to the west and this is predicted to continue for the next 50 years (MCCIP, 2013). As such, the baseline in the Hornsea Three study area described in paragraphs 2.7.1.1 to 2.7.4.4 is a 'snapshot' of the present benthic ecosystem within a gradual yet continuously changing environment. Any changes that may occur during the 25 year design life span of Hornsea Three should be considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment.

2.7.6 Data limitations

2.7.6.1 In contrast to the Hornsea Three array area, no pre-existing survey data from Hornsea Project One and Project Two were available for the Hornsea Three offshore cable corridor. Therefore the baseline characterisation of the Hornsea Three offshore cable corridor within this PEIR has primarily drawn upon the site-specific survey completed in 2016 and desktop information from third-party surveys, including surveys targeting areas within and in close proximity to areas designated for nature conservation. A further site-specific survey of the Hornsea Three offshore cable corridor is planned for Quarter Two 2017, as described in 2.6.4.3. Together with the existing data, the results will be used to update the Hornsea Three benthic ecology baseline characterisation for the Hornsea Three offshore cable corridor in the Environmental Statement.

2.7.6.2 Although the sampling design and collection process for the survey data analysed provided robust data on the benthic communities present, interpreting these data by classifying and grading biotopes has three main limitations:

- It is often difficult to interpolate data collected from discrete sample locations to cover the whole Hornsea Three benthic ecology study area and to define the precise extent of each biotope, even with site-specific geophysical data;
- Benthic communities generally show a transition from one biotope to another and therefore, boundaries of where one biotope ends and the next begins cannot be defined with absolute precision; and
- The classification of the community data into biotopes is not always straightforward, as some communities do not readily fit the available descriptions in the biotope classification system.

2.7.6.3 As a consequence of the limitations described above, the biotope map should not be interpreted as definitive areas; rather it should be used to describe the main habitats which characterised the Hornsea Three benthic ecology study area that have been used to identify the VERs, described in Table 2.12.

2.7.6.4 As described in paragraph 2.7.4.3 habitats with similar overall general ecology, species assemblages and sensitivities have been grouped together as VERs. Therefore any uncertainties in individual biotope codes assigned to certain sites will not affect the certainty of the overall impact assessment.

2.8 Key parameters for assessment

2.8.1 Maximum design scenario

2.8.1.1 The maximum design scenarios identified in Table 2.13 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (volume 1, chapter 3: Project Description). Effects of greater significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

2.8.2 Impacts scoped out of the assessment

2.8.2.1 No impacts have been scoped out of the assessment.

Table 2.13: Maximum design scenario considered for the assessment of potential impacts on benthic ecology.

<table>
<tr><th>Potential impact</th><th>Maximum design scenario</th><th>Justification</th></tr>
<tr><td colspan="3">Construction phase</td></tr>
<tr><td>Temporary habitat loss/disturbance due to cable laying operations (including anchor placements and sandwave clearance), spud-can leg impacts from jack-up operations and seabed preparation works for gravity base foundations (GBFs), may affect benthic ecology.</td><td>Total subtidal temporary habitat loss of up to 31,728,118 m² and total intertidal temporary habitat loss of up to 271,914 m² comprising the following:
Hornsea Three array area - Foundations
736,440 m² temporary loss due to jack-up barge deployments for foundations for up to 361 structures (maximum design scenario assumes up to 342 7 MW turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three offshore accommodation platforms) assuming six spud cans per barge, 170 m² seabed area affected per spud can and two jack up operations per turbine (361 foundations x 6 spud cans x 170 m² per spud can x 2 jack ups);
Up to a total of 4,351,094 m² of spoil from placement of coarse dredged material to a uniform thickness of 0.5 m (see justification, right) as a result of seabed preparation works prior to the installation of all GBFs. Comprising:
• 1,289,682 m³ (3,771 m³ x 342) from up 342 WTG foundation installation (2,579,364 m²);
• 735,000 m³ (61,250 m³ x 12) from up to 12 HVAC collector substations (1,470,000 m²);
• 139,552 m³ (34,888 m³ x 4) from up to four HVDC substations (279,104 m²); and
• 11,313 m³ (3,771 m³ x 3) from up to three accommodation platforms (22,626 m²).
Hornsea Three array area - Cables
8,500,000 m² from burial of up to 850 km of array cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m wide corridor).
2,250,000 m² from burial of up to 225 km of substation interconnector cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m corridor).
Up to a total of 163,222 m² from sandwave clearance activities for inter array and substation interconnector cables (30 m wide corridor in these areas).
Up to a total of 336,650 m² from placement of coarse dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance within the Hornsea Three array, assuming a volume of up to 168,325 m³, placed on the seabed within the array.
215,000 m² from cable barge anchor placement associated with inter array and substation interconnector cable laying assuming: one anchor (footprint 100 m²) repositioned every 500 m ((850,000 m + 225,000) x 1 x 100 m² / 500 m =215,000 m²).
Offshore cable corridor - Subtidal
14,460,000 m² from burial of up to 1,038 km of export cable (up to six trenches of 173 km length) by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development augmented by mobile sediment clearance and cable protection installation; up to 10 m width of seabed or 30 m for the 34 km of sandwaves along the offshore cable corridor).
Up to a total of 364,112 m² from placement of coarse, dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance on the offshore cable corridor, assuming a volume of up to 182,056 m³, placed on the seabed within the Hornsea Three offshore cable corridor.
351,600 m² from cable barge anchor placement associated with cable laying for all subtidal export cables broken down as follows:
• First 20 km of the offshore cable corridor: Up to seven anchors (footprint of 100 m² each) repositioned every 500 m for up to 6 export cables (20,000 m x 7 x 100 m² x 6 / 500 m = 168,000 m²); and
• Export cables beyond 20 km: one anchor (footprint of 100 m²) repositioned every 500 m for up to 6 export cables ((173,000 m – 20,000) x 1 x 100 m² x 6 / 500 m = 183,600 m²).
Offshore cable corridor - Intertidal
43,363 m² from works to bury up to 500 m of cable length (from MHWS to MLWS) with up to six cable circuits (i.e. up to 3 km of export cable in the intertidal) by trenching (assuming habitat loss/disturbance within the entire corridor width). Some limited habitat loss/disturbance may also occur within the intertidal temporary working areas either side of the intertidal cable corridor (228,551 m²) due to activities such as vehicle movements, anchor placement and the purposeful grounding of the cable laying barge.
Construction phase lasting up to 11 years over two phases, with a gap of up to 6 years between the same activity between phases.</td><td>The maximum design scenario presented is associated with HVDC transmission due to the larger foundation sizes associated with the offshore HVDC substations compared to the HVAC booster stations.
Seabed preparation works prior to gravity base installation represents the maximum design scenario, with respect to spatial extent, for temporary habitat loss, compared to the temporary habitat loss associated with drill arisings resulting from jacket foundation installation.
The area affected by the placement of material as a result of seabed preparation and sandwave clearance has been calculated based on the maximum volume of sediment placed across the entire Hornsea Three array, assuming all this sediment is coarse material and therefore is placed on the seabed (i.e. is not dispersed through tidal currents; see "Temporary increases in suspended sediment concentrations" impact assessment below). The total area of seabed affected was calculated assuming a mound of uniform thickness of 0.5 m height. As detailed in volume 5, annex 1.1: Marine Processes Technical Report, the area of seabed affected by this scenario broadly aligns with the scenario of a cone shaped mound of 1.7 m maximum height (see Table 4.24 of volume 5, annex 1.1). Temporary loss of benthic habitat is assumed beneath this within the Hornsea Three array.
The maximum design scenario for temporary habitat loss has considered the burial of all subtidal cables, except where the necessary burial depth cannot be achieved.
Temporary habitat loss within the entire offshore cable corridor and temporary working area at the landfall has been considered as the maximum design scenario (including anchor placements), though direct impacts (i.e. excavation) will only occur within a proportion of these areas.</td></tr>
</table>

Potential impact	Maximum design scenario	Justification
Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.	*Drilling operations for foundation installation: Greatest sediment disturbance from a single foundation location* Total sediment volume of 581,611 m^3 (113,104 + 253,338 + 193,962 + 21,207), comprising: 113,104 m^3 total spoil volume, from largest turbine monopile foundations (up to 160 monopiles), associated diameter 15 m, drilling to 40 m penetration depth, spoil volume per foundation 7,069 m^3, up to 10% of foundations may be drilled (160 x 10% x 7,069 m^3 = 113,104 m^3). 253,338 m^3 total spoil volume from largest offshore High Voltage Alternating Current (HVAC) collector substation piled jacket foundations (up to 12 foundations), 24 piles per foundation (six legs, four piles per leg), 4 m diameter, drilling to 70m penetration depth, spoil volume per foundation 21,112 m^3, up to 100% of foundations may be drilled (12 x 21,112 m^3 = 253,338 m^3). 193,962 m^3 total spoil volume from the largest offshore High Voltage Direct Current (HVDC) converter substation piled jacket foundations (up to four foundations), 72 piles per foundation (18 legs, four piles per leg), 3.5 m diameter, drilling to 70m penetration depth, spoil volume per foundation 48,490 m^3, up to 100% of foundations may be drilled (4 x 48,490 m^3 = 193,962 m^3). 21,207 m^3 total spoil volume from the largest offshore accommodation platform monopile foundations (up to 3 monopiles), associated diameter 15 m, drilling to 40 m penetration depth, spoil volume per foundation 7,069 m^3, up to 100% of foundations may be drilled (3 x 7,069 m^3 = 21,207 m^3). Up to two foundations may be simultaneously drilled, minimum spacing 1,000 m. Disposal of drill arisings at water surface. Construction phase lasting up to 11 years over two phases, with a gap of up to 6 years between the same activity between phases.	Drilling of individual turbine monopile foundations results in the release of relatively larger volumes of relatively fine sediment, at relatively lower rates (e.g. potentially leading to SSC effects over a wider area or longer duration), than similar potential impacts for bed preparation via dredging for individual gravity base foundations (which are separately assessed). The greatest volume of sediment disturbance by drilling, for both individual foundations and for the array as a whole, is associated with the largest diameter monopile and piled jacket foundations for substations in the array area. The volume of sediment released through drilling of other turbine and offshore accommodation platform foundation types (e.g. piled jackets) is smaller than for monopiles. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option.
	Dredging for seabed preparation for foundation installation: Greatest sediment disturbance from a single foundation location Total sediment volume of 1,827,287 m^3 (935,200 + 735,000 + 139,552 + 17,535), comprising: 935,000 m^3 total spoil volume from largest turbine gravity base foundation (up to 160 gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m), spoil volume per foundation 5,845 m^3 (160 x 5,845 = 935,000 m^3). 735,000 m^3 total spoil volume from largest offshore HVAC collector substation gravity base foundation (up to 12 gravity base foundations), associated base dimensions 75 m, associated bed preparation area dimensions 175 m, average depth 2 m, spoil volume per foundation 61,250 m^3 (12 x 61,250 m^3 = 735,000 m^3). 139,552 m^3 total spoil volume from largest offshore HVDC converter substation gravity base foundation (up to four gravity base foundations), associated base dimensions 90 x 170 m, associated bed preparation area dimensions 98 x 178 m, average depth 2 m, spoil volume per foundation 34,888 m^3 (4 x 34,888 m^3 = 139,552 m^3). 17,535 m^3 total spoil volume from largest offshore accommodation platform gravity base foundation (up to three gravity base foundations), associated base diameter 53 m, associated bed preparation area diameter 61 m, average depth 2 m), spoil volume per foundation 5,845 m^3 (3 x 5,845 m^3 = 17,535 m^3). Disposal of material on the seabed within Hornsea Three. Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal). Up to 2 dredgers to be working simultaneously, minimum spacing 1,000 m. Construction phase lasting up to 11 years over two phases, with a gap of up to 6 years between the same activity between phases.	Dredging as part of seabed preparation for individual gravity base foundations results in the release of relatively smaller overall volumes of relatively coarser sediment, at relatively higher rates (e.g. leading to higher concentrations over a more restricted area), than similar potential impacts for drilling of individual monopile or piled jacket foundations (which are separately assessed above). The greatest sediment disturbance from a single gravity base foundation location is associated with the largest diameter or dimension gravity base foundation, which results in the greatest volume of spoil from a single foundation. Due to differences in both scale and number, gravity base foundations for turbines, electrical substations and offshore accommodation platforms are separately considered. The HVDC transmission system option (up to12 offshore HVAC collector substations and up to four offshore HVDC converter substations) results in the largest number of offshore substation foundations and the largest total volume of associated sediment disturbance in the array area compared to the HVAC transmission system option. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations for foundation installation. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss.
	Cable Installation Total sediment volume of 13,026,381 m^3 5,100,000 + 168,325 + 1,350,000 + 6,226,000 + 182,056), comprising: Array cables • Installation method: mass flow excavator; • Total length 850 km; • 5,100,000 m^3 total spoil volume from installation of up to 850 km cables in a V-shape trench of width = 6 m and depth =2 m (850 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 5,100,000 m^3); and • 168,325 m^3 total spoil volume from sand wave clearance by dredging or mass flow excavation within the Hornsea Three array area (based on the Hornsea Three array area geophysical survey data combined with cable installation design specifications).	Cable installation may involve ploughing, trenching, jetting, rock-cutting, surface laying with post lay burial, and/or surface laying installation techniques. Of these, mass flow excavation will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum design scenario for sediment dispersion. The volume of material to be cleared from individual sandwaves will vary according to the local dimensions of the sandwave (height, length and shape) and the level to which the sandwave must be reduced (also accounting for stable sediment slope angles and the capabilities and requirements of the cable burial tool being used). Based on the available geophysical data, the bedforms requiring clearance are likely to be in the range 1 to 2 height in the array or 1 to 6 m in height in the offshore cable corridor.

Potential impact	Maximum design scenario	Justification
	Substation interconnector cables • Installation method: mass flow excavator; • 15 in-project cables, total length 225 km; and • 1,350,000 m³ total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (225 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 1,350,000 m³). Export cables • Up to six cable trenches; each 173 km in length (1,038 km in total); • Installation method: mass flow excavator; • 6,226,000 m³ total spoil volume from installation of up to 225 km cables in a V-shape trench of width = 6 m and depth =2 m (6 x 173 km x 6 m x 2 m x 0.5 (i.e. to account for V-shape of trench) = 6,226,000 m³); and • 182,056 m³ total spoil volume from sandwave clearance via either a dredger or mass flow excavator within the Hornsea Three offshore cable corridor (based on the Hornsea Three offshore cable corridor geophysical survey data combined with cable installation design specifications). Construction phase lasting up to 11 years over two phases, with a gap of up to 6 years between the same activity between phases.	Sandwave clearance may involve dredging or mass flow excavation tools. Of these, mass flow excavation will most energetically disturb sediment in the clearance profile and as such is considered to be the maximum design scenario for sediment dispersion causing elevated SSC over more than a very short period of time. Dredging will result in a potentially greater instantaneous local effect in terms of SSC and potentially a greater local thickness of sediment deposition, but likely of a shorter duration and smaller extent, respectively. Note: this assessment considers effects on benthic ecology from a passive plume (i.e. sediments transported via tidal currents) during dredging and disposal operations. Placements of coarse dredged materials during dredge disposal are considered in temporary habitat loss.
Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology.	Seabed disturbance arising from installation of foundations and cables as described above for temporary increases in suspended sediments (Cable Installation - Export cables only).	This scenario represents the maximum design scenario for offshore cable corridor installation and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities. Potential impacts of release of contaminants were scoped out for the Hornsea Three Array.
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Synthetic compound (e.g. from antifouling biocides), heavy metal and hydrocarbon contamination resulting from offshore infrastructure installation and up to 11,566 vessel movements during the construction phase: • 4,446 vessel movements over construction period based on gravity base foundations (self-installing concept); • Up to 3,420 vessel movements over construction period for WTG installation; • Up to 304 vessel movements over construction period for substations; • Up to 2,856 vessel movements over construction period for array cables; and • Up to 540 vessel movements over construction period for export cable. Water-based drilling muds associated with drilling to install foundations, should this be required. A typical offshore accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates. Offshore fuel storage tanks: • One tank on each of the up to three offshore accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across the entire wind farm; and • One on each of the up to three offshore accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000 l.	These parameters are considered to represent the likely maximum design scenario with regards to vessel movements during construction and the offshore storage of fuel.
Operation phase		
Long term loss of seabed habitat through presence of foundations, scour protection and cable protection, resulting in potential effects on benthic receptors.	Long term habitat loss of up to a total of 4,256,010 m² comprising the following: *Hornsea Three Array area – Foundations* Up to a total of 1,762,326 m² across the entire Hornsea Three array from GBFs (including scour protection) for up to 342 7 MW turbines, each affecting up to 5,153 m² of seabed; Up to a total of 158,700 m² from box GBFs (including scour protection) for up to 12 offshore HVAC collector substations, each affecting up to 13,225 m² of seabed; Up to a total of 85,884 m² from suction caisson jacket foundations (including scour protection) for up to three offshore accommodation platforms, each affecting up to 28,628 m² of seabed; Up to 109,200 m² from pontoon GBFs (including scour protection) for up to four offshore HVDC substations, each affecting up to 27,300 m² of seabed.	The maximum design scenario presented is associated with HVDC transmission due to the larger foundation sizes associated with the offshore HVDC substations compared to the HVAC booster stations. Maximum design scenario is associated with the installation of gravity based foundations for all turbines, box GBFs for HVAC collector substations, suction caisson jacket foundations for offshore accommodation platforms and pontoon GBFs for four offshore HVDC substations as these foundations have the largest total surface area in contact with the seabed and therefore result in the greatest long term habitat loss. The maximum design scenario also assumes scour protection is required for all foundations. The maximum design scenario for long term habitat loss has considered the use of cable protection (i.e. rock placement) along 10% of the subtidal array

Potential impact	Maximum design scenario	Justification
	Hornsea Three Array area – Cable protection Up to a total of 595,000 m^2 based on installation of cable protection for 10% of the up to 850 km of array cables (i.e. 85 km and 7 m wide cable corridor); Up to a total of 157,500 m^2 based on the installation of cable protection for 10% of the up to 225 km of substation interconnector cables (i.e. 22.5 km and 7 m wide cable corridor). This includes all cable links between HVAC or HVDC substations and offshore accommodation platforms; Up to a total of 39,200 m^2 for cable/pipeline crossings, with up to 14 crossings within the array, each with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m^2. *Offshore Cable Corridor - Cable Protection* Up to a total of 726,600 m^2 based on the installation of cable protection for 10% of the up to 1,038 km of export cable. Assumes up to six cables, and up to 7 m width of cable protection per cable; and Up to a total of 621,600 m^2 for cable/pipeline crossings, with up to 37 crossings, assuming up to six cables, with each crossing having a long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m^2. Cable protection may comprise gravel, concrete mattresses, rock placement, bags filled with gravel, grout or other concrete, artificial fronds or seaweed or bags of grout, concrete, or another substance that cures hard over time.	cables and substation interconnector power cables. The maximum design scenario assumes that 10% of the subtidal export cables will require cable protection (i.e. rock placement).
Colonisation of foundations/cable protection/scour protection may affect benthic ecology and biodiversity.	Total introduced hard substrate of up to 5,694,330 m^2 comprising the following: *Hornsea Three Array area – Foundations* Up to a total of 1,265,313 m^2 from GBFs for 342 turbines, assuming a conical/frustum shape, with a base diameter of 41 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 3,700 m^2. Up to a total of 1,310,886 m^2 of scour protection for 342 GBFs for turbines, with a per foundation scour protection of 3,833 m^2. Up to a total of 144,000 m^2 from Box GBFs for up to 12 offshore HVAC collector substations, each with a length and width of 75 m in a water depth of 40 m, giving a per foundation surface area of approximately 12,000 m^2. Up to a total of 91,200 m^2 of scour protection for 12 offshore HVAC collector substations, with a per foundation scour protection of 7,600 m^2. Up to a total of 174,400 m^2 from Pontoon GBFs (Type 1) for up to four offshore HVDC substations, with three pontoons per foundation and each pontoon having a length of up to 170 m and width of up to 35 m in a water depth of 40 m, giving a per foundation surface area of approximately 43,600 m^2. Up to a total of 37,800 m^2 of scour protection for four offshore HVDC substations, with a per foundation scour protection of 9,450 m^2. Up to a total of 12,079 m^2 from GBFs for three offshore accommodation platforms, assuming a conical/frustum shape, with a base diameter of 45 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 4,026 m^2. Up to a total of 12,252 m^2 of scour protection for three offshore accommodation platforms, with a per foundation scour protection of 4,084 m^2. *Hornsea Three Array area – Cable protection* Up to a total of 930,612 m^2 from the installation of cable protection for 10% of the up to 850 km of array cables and up to 225 km substation interconnector cables. Assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m^2. Up to a total of 48,478 m^2 from installation of cable protection for 12 cable/pipeline crossings within the array. Each crossing will be of 400 m length each and assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m^2. *Offshore Cable Corridor - Cable Protection* Up to a total of 898,581 m^2 from the installation of cable protection for 10% of the up to 1,038 km of export cables. Assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m^2. Up to a total of 768,729 m^2 from installation of cable protection for up to 37 cable/pipeline crossings along the offshore cable corridor. Each crossing will be of 400 m length each and assumes an up to 7 m wide cable corridor, cable protection to an indicative height of up to 2 m and a berm 3 m wide at the top, giving a per metre surface area of approximately 8.7 m^2.	Maximum surface area created by turbines, substation and offshore accommodation platform foundations, scour protection and surface protection for cables where secondary cable protection is required. This assumes that 10% of inter-array and subtidal export cables require secondary protection. It also assumes no rock placement will be used in the intertidal. For GBFs, this area includes the surfaces of the foundation shaft, cone and base from the seabed to MHWS (i.e. including intertidal habitat).

Potential impact	Maximum design scenario	Justification
Increased risk of introduction or spread of invasive and non-native species (INNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity.	Introduced hard substrate: Maximum design scenario as above for Colonisation of foundations/cable protection/scour protection impact above. Increased risk of introduction or spread of INNS from up to 11,566 vessel movements during the construction phase (see Accidental release of pollutants impact assessment above for breakdown) and up to 2,832 round trips to port by operational and maintenance vessels (including supply/crew vessels and jack-up vessels).	Maximum surface area created by offshore infrastructure as above for Colonisation of foundations/cable protection/scour protection impact. Maximum design scenario with regards to maximum number of vessel movements during operation and maintenance activities.
Alteration of seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic ecology.	*Changes in wave and tidal regime* Largest number of gravity base foundations for turbines (up to 342 of 41 m diameter) and offshore accommodation platforms (up to three of 41 m diameter) and the largest dimensions of gravity base foundation for offshore HVAC collector substations (up to 12 of 75 m length scale) and offshore HVDC converter substations (up to four 75 m length scale) in the array area Largest number of offshore HVAC booster station gravity base foundations (up to four foundations, associated base dimensions 75 m) in the Hornsea Three offshore cable corridor. Minimum spacing of 1,000 m. *Scour effects* Local scour around an individual turbine is greatest for a 15 m diameter monopile foundation. Global scour around an individual turbine foundation is greatest for a piled jacket foundation of 40 m base length. For the Hornsea Three array as a whole, local scour footprint was greatest around an array of 160 x 15 m diameter monopile foundations. For the Hornsea Three array as a whole, the global scour footprint was greatest for an array of 342 x piled jacket foundations of 32 m base diameter.	*Changes in wave and tidal regime* The greatest total in-water column blockage to waves and currents is presented by the greatest number of gravity base foundation foundations in the array area, with at least the minimum spacing between turbines. This combination was determined via calculations that quantitatively compare the blockage presented by a range of minimum and maximum sizes of varying foundation types and numbers (see volume 5, annex 1.1: Marine Processes Technical Annex for details). *Scour effects* The maximum design scenario for scour effects was based on the results of the scour assessment presented in volume 5, annex 1.1: Marine Processes Technical Annex. Each foundation type may produce different scour patterns therefore monopiles, gravity base foundations and jacket foundations were all considered. Suction caissons for jackets and monopiles were not explicitly assessed as they fall within the envelope of change of the other three foundation types.
Maintenance operations may result in temporary seabed disturbances and potential effects on benthic ecology.	Temporary habitat loss/disturbance of up to 2,218,500 m² comprising: A total of up to 87 jack-ups per year over the 25 year design life, assuming six spud cans per jack-up barge and 170 m² seabed area affected per spud can (i.e. 87 x 25 x 6 x170). Preventive maintenance of subsea cables including routine inspections to ensure the cable is buried to an adequate depth and not exposed. The integrity of the cable and cable protection system (i.e., bending restrictors and bend stiffeners) will also be inspected. It is expected that on average the subsea cables will require up to two visits per year for the first three years before being reduced to yearly thereafter. Maintenance works to rebury/replace and carry out repair works on subtidal inter-array, substation interconnector and export cables, should this be required.	These parameters are considered to represent the likely maximum design scenario for the requirement for jack-up barge operations for all WTGs and substations for the lifetime of the project. No substantive maintenance works on the export cables at the offshore cable corridor landfall site is anticipated, only access will be required periodically as outlined to inspect the cable and for geophysical surveys. Though the burial depth of the cables will be designed so they will remain buried for the full lifetime of the project and beyond, it will be necessary to bury the cables if erosion or other natural processes cause them to become exposed. The most appropriate means of reburying any exposed cables will be assessed on an ad-hoc basis but will be no more intrusive than those used during construction.
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Synthetic compound (e.g. from antifouling biocides), heavy metal and hydrocarbon contamination resulting from up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations (or up to four offshore HVAC booster stations on the offshore cable corridor) and up to three offshore accommodation platforms. Accidental pollution may also result from offshore refuelling for crew vessels and helicopters: i.e. up to 2,832 round trips to port by operational and maintenance vessels (including supply/crew vessels and jack-up vessels) and up to 25,234 round trips by helicopter per year over the 25 year design life. A typical 7 MW turbine is likely to contain approximately 1,300 l of grease, 20,000 l of hydraulic oil and 2,000 l of gear oil, 80,000 l of liquid nitrogen and 7,000 kg of transformer silicon/ester oil, 2,000 l of diesel and 13,000 l of coolant. A typical offshore accommodation platform is likely to contain up to 10,000 l of coolant, up to 10,000 l of hydraulic oil and up to 3,500 kg of lubricates. Offshore fuel storage tanks: • One tank on each of the up to three offshore accommodation platforms for helicopter fuel and with a total capacity of up to 255,000 l across the entire wind farm; and • One on each of the up to three offshore accommodation platforms for crew transfer vessel fuel and each with a capacity of 210,000 l. Potential leachate from zinc or aluminium anodes used to provide cathodic protection to the turbines. Potential contamination in the intertidal resulting from machinery use and vehicle movement.	These parameters are considered to represent the maximum design scenario with regards to maximum number of turbines, vessel and vehicle movements, and machinery required, and therefore the maximum volumes of potential contaminants carried during operation and maintenance activities.

Potential impact	Maximum design scenario	Justification
Decommissioning phase		
Temporary loss of habitat due to operations to remove inter-array cables, substation interconnector cables and export cables, and jack-up operations to remove foundations, resulting in potential effects on benthic ecology.	Total subtidal temporary habitat loss of up to 27,377,024m² and total intertidal temporary habitat loss of up to 271,914 m² comprising the following: *Hornsea Three array area - Foundations* Temporary habitat loss as per construction phase, but excluding seabed preparation works, i.e.: 736,440 m² due to jack-up barge deployments for removal of foundations for up to 361 structures (maximum design scenario assumes up to 342 7 MW turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations and up to three offshore accommodation platforms) assuming six spud cans per barge, 170 m² seabed area affected per spud can and two jack up operations per turbine (361 foundations x 6 spud cans x 170 m² per spud can x 2 jack ups). *Hornsea Three array area - Cables* 8,500,000 m² from removal of up to 850 km of array cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m wide corridor); 2,250,000 m² from removal of up to 225 km of substation interconnector cables, by trenching, jetting, mass flow excavator, ploughing or vertical injection and similar tools currently under development (up to 10 m corridor); Up to a total of 163,222 m² from sandwave clearance activities for inter array and substation interconnector cables (30 m wide corridor in these areas). Up to a total of 336,650 m² from placement of coarse dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance within the Hornsea Three array, assuming a volume of up to 168,325 m³, placed on the seabed within the array. 215,000 m² from cable barge anchor placement associated with inter array and substation interconnector cable laying assuming: one anchor (footprint 100 m²) repositioned every 500 m ((850,000 m + 225,000) x 1 x 100 m² / 500 m =215,000 m²). *Offshore cable corridor - Subtidal* 14,460,000 m² from removal of up to 1,038 km of export cable (up to six trenches of 173 km length) by trenching, jetting, mass flow excavator or vertical injection and similar tools currently under development augmented by mobile sediment clearance and cable protection installation (up to 10 m width of seabed or 30 m for the 34 km of sandwaves along the offshore cable corridor). Up to a total of 364,112 m² from placement of coarse, dredged material to a uniform thickness of 0.5 m as a result of sandwave clearance on the offshore cable corridor, assuming a volume of up to 182,056 m³, placed on the seabed within the Hornsea Three offshore cable corridor. 351,600 m² from cable barge anchor placement associated with cable laying for all subtidal export cables broken down as follows: • First 20 km of offshore cable corridor: Up to seven anchors (footprint of 100 m² each) repositioned every 500 m for up to 6 export cables (20,000 m x 7 x 100 m² x 6 / 500 m = 168,000 m²); and • Export cables beyond 20 km: one anchor (footprint of 100 m²) repositioned every 500 m for up to 6 export cables ((173,000 m – 20,000) x 1 x 100 m² x 6 / 500 m = 183,600 m²). *Offshore cable corridor - Intertidal* 43,363 m² from works to remove up to 500 m of cable length (from MHWS to MLWS) with up to six cable circuits (i.e. up to 3 km of export cable in the intertidal) assuming habitat loss/disturbance within entire corridor width. Some limited habitat loss/disturbance may also occur within the intertidal temporary working areas either side of the intertidal cable corridor (228,551 m²) due to activities such as vehicle movements, anchor placement and the purposeful grounding of vessel (e.g. barge) involved in decommissioning.	Maximum design scenario as per construction phase, excluding seabed preparation works, and assumes the removal of all foundations and all buried subtidal and intertidal cables. Piled foundations would be removed to approximately 2 m below the seabed. The necessity to remove cables will be reviewed at the time, after consideration of the environmental impact of the removal operation and safety of the cables left in situ (see volume 1, chapter 3: Project Description). Therefore, the maximum design scenario has assumed the removal of all cables, although this is likely to be over precautionary.
Temporary increases in suspended sediment concentrations and deposition from removal of array cables, export cables and foundations resulting in potential effects on benthic ecology.	Increases of suspended sediment concentrations and sediment deposition associated with the removal of up to 361 foundations (i.e. up to 342 turbines, up to 12 offshore HVAC collector substations, up to four offshore HVDC substations (or up to four offshore HVAC booster stations on the offshore cable corridor) and up to three offshore accommodation platforms) and up to 2,113 km of inter-array (including substation interconnector cables) and export cables.	Maximum design scenario as per construction phase and assumes the removal of all foundations and all subtidal and intertidal cables.

Potential impact	Maximum design scenario	Justification
Removal of foundations and cable protection leading to loss of species/habitats colonising these structures.	Total removal of up to 1,595,791 m² of hard substrate comprising the following: *Hornsea Three array area - Foundations* Up to a total of 1,265,312 m² from GBFs for 342 turbines, assuming a conical/frustum shape, with a base diameter of 41 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 3,700 m². Up to a total of 144,000 m2 from Box GBFs for up to 12 offshore HVAC collector substations, each with a length and width of 75 m in a water depth of 40 m, giving a per foundation surface area of approximately 12,000 m². Up to a total of 174,400 m² from Pontoon GBFs (Type 1) for up to four offshore HVDC substations, with three pontoons per foundation and each pontoon having a length of up to 170 m and width of up to 35 m in a water depth of 40 m, giving a per foundation surface area of approximately 43,600 m². Up to a total of 12,079 m² from GBFs for three offshore accommodation platforms, assuming a conical/frustum shape, with a base diameter of 45 m and a sea surface diameter of 15 m and a water depth of 40 m, giving a per foundation surface area of approximately 4,026 m².	Maximum design scenario for introduced hard substrate as per operational phase but assuming that scour protection and cable protection will be left in situ.
Permanent habitat loss due to presence of scour/cable protection left in situ post decommissioning, and potential effects on benthic ecology.	Permanent habitat loss/alteration of up to 3,592,038 m² comprising the following: *Hornsea Three array area - Foundations* Up to a total of 1,310,886 m² of scour protection for 342 GBFs for WTGs, with a per foundation scour protection of 3,833 m². Up to a total of 91,200 m² of scour protection for 12 offshore HVAC collector substations, with a per foundation scour protection of 7,600 m². Up to a total of 37,800 m² of scour protection for four offshore HVDC substations, with a per foundation scour protection of 9,450 m². Up to a total of 12,252 m² of scour protection for three offshore accommodation platforms, with a per foundation scour protection of 4,084 m². *Hornsea Three array area - Cables* Up to a total of 595,000 m² based on installation of cable protection for 10% of the up to 850 km of array cables (i.e., 85 km and 7 m wide cable corridor); Up to a total of 157,500 m² based on the installation of cable protection for 10% of the up to 225 km of substation interconnector cables (i.e., 22.5 km and 7 m wide cable corridor). This includes all cable links between HVAC or HVDC substations and offshore accommodation platforms; Up to a total of 39,200 m² for cable/pipeline crossings, with up to 14 crossings within the array, each with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m². *Offshore cable corridor - Subtidal* Up to a total of 726,600 m² based on the installation of cable protection for 10% of the up to 1,038 km of export cable. Assumes up to six cables, and up to 7 m width of cable protection per cable; and Up to a total of 621,600 m² for cable/pipeline crossings, with up to 37 crossings along the offshore cable corridor, assuming up to six cables, with each crossing with long term loss of seabed (i.e. through placement of rock berms across a length of up to 400 m) of up to 2,800 m². Cable protection may comprise gravel, concrete mattresses, rock placement, bags filled with gravel, grout or other concrete, artificial fronds or seaweed or bags of grout, concrete, or another substance that cures hard over time.	Maximum design scenario for long term habitat loss as per operational phase but assuming that foundations will be removed but scour and cable protection will be left in situ.
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Maximum design scenario is identical to that of the construction phase.	Maximum design scenario as per construction phase.

2.9 Impact assessment criteria

2.9.1.1 The criteria for determining the significance of effects is a two stage process that involves defining the sensitivity of the receptors and the magnitude of the impacts. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts. The terms used to define sensitivity and magnitude are based on those used in the Design Manual for Roads and Bridges (DMRB) methodology, which is described in further detail in volume 1, chapter 5: Environmental Impact Assessment Methodology.

2.9.1.2 The benthic ecology assessment has followed this methodology. Specific to the benthic ecology EIA, the following guidance documents will also be considered:

- Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal (CIEEM, 2016);
- Offshore Wind Farms. Guidance note for EIA in respect of the Food and Environmental Protection
- Act 1985 (FEPA) and the Coast Protection Act 1949 (CPA) requirements (Cefas *et al*., 2004);
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008).
- Guidelines for the conduct of benthic studies at aggregate dredging sites (DTLR, 2002).

2.9.1.3 In addition, the benthic ecology assessment has followed the legislative framework as defined by the Infrastructure Planning (Environmental Impact Assessment) Regulations, while also giving due consideration to the Offshore Marine Conservation (Natural Habitats, and c.) Regulations 2007 (Offshore Habitats Regulations) (as amended), the Conservation of Habitats and Species Regulations 2010 (Habitats Regulations) (as amended), the Wildlife and Countryside Act 1981 (as amended) and the MCAA 2009 (as amended).

2.9.1.4 The assessment has also taken into consideration the requirements of the United Nations Environment Programme (UNEP) Convention on Biological Diversity (CBD), in particular those listed under Article 8 of the Convention. Article 8 of the CBD relates to *in-situ* conservation and includes reference to the need to protect areas for nature conservation. Therefore, where necessary, mitigation measures have been designed in to Hornsea Three to ensure the *in-situ* conservation of benthic ecology.

2.9.1.5 The sensitivity of benthic ecology VERs has been defined by an assessment of the combined vulnerability of the receptor to a given impact and the likely rate of recoverability to pre-impact conditions. Vulnerability is defined as the susceptibility of a species to disturbance, damage or death, from a specific external factor. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. It is dependent on its ability to recover or recruit subject to the extent of disturbance/damage incurred. Information on these aspects of sensitivity of the benthic ecology VERs to given impacts has been informed by the best available evidence following environmental impact or experimental manipulation in the field and evidence from analogous activities such as those associated with aggregate extraction and oil and gas industries. These assessments have been combined with the assessed status (i.e. the level of designation/importance) of the affected receptor as defined in Table 2.11 and as presented in Table 2.12.

2.9.1.6 For the benthic ecology VERs being considered in this assessment. The overall sensitivity of a receptor to an impact is then identified from a five point scale as presented in Table 2.14 below.

Table 2.14: Definition of terms relating to the sensitivity of the receptor.

Sensitivity	Definition used in this chapter
Very High	Nationally and internationally important receptors with high vulnerability and no ability for recovery.
High	Regionally important receptors with high vulnerability and no ability for recovery. Nationally and internationally important receptors with high vulnerability and low recoverability.
Medium	Locally important receptors with high vulnerability and no ability for recovery. Regionally important receptors with medium to high vulnerability and low recoverability. Nationally and internationally important receptors with medium vulnerability and medium recoverability.
Low	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium to high recoverability. Nationally and internationally important receptors with low vulnerability and high recoverability.
Negligible	Receptor is not vulnerable to impacts regardless of value/importance. Locally important receptors with low vulnerability and medium to high recoverability.

2.9.1.7 The criteria for defining magnitude in this chapter are outlined in Table 2.15 below.

Table 2.15: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition used in this chapter
Major	The proposal would affect the conservation status of the site or feature, with loss of ecological functionality.
Moderate	The feature's conservation status would not be affected, but the impact is likely to be significant in terms of ecological objectives or populations.
Minor	Minor shift away from baseline but the impact is of limited temporal or physical extent.
Negligible	Very slight change from baseline condition.
No change	No change from baseline conditions.

2.9.1.8 The significance of the effect upon benthic ecology is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 2.16. Where a range of significance of effect is presented in Table 2.16, the final assessment for each effect is based upon expert judgement.

2.9.1.9 For the purposes of this assessment, any effects with a significance level of minor or less have been concluded to be not significant in terms of the EIA Regulations unless otherwise stated.

Table 2.16: Matrix used for the assessment of the significance of the effect.

		Magnitude of impact				
Sensitivity of receptor		*No change*	*Negligible*	*Minor*	*Moderate*	*Major*
	Negligible	Negligible	Negligible	Negligible or minor	Negligible or minor	Minor
	Low	Negligible	Negligible or minor	Negligible or minor	Minor	Minor or moderate
	Medium	Negligible	Negligible or minor	Minor	Moderate	Moderate or major
	High	Negligible	Minor	Minor or moderate	Moderate or major	Major or substantial
	Very high	Negligible	Minor	Moderate or major	Major or substantial	Substantial

2.9.1.10 Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the interest features of internationally designated sites as described within section 2.6.3 of this chapter (with the assessment on the site itself deferred to the Draft Report to Inform Appropriate Assessment for Hornsea Three). With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site (e.g. SSSIs which have not been assessed within the Draft Report to Inform Appropriate Assessment for Hornsea Three), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken).

2.9.1.11 The Draft Report to Inform Appropriate Assessment is currently being prepared in accordance with Advice Note Ten: Habitats Regulations Assessment Relevant to Nationally Significant Infrastructure Projects (PINS, 2016) and will be submitted as part of the Application for Development Consent.

2.9.1.12 Habitats which constitute protected benthic ecology features for which an MCZ has been designated, or which constitute benthic ecology features for which an rMCZ has been recommended, are considered in this chapter. Each site will be fully assessed in the volume 5, annex 2.3: MCZ Assessment.

2.10 Measures adopted as part of Hornsea Thee

2.10.1.1 As part of the project design process, a number of designed-in measures have been proposed to reduce the potential for impacts on benthic ecology (see Table 2.17). This approach has been employed in order to demonstrate commitment to measures by including them in the design of Hornsea Three and have therefore been considered in the assessment presented in section 2.11 below. These measures are considered standard industry practice for this type of development. Assessment of sensitivity, magnitude and therefore significance includes implementation of these measures.

Table 2.17: Designed-in measures adopted as part of Hornsea Three.

Measures adopted as part of Hornsea Three	Justification
Pre-construction surveys will be undertaken along the Hornsea Three offshore cable corridor to identify benthic habitats of conservation, ecological and/or economic importance. Should Annex I reef habitat be identified during pre-construction surveys of the Hornsea Three offshore cable corridor, appropriate mitigation will be discussed with statutory consultees to avoid direct impacts to these features (where appropriate this may include micro-siting). This approach is typical for offshore wind farm and cable developments.	Annex I reefs were not identified at the Hornsea Three array area, *S. spinulosa* aggregations assessed as being 'low reef' identified within the Hornsea Three offshore cable corridor during the site specific survey and *S. spinulosa* are reefs known to occur within this part of the southern North Sea benthic ecology study area. Direct impacts (e.g. habitat loss) to ecologically sensitive Annex I biogenic (e.g. *S. spinulosa*) reefs are to be avoided and given the evidence for the propensity for reef to develop in this area, pre-construction surveys will identify the presence of such reefs and ensure that measures can be designed, if necessary, to avoid direct impacts. Similarly, exposed chalk features, which may be determined as Annex I reefs, are known to be present in the nearshore waters off the coast of north Norfolk. [a] Pre-construction surveys will investigate locations of such habitats and Hornsea Three will continue to investigate the feasibility of avoiding these features as the project progresses.
A CoCP will be developed and implemented to cover the construction phase and an appropriate PEMMP will be produced and followed to cover the operation and maintenance phase of Hornsea Three. The latter will include planning for accidental spills, contain a biosecurity plan to limit the spread of INNS, address all potential contaminant releases and include key emergency contact details (e.g. EA, Natural England and MCA). A Decommissioning Programme will be developed to cover the decommissioning phase.	Measures will be adopted to ensure that the potential for release of pollutants from construction, operation and decommissioning plant is minimised. These will likely include: designated areas for refuelling where spillages can be easily contained; only using chemicals included on the approved Cefas list under the Offshore Chemical Regulations 2002; storage of these in secure designated areas in line with appropriate regulations and guidelines; double skinning of pipes and tanks containing hazardous substances; and storage of these substances in impenetrable bunds. In this manner, the potential for release of contaminants from rigs and supply/service vessels will be strictly controlled, thus providing protection for marine life across all phases of the wind farm development.

a A site specific survey is planned to be undertaken in Quarter Two 2017. This will characterise the chalk features and determine their extent in relation to the Hornsea Three offshore cable corridor, the results of which will inform the Environmental Statement.

2.11 Assessment of significance

2.11.1 Construction phase

2.11.1.1 The impacts of the offshore construction of Hornsea Three have been assessed on benthic ecology. The potential environmental impacts arising from the construction of Hornsea Three are listed in Table 2.13 above along with the maximum design scenario against which each construction phase impact has been assessed.

2.11.1.2 A description of the potential effect on benthic ecology receptors caused by each identified impact is given below.

Temporary habitat loss/disturbance due to cable laying operations (including anchor placements and sandwave clearance), spud-can leg impacts from jack-up operations and seabed preparation works for gravity base foundations (GBFs), may affect benthic ecology.

Magnitude of impact

2.11.1.3 As detailed in Table 2.13 above, direct temporary loss/disturbance of subtidal habitat within Hornsea Three will occur as a result of jack-up barge operations to install foundations, seabed preparation prior to gravity base installation, the burial of inter-array, substation interconnector and export cables and the anchor placements associated with these operations. As described in Table 2.13, for the purposes of the current assessment, coarse, granular material disturbed during seabed preparation and sandwave clearance activities and disposed within Hornsea Three during construction will result in sediment deposition with a uniform depth of 0.5 m. Due to the depth of sediment deposition, this has been considered temporary habitat loss as many benthic species will most likely suffer mortality beneath these areas. It is likely that any mounds of granular material will erode over time, reducing the size of the mounds and as the sediment type deposited to the seabed will be similar to those in surrounding areas, benthic assemblages would be expected to recolonise these areas (discussed further below).

2.11.1.4 The total maximum area of temporary subtidal habitat loss due to construction activities described in Table 2.13 is predicted to be approximately 31,728,118 m^2 (31.73 km^2). This equates to 0.05% of the total seabed area within the southern North Sea benthic ecology study area (64,786 km^2) and 0.86% of the Hornsea Three benthic ecology study area. Activities resulting in the temporary habitat loss of both subtidal and intertidal habitats will occur intermittently throughout the construction period.

2.11.1.5 The total maximum area of intertidal temporary direct habitat loss/disturbance is estimated at approximately 271,914 m^2. This includes the cable corridor and the temporary working area in which all cable laying activity, including plant and machinery movements, excavation of exit pits, anchor placements and purposeful barge grounding will occur (Table 2.13). As no VERs were recorded at the export cable landfall, due to the barren nature of the sediments (see section 2.7.2), the effect of intertidal habitat loss on benthic ecological receptors is not considered further for this impact.

2.11.1.6 Of the total area of temporary habitat loss described in Table 2.13, a maximum of 16,552,406 m^2 is predicted to be temporarily lost/disturbed within the Hornsea Three array as a result of jack-up barge operations, burial of inter-array and substation interconnector cables (including associated anchor placements) and seabed preparation material within the Hornsea Three array. The maximum design scenario for each VER affected by temporary habitat loss is estimated based on a scenario of all this loss occurring wholly within Habitat A (Sandy sediments with low infaunal diversity and sparse epibenthic communities), Habitat B (Brittlestar dominated communities in deep muddy sands) or Habitat C (Coarse and mixed sediments with moderate to high infaunal diversity and scour tolerant epibenthic communities, Table 2.12, Figure 2.7). This would equate to approximately 0.81% of Habitat A within the Hornsea Three benthic ecology study area, approximately 1.58% of Habitat C within the Hornsea Three benthic ecology study area, and approximately 3.26% of Habitat B within the Hornsea Three benthic ecology study area.

2.11.1.7 Of the total temporary habitat loss/disturbance described in Table 2.13, a maximum of 15,175,712 m^2 will be temporarily lost from the subtidal areas of the Hornsea Three offshore cable corridor as a result of cable burial and associated anchor placements and sandwave clearance activities. The release of granular material as a result of sandwave clearance along the Hornsea Three offshore cable corridor is predicted to result in depositions with a uniform thickness of 0.5 m (see Table 2.21) and therefore for the purposes of this assessment, this activity has been assessed as temporary habitat loss. The proposed sandwave clearance activities will result in local displacement of the disturbed sediment volume, which will remain the same sediment type as the surrounding seabed and with no loss of seabed sediments from the local area. In the case of dredging, material will be disposed of in close proximity to the dredge location and will immediately be available again for transport at the naturally occurring rate, with no sediment volume removed from the sandwave systems overall. Due to the dynamic nature of the sandwaves within Hornsea Three, these features are considered to have moderate to high recoverability (see chapter 1: Marine Processes).

2.11.1.8 The patterns of processes governing the overall evolution of the systems (the flow regime, water depths and sediment availability) are at a much larger scale than, and so would not be affected by, the proposed local works. As a result, the proposed clearance is not likely to influence the overall form and function of the system and eventual recovery via natural processes is therefore expected. The rate of recovery would vary in relation to the rate of sediment transport processes, faster infill and recovery rates will be associated with higher local flow speeds and more frequent wave influence (chapter 1: Marine Processes).

2.11.1.9 The maximum potential losses of each VER affected within the Hornsea Three offshore cable corridor is 9,721,030 m^2 of Habitat A, 2,505,300 m^2 of Habitat C and 2,949,382 m^2 of Habitat D (Mixed sediments with high infaunal and epifaunal diversity), which equates to 0.48%, 0.24% and 0.58%, respectively, of the total area of each VER within the Hornsea Three benthic ecology study area. The maximum design scenario, for each VER affected by temporary habitat loss along the Hornsea Three offshore cable corridor, is estimated based on a scenario of all loss associated with sandwave clearance occurring wholly within Habitat A.

2.11.1.10 The total maximum potential temporary losses of each VER as a result of all subtidal operations are therefore as follows (see Figure 2.7):

- Habitat A – 26,273,436 m^2 (1.29% of Habitat A within Hornsea Three benthic ecology study area);
- Habitat B – 16,552,406 m^2 (3.26% of Habitat B within Hornsea Three benthic ecology study area);
- Habitat C – 19,057,706 m^2 (1.82% of Habitat C within Hornsea Three benthic ecology study area); and
- Habitat D – 2,949,382 m^2 (2.78% of Habitat D within Hornsea Three benthic ecology study area).

2.11.1.11 The temporary loss/disturbance will be highly localised to the vicinity of the construction activity (i.e. limited to the immediate footprints). The predominantly sand and coarse sediment habitats that are most likely to be affected are typical of, and widespread throughout, the southern North Sea and the Hornsea Three benthic ecology study areas.

2.11.1.12 The total area of temporary subtidal habitat loss represents a very small percentage loss (0.004%) of the total area of the OSPAR Region II (Greater North Sea) within which *A. islandica* (Species L: Ocean quahog *A, islandica*; Table 2.12) is listed as under threat and/or decline.

2.11.1.13 The maximum habitat loss/disturbance predicted to occur within the boundary of the Markham's Triangle rMCZ assumes that 22% of all array infrastructure could be placed in the part of the array which overlaps with the rMCZ. This scenario assumes the maximum number of foundations which could possibly be placed within this part of the array, based on a minimum spacing of 1 km between offshore structures (i.e. turbines, substations and accommodation platforms), representing the maximum adverse scenario for Markham's Triangle rMCZ. This would result in temporary loss/disturbance of up to 3,624,936 m^2 within the rMCZ, equating to 2.49% of the qualifying feature Habitat G (Subtidal coarse sediments within an MCZ or rMCZ; Table 2.12), or 11.78% of Habitat H (Subtidal sandy sediments within an MCZ or rMCZ; Table 2.12) within the rMCZ. Note that the seabed throughout the rMCZ mostly comprises of coarse sediments, therefore the likelihood of all infrastructure being placed within Habitat H is very low. As such, the estimate of 11.78% temporary loss/disturbance within Habitat H is highly precautionary.

2.11.1.14 The maximum habitat loss/disturbance predicted to occur (i.e. from cable installation, including sandwave clearance, cable burial and anchor placements) within the North Norfolk Sandbanks and Saturn Reef SCI is 4,086,405 m^2, which represents 0.11% of the total area of the SCI (i.e. all potential Annex I sandbank habitat). The area of temporary habitat loss/disturbance affecting the current distribution of Annex I sandbank features as mapped by JNCC (Jenkins *et al*., 2015; i.e. Habitat E: Annex I 'sandbanks' within an SAC, see Table 2.12) is predicted to be approximately 655,485 m^2, which represents approximately 0.06% of this feature within the SCI (as mapped by Jenkins *et al*., 2015). As discussed in paragraph 2.11.1.7 and chapter 1: Marine Processes, these features would be expected to recover following sandwave clearance activities.

2.11.1.15 There are uncertainties with regard to the distribution and extents of protected features of the Cromer Shoal Chalk Beds MCZ within the Hornsea Three offshore cable corridor, with further site-specific data to be collected to address these data uncertainties (see section 2.6.4). As such, the figures discussed here are indicative for the PEIR. Assuming approximately 15 km of export cables are located within the boundary of the MCZ, the maximum temporary habitat loss/disturbance predicted to occur within the MCZ is 1,026,000 m^2 with all of this habitat loss/disturbance predicted to occur within one of the subtidal coarse, sandy or mixed sediment areas within the MCZ (i.e. Habitats G (Subtidal coarse sediments within an MCZ or rMCZ; Table 2.12), H (Subtidal sandy sediments within an MCZ or rMCZ) and I (Subtidal mixed sediments within an MCZ or rMCZ), respectively). This would represent 0.69% of Habitat G, 5.70% of Habitat H or 2.09% of Habitat I within the MCZ (according to the latest habitat extents provided in Defra, 2015).

2.11.1.16 Cable installation may also occur within Habitat J (subtidal chalk), with known overlap between the Hornsea Three offshore cable corridor and temporary working area and the known areas of subtidal chalk habitat (see Figure 3.3 in volume 5, annex 2.1: Benthic Ecology Technical Report). Based on the extent of this habitat within the Hornsea Three offshore cable corridor, the maximum length of cable which could be buried within this habitat is 13.16 km, based on the highly precautionary assumption of all six cables being laid in this part of the offshore cable corridor, with minimum spacing of 100 m between cables. This would result in loss/disturbance of up to 150,070 m^2 from cable burial and anchor placement during cable burial operations, representing 0.5% of the subtidal chalk habitat within the MCZ. Where cables are buried, it would be expected that this would result in removal of the surface substrate and subsequent infill of cable trenches by superficial sediments from the local area (e.g. sand, coarse and mixed sediments), resulting in loss of a proportion of the subtidal chalk feature, with no potential for recovery and a change of habitat type in these discrete areas. Where anchor placement occurs (i.e. up to 18,430 m^2), it is expected that the substrates would be left intact although with some damage impacts to the physical structure of the substrates. These effects may be relatively inconspicuous in areas of relatively flat substrate or more noticeable in areas where the structural complexity is greater (e.g. pinnacles, ridges, overhangs or gullies).

2.11.1.17 For Habitat K (peat and clay exposures), effects would be expected to be analogous to subtidal chalk, although estimates of potential areas affected are difficult to make as the extent of this habitat feature within the MCZ is not accurately mapped. This habitat feature has been recorded at discrete locations within the MCZ, primarily in the northwest of the MCZ (see Figure 3.3 in volume 5, annex 2.1: Benthic Ecology Technical Report), some of which coincide with the offshore cable corridor and therefore have the potential to be affected by cable installation. Like subtidal chalk, where cable installation occurs within areas of peat and clay exposures, this would result in loss of this habitat feature, with no potential for recovery and a change in substrate type, with surrounding sediments likely to infill the cable trench from surrounding areas. Where anchor placement occurs, effects may be more limited, depending on the complexity of the peat and clay exposures.

2.11.1.18 The impact of temporary loss/disturbance to Habitats A, B, C, D and Species L is predicted to be localised to Hornsea Three, of medium term duration (i.e. construction phase of up to 11 years; see Table 2.13) and intermittent in nature. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be minor.

2.11.1.19 The impact of temporary loss/disturbance on features of the Markham's Triangle rMCZ (i.e. Habitats G and H) is predicted to be localised within the western area of the rMCZ, of medium term duration (i.e. construction phase of up to 11 years; see Table 2.13) and intermittent in nature. It is predicted that the impact will affect the receptors directly resulting in a small change in the baseline condition. The magnitude is therefore, considered to be minor.

2.11.1.20 The impact of temporary loss/disturbance to Habitat E (Annex I sandbanks) within the North Norfolk Sandbanks and Saturn Reef SCI is predicted to be localised to discrete sections of the Hornsea Three offshore cable corridor, will be medium term (i.e. construction phase of up to 11 years, although export cable installation will only comprise a small proportion of this; see Table 2.13) and intermittent in nature and will impact receptors directly with a small change in the baseline condition. The magnitude is therefore considered to be minor.

2.11.1.21 The impact of temporary loss/disturbance on features of the Cromer Shoal Chalk Beds MCZ (i.e. Habitats G, H and I) is predicted to be localised to within the Hornsea Three offshore cable corridor, of medium term duration (i.e. construction phase of up to 11 years, although export cable installation will only comprise a small proportion of this; see Table 2.13) and intermittent in nature. It is predicted that the impact will affect the receptors directly resulting in a small change in the baseline condition. The magnitude is therefore, considered to be minor.

2.11.1.22 Should cable installation occur within Habitats J (subtidal chalk) or K (peat and clay exposures), these will result in permanent loss of these habitat features and a change in the substrate type, with no potential for recovery. Only a relatively small proportion of this habitat would be potentially affected particularly given the precautionary assumptions made with respect to the area affected (see paragraph 5.1.2.4). The magnitude of the impact on these protected features was predicted to be minor. Hornsea Three is currently investigating the feasibility of avoiding these features and will seek to use this to mitigate these potential impacts, where possible, as the project evolves. Discussions on the effects of Hornsea Three on the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: MCZ Assessment.

Sensitivity of the receptor

2.11.1.23 The subtidal habitats directly affected by temporary habitat loss and disturbance (Habitats A, B, C and D) typically have low sensitivity to disturbance of this nature. Sandy biotopes such as NcirBat and FfabMag and IMoSa, represented by Habitat A, are typical of high energy environments and are therefore naturally subject to, and tolerant of, high levels of physical disturbance. The communities that characterise these biotopes are predominantly infaunal mobile species including polychaetes and venerid bivalves, which are capable of re-entering the substratum following disturbance (Budd, 2008a; Tillin, 2016a). For example, the mollusc *F. fabula* and the polychaetes *M. mirabilis* and *N. cirrosa* are all active burrowers capable of reburying themselves (Rayment, 2008a; Tillin and Rayment, 2016). Although while at the sediment surface any displaced infauna may be vulnerable to predation from echinoderms and bottom feeding fish, significant declines in overall species richness are unlikely to be seen and the recoverability of these communities is therefore assessed as high (Budd, 2008a; Rayment, 2008a; Tillin, 2016a and 2016b).

2.11.1.24 The recoverability of such communities within Habitat A is likely to occur as a result of the combination of recruitment from surrounding unaffected areas and larval dispersal, and recovery is likely to occur within five years. This is supported by evidence relating to the recovery of benthic communities following aggregate extraction activities (Newell *et al.,* 1998; Desprez, 2000; Newell *et al*., 2004). Newell *et al*. (1998) reported that following the cessation of dredging activities, the characteristic recovery time for sand communities may be two to three years. Data from a marine aggregate site off the south coast of the UK indicated that following the initial suppression of species' diversity, abundance and biomass recovery of species' diversity to within 70 to 80% of that in non-dredged areas was achieved within 100 days (Newell *et al.,* 2004). Species' abundance also recovered within 175 days (Newell *et al*., 2004). Desprez (2000) also reported that the dredging of an industrial site off Dieppe resulted in decreases in species richness, abundance and biomass by 63%, 86% and 83% respectively, resulting in a shift in benthic community. However within 16 months following cessation of dredging, species richness had been fully restored, abundances had recovered by up to 56%, and after 28 months, biomass had recovered by 75%. It is important to acknowledge however, that the activities associated with aggregate extraction are quite different to those associated with offshore wind farm construction activities. (i.e. they involve the complete removal of sediment). Data collated from more analogous activities such as the burial of telecommunications cables has shown that recovery of sand sediments is likely to occur within one year (Foden *et al*., 2011).

2.11.1.25 With respect to abrasion/physical disturbance resulting from jack-up operations and anchor placements, the majority of the infauna in Habitat A is likely to have intermediate intolerance to such disturbance at the surface, due to the depths in the sediment in which infauna live. Venerid bivalves including *F. fabula* for example, which have a fragile shell and are shallower burrowers, are more vulnerable. Polychaetes such as *M. mirabilis* which expose their palps at the surface while feeding are similarly vulnerable (Rayment, 2008a). Although epifaunal communities were typically absent in Habitat A, the larger faunal components of these communities, for example the echinoderms *A. rubens*, are also likely to be vulnerable. However this species typically exhibits good powers of regeneration and high fecundity, and so recoverability is also likely to be high (Budd, 2008b). Overall, as discussed in paragraph 2.11.1.24, the recoverability of Habitat A is likely to occur as a result of the combination of recruitment from surrounding unaffected areas and larval dispersal, and recovery is likely to occur within five years. Although the jack-up footprints will potentially remain on the seabed for a number of years, as demonstrated by monitoring studies of Round 1 wind farms (BOWind, 2008; EGS, 2011), the communities within them are expected to recover within this time span.

2.11.1.26 Habitat B is represented by the sandy mud biotope AfilMysAnit. These communities are characterised by high abundances of the echinoderm *A. filiformis* which has very low sensitivity to physical disturbance and abrasion (Hill and Wilson 2008; Marine Ecological Surveys Limited, 2008), and the bivalves *Mysella bidentata* and *Abra nitida* which are well adapted for recovery and recolonisation following disturbance. For example, *A. nitida* has a relatively short life span (approximately three years) and high fecundity and larval dispersal, which suggest this genus has high recoverability and is capable of restoring biomass within three years following disturbance (Marine Ecological Surveys Limited, 2008). Associated epifaunal species which include the shrimp *Crangon allmanni*, and a variety of crab species including *L. holsatus*, *L. depurator* and *P. bernhardus* are considered sufficiently mobile to avoid the physical impacts of disturbance.

2.11.1.27 Habitat C includes the MoeVen, PoVen and other coarse and mixed sediment biotopes such as MysThyMx, which have typically low sensitivity to impacts resulting from physical disturbance/abrasion and displacement (Durkin, 2008; Rayment 2008b; Tillin, 2016c; Tillin, 2016d; De-Bastos and Marshall, 2016). This habitat, which is characterised by relatively diverse communities of polychaetes and venerid bivalves, is unlikely to experience anything other than minor localised declines in species richness. The majority of the infauna will be expected to rebury following displacement with only a small degree of mortality resulting from predation. Although some permanently attached species such as epifaunal hydroids and bryozoans will suffer mortality when removed from the substratum during construction activities, other epifaunal species which remain attached to their substrate will likely survive any physical damage and repair themselves. For example, Silén (1981) demonstrated that damage to the fronds of these species can be repaired within five to ten days. Overall, the high recoverability of the component species of this habitat following removal, displacement and physical disturbance, indicates that damaged or reduced populations will recover numbers and percentage cover within months, with full recovery within five years (Rayment, 2008b). This is also supported by some data from the aggregates industry which has shown that following the cessation of dredging activities, sand and gravel communities typically recover in two to three years (Newell *et al.,* 1998). More recent data has suggested that recovery of gravel communities to dredging activities could take up to nine years (Foden *et al*., 2009); however, as outlined in paragraph 2.11.1.24, the complete removal of sediment associated with aggregate extraction is quite different to that associated with the construction of Hornsea Three. Gravel sediments have been reported as recovering from cable burial activities within one year (Andrulewicz *et al*., 2003 in Foden *et al*., 2011).

2.11.1.28 Habitat D, represented by the SspiMx and overlying Sspi.ByB biotopes with typically diverse epibenthic communities, was found exclusively along the Hornsea Three offshore cable corridor and could therefore be affected by export cable laying operations and associated anchor placements. Although this habitat is typically highly intolerant to temporary disturbance and displacement, recoverability is also high resulting in overall moderate sensitivity to impacts of this nature (Marshall, 2008; Tillin and Marshall, 2015). Following displacement, *S. spinulosa* is not able to rebuild tubes once removed from them and, although associated mobile epifaunal species such as hermit crabs and amphipods may be able to escape unharmed, sessile attached fauna including bryozoans such as *F. foliacea* and *Alcyonidium diaphanum* may be lost resulting in potential declines in overall species richness (Marshall, 2008). Although the key characterising species (i.e. *S. spinulosa*) is predicted to recover quickly, the high biodiversity often associated with this habitat may take slightly longer to develop. With respect to anchor placements and jack-up disturbance, intolerance is assessed as intermediate as although abrasion is likely to cause damage to erect epifauna, recovery is likely to be high. *S. spinulosa* is commonly found in disturbed environments and has a typically high rate of reproduction (Holt *et al*., 1998). The presence of any remaining *S. spinulosa* adults will also assist in larval settlement of this species (Jackson and Hiscock, 2008). The recoverability of associated epifauna is also expected to be high, with complete recovery likely within five years (Marshall, 2008; Tillin and Marshall, 2015).

2.11.1.29 The conclusion of recovery of Habitat D within five years is supported by the results of a study funded by Natural England through the Marine Aggregate Levy Sustainability Fund (MALSF) investigating the recoverability or colonisation potential of *S. spinulosa* following cessation of aggregate extraction activities at Hastings Shingle Bank (Pearce *et al*., 2007). The study found that dredging had not altered the seabed in a way that was detrimental to colonisation, and initial colonisation and development of a significant *S. spinulosa* aggregation was observed at the site within 18 months and development to a stage equivalent to the oldest aggregations observed in the area was assessed as likely to be complete within three years. It was concluded that a similar pattern could be expected in other extraction areas assuming a supply of larvae in the plankton and that the process would likely be significantly quicker in areas less hampered by trawling (Pearce *et al.*, 2007).

2.11.1.30 As discussed in volume 5, annex 2: Benthic Ecology Technical Report, one of the typical characterising species of the subtidal chalk and peat and clay exposures is likely to be the piddock *Pholas dactylus* which is one of the main characterising species of the CR.MCR.SfRPid (SfRPid): 'Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay' biotope (Connor *et al*., 2004). In addition to this species' requirements for clay and soft rock to bore into, its empty burrows also provide a habitat for other species (Pinn *et al*., 2008). Following removal of the substratum, recovery of the habitat is not possible. While sub-surface layers of the same substratum type may be exposed (Tillin and Hill, 2016), these may be covered over by mobile sands or gravels making them unavailable for the associated communities such as piddocks and other sessile epifaunal species including sponges, hydroids, anemones, sea slugs, seaweed and sea squirts which were found to characterise the subtidal chalk habitats (clay exposures were found to be more sparse; see volume 5, annex 2: Benthic Ecology Technical Report). A change of substrate type to a sedimentary material would result in the removal of these species from the areas affected, therefore these communities are considered to have high vulnerability to this impact (Tillin and Hill, 2016). Some recovery may be expected in areas where anchor placements occur and the substrates are left intact, although this depends on the extent of the impact to the physical characteristics of the substrate (e.g. elevation from the seabed, structural complexity of the residual substrate and the extent of surrounding unaffected habitat from which recovery could occur).

2.11.1.31 With the exception of subtidal chalk and peat and clay exposures, any effects of habitat loss/disturbance within the construction phase will be temporary and will cease following completion of construction activities. Whilst fauna and flora will be affected, as discussed above recovery in most cases is likely to be high and typically within five years or less, as a result of passive import of larvae and active migration of juveniles and adults from adjacent non-affected areas. Habitats A, B and C are deemed to be of low to medium vulnerability, high recoverability and regional value. The sensitivity of these receptors is therefore considered to be **low**. Habitat D is deemed to be of medium to high vulnerability, high recoverability and regional value. Although *S. spinulosa* is likely to recover quickly, the associated high biodiversity may take longer to recover and, as such, the sensitivity of Habitat D is considered to be **medium**.

2.11.1.32 Despite its thick and solid shell, *A. islandica* (i.e. Species L) is intolerant to displacement and abrasion/physical disturbance. In addition, individuals exposed at the surface by the construction activities outlined in Table 2.13 could potentially be subject to a higher risk of predation from starfish and other predators, although they would be expected to bury themselves back into the sediment quickly (Sabatini *et al*., 2008). *A islandica* is a slow growing, long lived species with a very low recruitment rate. However, due to its ability to rebury in the sediment following displacement, recoverability to this type of impact is predicted to be moderate. Therefore *A. islandica* are deemed to be of medium vulnerability, medium recoverability and national value, and the sensitivity of this receptor is considered to be medium.

2.11.1.33 Sensitivity of the features of the Markham's Triangle rMCZ, i.e. Habitats G and H, are considered to be identical to Habitats A and C, respectively, although these are of national importance and therefore are considered to be of medium sensitivity.

2.11.1.34 Sensitivity of Habitat E, the Annex I sandbank feature of the North Norfolk Sandbanks and Saturn Reef SCI is considered to be medium in chapter 1: Marine Processes and the benthic communities associated with these features are considered to be identical to Habitat A, although these are of international importance and are therefore considered to be of medium sensitivity.

2.11.1.35 Sensitivity of the features of the Cromer Shoal Chalk Beds MCZ which may be affected by temporary habitat loss/disturbance, i.e. Habitats G, H and I, are considered to be identical to Habitats A, C and D, respectively, although these are of national importance and therefore are considered to be of medium sensitivity. Sensitivities of subtidal chalk and peat and clay exposures to this impact are considerably different to those of the sediment communities, in that any physical disturbance would be on a permanent basis, i.e. damage to or removal of subtidal chalk or peat and clay exposures via cable burial would not be reversible. These habitat features are considered to be of high vulnerability, not recoverable and of national value. The sensitivity of the receptor is therefore, considered to be very high.

Significance of the effect

2.11.1.36 The magnitude of the impact on Habitat A, Habitat B, Habitat C and Habitat D and Species L is of limited spatial extent and minor magnitude. The sensitivity of these VERs is low to medium and therefore the effect of temporary habitat loss/disturbance on Habitats A, B, C and D, and Species L is considered to be of minor adverse significance, which is not significant in EIA terms.

2.11.1.37 The magnitude of impact on features of the Markham's Triangle rMCZ (Habitat G & H) is predicted to be minor and sensitivity of these features is medium. The effect of temporary habitat loss on the features of Markham's Triangle rMCZ is therefore considered to be minor adverse, which is not significant in EIA terms. Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ are presented in full within volume 5, annex 2.3: MCZ Assessment.

2.11.1.38 The magnitude of impact on Habitat E, the Annex I sandbank feature of the North Norfolk Sandbanks and Saturn Reef SCI, is minor and sensitivity of this receptor is considered to be medium. The effect of temporary habitat loss/disturbance on this habitat feature of the SCI is therefore considered to be minor adverse, which is not significant in EIA terms. Conclusions on the effect on the site integrity of the North Norfolk Sandbanks and Saturn Reef SCI are beyond the scope of this PEIR and a full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment for Hornsea Three.

2.11.1.39 The magnitude of impact on the sediment features of the Cromer Shoal Chalk Beds MCZ (Habitats G, H and I) is predicted to be low and sensitivity of these features is medium. The effect of temporary habitat loss on the features of Cromer Shoal Chalk Beds MCZ is therefore considered to be minor adverse, which is not significant in EIA terms.

2.11.1.40 With respect to subtidal chalk and peat and clay exposures features of the Cromer Shoal Chalk Beds MCZ, the magnitude of impact was predicted to be minor (particularly given the precautionary assumptions made with respect to the area potentially affected; see paragraph 2.11.1.16), with a very high sensitivity for these habitat features and therefore the significance of effect was considered to be moderate adverse, which is significant in EIA terms. As noted in paragraph 2.11.1.22, Hornsea Three is currently investigating the feasibility of avoiding these features and will seek to use this to mitigate these potential impacts, where possible, as the project evolves. As outlined in section 2.10, this will be implemented by undertaking a pre-construction survey of the final offshore cable corridor and where necessary and possible, employing appropriate mitigation to avoid direct impacts on these features. Conclusions on the effects of Hornsea Three on the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: MCZ Assessment.

Future monitoring

2.11.1.41 A survey will be undertaken prior to construction to determine the location, extent and composition of any benthic habitats of conservation or ecological importance in the part(s) of the Hornsea Three array area and the Hornsea Three offshore cable corridor in which construction works will be carried out, the exact scope of which will be agreed with the relevant statutory consultees.

Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.

2.11.1.42 As detailed in Table 2.13 above, increases in suspended sediment concentrations (SSC) and associated sediment deposition are predicted to occur during the construction phase as a result of cable and foundation installation (including seabed preparation and sandwave clearance). Chapter 1: Marine Processes and volume 5, annex 1.1: Marine Processes Technical Report provide a full description of the physical assessment, including the numerical modelling used to inform the predictions made with respect to increases in SSC and subsequent sediment deposition, with a summary of maximum design scenarios associated with this impact, as detailed in Table 2.13, provided in this section.

2.11.1.43 Values of suspended sediment in the southern North Sea in the summer are generally low in offshore areas with typical concentrations of 0 to 10 mg/l. During the winter, background levels in the southern North Sea can reach over 30 mg/l (Dolphin *et al*., 2011). For both summer and winter months, SSC generally increase with greater proximity to the coast (Dolphin *et al*., 2011; see chapter 1: Marine Processes). Background SSC recorded within the Hornsea Three array were typically found to be in the range 10 to 30 mg/l, although SSC in shallow, nearshore areas exposed to larger waves may be in the order of 100's to 1,000's mg/l during storm conditions (see chapter 1: Marine Processes), demonstrating the natural variability in SSC values in this part of the southern North Sea.

Magnitude of impact

2.11.1.44 Table 2.13 presents the maximum design scenario associated with increases in SSC and deposition associated with drilling operations for monopile foundation installation. The Marine Processes assessment concluded that SSC during this activity will be increased by tens to hundreds of thousands of mg/l at the point of sediment release (i.e. near the water surface). Further afield SSC increases of low tens of mg/l will be present in a narrow plume, tens to a few hundreds of metres wide and between 3.5 and 7 km length, aligned with the tidal stream downstream from the source. Outside this area, SSC of less than 10 mg/l may occur due to ongoing dispersion and dilution of fine material. Fine sediment concentrations may persist in suspension for hours to days, but will become diluted to concentrations indistinguishable from the background levels within around one day. Deposition of coarse grained and sandy deposits from drilling of a single monopile foundation will result in sediment accumulation of tens of centimetres to metres and for the purposes of this impact assessment this would be considered habitat loss and is therefore assessed in paragraph 2.11.1.3 *et seq*. Fine grained material from drilling operations will be dispersed widely within the surrounding region and will not settle with a measurable thickness.

2.11.1.45 Table 2.13 presents the maximum design scenario associated with increases in SSC and deposition associated with seabed preparation for installation of GBF. As detailed in Table 2.13, this impact assessment considers increases in SSC and deposition as a result of foundation installation using drilling and seabed preparation as these foundation installation methodologies result in releases of different materials, i.e. drilling operations result in release of relatively larger volumes of fine sediment at low rates, while seabed preparation releases relatively small volumes of coarser material at relatively higher rates. As described in paragraph 2.11.1.3, deposition of coarse, granular sediments from seabed preparation activities is considered temporary habitat loss for the purposes of this assessment. Increases in SSC and subsequent deposition are therefore related to the passive phase of the plume comprised of finer sediments which are likely to stay in suspension and therefore will affect a larger area. Chapter 1: Marine Processes predicted that sand sized material could remain in suspension for up to approximately 15 minutes and therefore may be transported up to approximately 0.5 km, with increases in SSC in excess of natural ranges over a short timescale. Finer sediment fractions would remain in suspension for a longer period, affecting a larger area for a longer period. Elevations in SSC above background levels at distances of hundreds of metres to a few kilometres are predicted to be relatively low (i.e. less than ~20 mg/l) and within the range of natural variability and after 24 hours, elevations in SSC are predicted to typically be less than 5 mg/l.

2.11.1.46 The maximum design scenario for increases in SSC associated with inter array, substation interconnector and export cable installation are predicted to occur as a result of installation by mass flow excavator (see Table 2.13 and chapter 1: Marine Processes for full details). Disturbance of medium to coarse sand and gravels during cable installation are likely to result in a temporally and spatially limited plume affecting SSC levels (and settling out of suspension) near the point of release. SSC will be locally elevated within the plume close to active cable burial up to tens or hundreds of thousands of mg/l, although the change will only be present for a very short time locally (i.e. seconds to tens of seconds) before the material resettles to the seabed. Depending on the height to which the material is ejected and the current speed at the time of release, changes in SSC and deposition will be spatially limited to within metres downstream of the cable for gravels and within tens of metres for sands. Finer material will be advected away from the release location by the prevailing tidal current. High initial concentrations (similar to sands and gravels) are to be expected but will be subject to rapid dispersion, both laterally and vertically, to near-background levels (tens of mg/l) within hundreds to a few thousands of metres of the point of release. Only a small proportion of the material disturbed is expected to be fines, with a corresponding reduction in the expected levels of SSC.

2.11.1.47 Irrespective of sediment type, the volumes of sediment being displaced and deposited locally are relatively limited (up to 6 m^3 per metre of cable burial) which also limits the combinations of sediment deposition thickness and extent that might realistically occur. The assessment presented in chapter 1: Marine Processes suggests that the extent and so the area of deposition will normally be much smaller for sands and gravels, leading to a greater average thickness of deposition in the order of tens of centimetres to a few metres in the immediate vicinity of the cable trench. Fine material, by contrast, will be distributed much more widely, becoming so dispersed that it is unlikely to settle in measurable thickness locally.

2.11.1.48 As detailed in Table 2.13, sandwave clearance is also expected to be required at discrete locations both within the Hornsea Three array area and along the Hornsea Three offshore cable corridor. As described in paragraph 2.11.1.3, deposition of coarse, granular sediments from sandwave clearance is considered temporary habitat loss for the purposes of this assessment. Increases in SSC and subsequent deposition are therefore related to the passive phase of the plume comprised of finer sediments which are likely to stay in suspension and therefore will affect a larger area. Chapter 1: Marine Processes predicted that impacts related to increases in SSC were likely to be similar to those for seabed preparation for gravity base foundation installation (see paragraph 2.11.1.44), with elevated SSCs in close proximity to sandwave clearance activities and lower levels, reflective of natural baseline conditions, at greater distances. It was predicted that increases in depth averaged SSC of 5-10 mg/l would extend less than 13 km upstream and downstream of the source where a trailing suction hopper dredger was used for sandwave clearance and SSC of 5-10 mg/l would extend less than 17.5 km from the source where a mass excavator tool was used (chapter 1: Marine Processes).

2.11.1.49 The impact to subtidal benthic receptors from drilling and seabed preparation for foundation installation and cable installation, including sandwave clearance, is predicted to be of regional spatial extent (i.e. within kilometres of Hornsea Three), of medium term (i.e. construction phase of up to 11 years; see Table 2.13) and intermittent duration, and reversible to baseline conditions following cessation of activities. It is also predicted that the impact will affect benthic receptors indirectly and therefore, the magnitude is considered to be minor.

Sensitivity of the receptor

2.11.1.50 Habitats A, B, E and H have very low to almost no sensitivity to increased SSC and smothering as a result of deposition. These conditions are a natural feature of the environment in which these habitats occur and as the majority of the characterising species are burrowing infaunal polychaetes these species are unlikely to be affected by smothering (De-Bastos and Hill, 2016; Tillin and Rayment, 2016; Tillin, 2016a). Although high levels of SSC (i.e. over 100 mg/l over one month) may potentially clog the gill filaments of active suspension and filter feeders (Nicholls *et al.,* 2003) such as venerid bivalves, these species are likely to be able to clear these structures with limited effects of mortality on most of the associated species (De-Bastos and Hill, 2016; Tillin and Rayment, 2016). The increase in SSC may actually increase the food supply for some deposit feeders in these habitats (De-Bastos and Hill, 2016; Tillin and Rayment, 2016). In comparison, smothering of characteristic species such as venerid bivalves would temporarily halt feeding. However, as these and the associated polychaetes and amphipods are active burrowers this is unlikely to result in any change to overall species richness, as relocation of these species to their preferred depth would be expected (De-Bastos and Hill, 2016; Tillin and Rayment, 2016; Tillin, 2016a). When SSC return to normal, background concentrations, feeding and respiration should quickly return to normal and as such the recovery of these habitats is expected to be very high to immediate, and overall species richness is likely to be unaffected.

2.11.1.51 Habitats C, D, G and I are considered to have medium resilience to and high recoverability from, increased SSC and sediment deposition. The response of characterising species including burrowing infaunal polychaetes and venerid bivalves, are the same as described above in paragraph 2.11.1.50 for sandy sediment communities. Species in these habitats are likely able to relocate to their preferred depth with only minor energetic cost following smothering (Tillin, 2016d; Tillin, 2016e). Larger and more mobile epifauna such as crabs, fish, shrimps and prawns are expected to be able to avoid adverse SSC and areas of deposition. Colonial epifaunal species such the bryozoan *F. foliacea*, where present in these habitats are considered to be tolerant of such impacts due to their tough and flexible form and also because these conditions are typical of the sand scoured environments where these species are usually found (Tyler-Walters and Ballerstedt, 2007). These species are also characteristic of strong to moderate tidal streams and as such deposition would be unlikely to affect these species for long. The soft coral *Alcyonium digitatum* has also been shown to be able to shed settled particles with large amounts of mucous (Hill *et al.,* 1997).

2.11.1.52 *S. spinulosa*, which is a feature of Habitats D and F (Annex I reefs of the North Norfolk Sandbanks and Saturn Reef SCI), is tolerant of increased SSC (Tillin and Marshall, 2015). Experimental evidence relating to the burial tolerance of *S. spinulosa* has demonstrated that short term (i.e. <32 days) burial to depths of up to 7 cm has no effect on survival (Last *et al.,* 2011). Therefore the limited amount of sediment deposition by fine sediment predicted to result from cable installation, including sandwave clearance, as outlined in paragraphs 2.11.1.46 to 2.11.1.48, is likely to be well within the tolerance of *S. spinulosa*. Recoverability from smothering is considered to be high (Tillin and Marshall, 2015). Pearce *et al.* (2007) found that *S. spinulosa* was present around the periphery of the Hastings Shingle Bank dredge site where sediments were being moved in all directions. This provides supporting evidence that suspended sediments released during dredging, which have been reported at other aggregate extraction sites in the English Channel at levels up to 5.5 g/l within 100 m of the dredger (Hitchcock and Bell, 2004), is not damaging to *S. spinulosa* aggregations, and could in fact enhance them as the worms rely on suspended sediments as a source of both food and building material (Pearce *et al*., 2007). *A. islandica* (Species L) is not considered to be sensitive to increases in SSC, which are likely to increase food availability. Similarly it is not sensitive to sediment deposition, with individuals known to burrow to the sediment surface through any deposited sediment, with no mortality observed (Tyler-Walters and Sabatini, 2017).

2.11.1.53 Communities associated with Habitats J (subtidal chalk reefs) and K (Peat and clay exposures) within the Cromer Shoal Chalk Beds MCZ are likely to have some tolerance to increases in SSC (De-Bastos and Hill, 2016; Tillin and Hill, 2016), particularly as these habitats are located in close proximity to the coast, where SSC are highest (see chapter 1: Marine Processes). Sensitivity of many species associated with Habitat J and K to sediment deposition would also be expected to be limited due to the resilience of some characterising species (De-Bastos and Hill, 2016) and the natural sediment mobility in these areas. Piddocks, which are known to burrow into areas of soft rock and clay which may characterise Habitats J and K have increased sensitivity to sediment deposition as they are essentially sedentary and the short length of their siphons makes them vulnerable to smothering (Tillin and Hill, 2016). These species have some tolerance to some degree of smothering (i.e. a few centimetres) with observations of siphons protruding through sediments and some species surviving smothering after periods of rough weather. However, where smothering occurs over a longer period of time, mortality could occur (Tillin and Hill, 2016). These habitats occur within the Cromer Shoal Chalk Beds MCZ in the vicinity of the inshore sections of the Hornsea Three offshore cable corridor and therefore have the potential to be affected by increased SSC and sediment deposition from cable installation only. As outlined in paragraphs 2.11.1.46 to 2.11.1.48, effects of sediment deposition (i.e. of coarse sediments) are likely to be limited primarily to the immediate vicinity of the cable trench, with fine material distributed much more widely and becoming so dispersed that it is unlikely to settle in measurable thickness locally. Furthermore any effects of individual cable installation operations will be short term (i.e. hours; paragraphs 2.11.1.46 to 2.11.1.48) and intermittent, with SSC returning to baseline levels quickly following cable installation.

2.11.1.54 The benthic ecology VERs Habitats A to I and Species L are considered to be of low vulnerability, high to immediate recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be **low**.

2.11.1.55 The Habitats J and K of the Cromer Shoal Chalk Beds MCZ are considered to be of low to medium vulnerability, medium to high recoverability and of national importance. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of the effect

2.11.1.56 The magnitude of the impact on benthic VERS Habitats A to I and Species L is of limited spatial extent, temporary and reversible and therefore of **low** magnitude. The sensitivity of these VERs is **low** and therefore the effect of increases in SSC and associated sediment deposition on these benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.11.1.57 The magnitude of the impact on Habitats J and K (habitat features of the Cromer Shoal Chalk Beds MCZ) is of limited spatial extent, temporary and reversible and therefore of **low** magnitude. The sensitivity of these VERs is **medium** and therefore the effect of temporary habitat loss/disturbance on all benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms. Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology.

2.11.1.58 Site-specific subtidal sediment contamination data is currently not available for the Hornsea Three offshore cable corridor, therefore it is not possible to assess this impact in the PEIR. However, as discussed in section 2.6.4.3, a site-specific survey will be undertaken along the Hornsea Three offshore cable corridor, as agreed through the Marine Processes, Benthic Ecology and Fish and Shellfish Ecology EWG, and sediment contaminant data acquired in the pending survey will inform the assessment for this impact in the final EIA report.

Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.

Magnitude of impact

2.11.1.59 The total additional number of construction-related vessel round trips to port expected as a result of construction activities over the construction period is up to 3,420. There will also be vehicle and machinery movements in the intertidal part of the Hornsea Three benthic ecology study area. The magnitude of the impact of this increase will be dependent on the quantities of potential pollutants carried by construction vessels and intertidal vehicles/machinery. The size of the majority of these potential sources of pollution in the intertidal will be relatively small, which immediately reduces the potential magnitude of any spill and although a spill in the intertidal at low water would directly affect benthic habitats, it would be easy to contain. In addition, although many of the large construction vessels may contain large quantities of diesel oil, any accidental spill from vessels, vehicles, machinery or from construction activities would be subject to immediate dilution and rapid dispersal in the high energy environment found within the subtidal parts of Hornsea Three.

2.11.1.60 Given the designed-in mitigation (see Table 2.17) the likelihood of accidental release is considered to be extremely low. The measures to be included in the CoCP and PEMMP will include: designating areas for refuelling; only using chemicals included on the approved Cefas list under the Offshore Chemical Regulations 2002; storage of chemicals in secure designated areas in line with appropriate regulations and guidelines and double skinning of any tanks and pipes containing hazardous substances. Adherence to the mitigation outlined in Table 2.17 (i.e. a CoCP) and best working practices will significantly reduce the likelihood of an accidental pollution incident occurring. The likelihood of an accident between vessels resulting in an accidental spill during the construction period will be further reduced by the Health, Safety and Environmental Management System (HSE MS) which will be developed and implemented by DONG Energy which incorporates the elements of the Active Safety Management System (ASMS), as required by Marine Guidance Note (MGN) 371. This will be particularly focused on ensuring safety of navigation within proximity of the offshore wind farm (see chapter 7: Traffic and Transport).

2.11.1.61 There is a risk to subtidal benthic receptors from water based drilling mud (i.e. bentonite) which is used as a lubricant during the horizontal directional drilling (HDD) process, should HDD be used at the landfall to install the export cable. A limited volume of drilling mud will be discharged at the point where the bore punches out of the seabed in the subtidal zone. However the volume of fluids released will be small and quickly dispersed in the high-energy conditions of the marine environment. As such, impacts to surrounding subtidal receptors will be minimal.

2.11.1.62 The impact on subtidal benthic receptors is predicted to be of a local to regional spatial extent, short term duration (i.e. in the unlikely event that a spillage occurs, the impact would last hours to days), intermittent and reversible. It is predicted that the impact will affect the receptors indirectly. The magnitude is therefore, considered to be **negligible**.

Sensitivity of the receptor

2.11.1.63 All of the VERs that would be potentially affected by the accidental release of pollutants (i.e. Habitats A, B, C, D, E, F, G, H, I, J and K and Species L) are identified as having intermediate to high intolerance to synthetic compound and hydrocarbon contamination, with localised declines in species richness likely as a result. Crustaceans are widely reported to be intolerant to synthetic chemicals (Budd, 2008a), and there is varying evidence of individual sensitivities of species to impacts such as major oil spills and to tributyltin (TBT) (Beaumont *et al*., 1989; Haggera *et al*., 2005; Antizar-Ladislao, 2008). *S. spinulosa* larvae are known to be highly intolerant of some oil dispersants although adult forms have been found to thrive in polluted areas (Jackson and Hiscock, 2008). Gomez Gesteira and Dauvin (2000) found that amphipods are highly sensitive to oil pollution, whereas polychaetes appear to be resistant to high hydrocarbon levels in sediment although both of these impacts are unlikely in respect to Hornsea Three. The recoverability of these communities to contaminants of this nature is likely to be moderate to high as a result of the life history characteristics of the component species (see paragraphs 2.11.1.23 to 2.11.1.28). These would facilitate rapid recolonisation of affected areas via adult migration and larval settlement following a return to ecological baseline conditions and baseline levels of contaminants. Experimental evidence is limited and the assessments described above have been derived from sources that only cover some aspects of the habitats and species, or from general understanding of the habitats or species (www.marlin.ac.uk). However, subtidal sediments in high energy environments such as those represented by Habitats A to K (except Habitat B) are generally less vulnerable to this type of pollution than low-energy intertidal habitats. The hydrodynamic regime in the offshore parts of Hornsea Three would also lead to high dispersion and breakdown of pollutants, which would be expected to reduce the concentration of contaminants and therefore also the effects on subtidal receptors associated with a severe pollution event (Elliott *et al.,* 1998). The levels of contaminants that subtidal receptors are likely to be exposed to as a result of accidental pollution is likely to be much lower than the benchmarks used in MarLIN to determine sensitivity due to the large dilution and dispersion that would occur offshore. Therefore, the sensitivity of benthic receptors to the levels of pollution is likely to be lower than that described here using the MarLIN benchmarks.

2.11.1.64 As no VERs were recorded at the Hornsea Three landfall, due to the barren nature of the sediments (see section 2.7.2), no impact assessment has been undertaken for intertidal habitat loss on benthic ecological receptors.

2.11.1.65 The subtidal benthic VERs (i.e. Habitats A to D) are deemed to be of medium vulnerability, high recoverability and regional value. The sensitivity of the subtidal receptors is considered to be **low**.

2.11.1.66 Habitats E to K and Species L are deemed to be of medium vulnerability, high recoverability and national and international value. The sensitivity of the receptor is therefore, considered to be **medium**.

Significance of the effect

2.11.1.67 Provided published guidelines, best working practices and the mitigation measures outlined in Table 2.17 (i.e. implementation of a PEMMP) are adhered to, the likelihood of an accidental spill is extremely low and, in the event of a spill, the volumes of potential contaminants released would be small and rapidly dispersed to concentrations below which deleterious effects would be expected.

2.11.1.68 Therefore the effect of accidental release of pollutants on subtidal benthic receptors (Habitats A, B, C, D E, F, G, H, I, J and K and Species L) is considered to be of **negligible** significance, which is not significant in EIA terms.

2.11.1.69 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: MCZ Assessment.

2.11.2 Operational and maintenance phase

2.11.2.1 The impacts of the offshore operation and maintenance of Hornsea Three have been assessed on benthic ecology. The potential environmental impacts arising from the operation and maintenance of Hornsea Three are listed in Table 2.13 along with the maximum design scenario against which each operation and maintenance phase impact has been assessed.

2.11.2.2 A description of the potential effect on benthic ecology receptors caused by each identified impact is given below.

Long term loss of seabed habitat through presence of foundations, scour protection and cable protection, resulting in potential effects on benthic receptors.

2.11.2.3 Long term habitat loss will occur directly under all foundation structures and associated scour protection, and all inter-array, substation interconnector and export cables, where cable protection is required. Within Hornsea Three, long term habitat loss will be limited to Habitats A, B and C, Habitats G and H (i.e. features of Markham's Triangle rMCZ) and Species L. Within the Hornsea Three offshore cable corridor, the VERs that have the potential to be affected will be Habitats A, C and D, Species L and Habitats G, H and I (i.e. features of the Cromer Shoal Chalk Beds MCZ). Habitats E and F (features of the North Norfolk Sandbanks and Saturn Reef SCI) will not be affected by long term habitat loss during the operational phase. In areas where cable installation occurs within Habitats J and K (features of the Cromer Shoal Chalk Beds MCZ), this was predicted to result in permanent habitat loss (see paragraphs 2.11.1.16 and 2.11.1.17). If cable protection was required in these areas, this would not lead to further loss of this habitat due to the corridor width for placement of cable protection being smaller than the relevant width of the trench for cable burial (i.e. 7 m and 10 m, respectively; see Table 2.13). Therefore no effects are predicted to occur on subtidal chalk or peat and clay exposures as a result of placement of cable protection.

Magnitude of impact

2.11.2.4 The maximum total area of long term habitat loss associated with the installation of foundations and scour protection, and all associated subsea cables requiring cable protection (including cable/pipeline crossings), is estimated at 4,256,010 m^2 (Table 2.13) which equates to 0.11% of the area of Hornsea Three benthic ecology study area, and 0.007% of the southern North Sea benthic ecology study area.

2.11.2.5 The area of the total long term loss which will fall within the Hornsea Three array is approximately 2,907,810 m^2 which equates to a total loss of 0.08% of the total Hornsea Three benthic ecology study area. The maximum total area of each VER potentially lost as a result of these activities is based on a Design Envelope of maximum habitat loss for Habitats A, B and C, resulting from the location of all structures within one or other of these habitats. The maximum loss of each of the VERs is therefore 2,907,810 m^2 (Table 2.18), assuming all habitat loss occurs within one or other of the habitats which equates to approximately 0.14%, 0.57% and 0.28% of the total area of Habitat A, B and C, respectively within the Hornsea Three benthic ecology study area.

2.11.2.6 Within the Hornsea Three offshore cable corridor the VERs which would be affected by long term habitat loss due to cable protection where burial is not possible, including cable/pipeline crossings, are Habitats A, C and D. Of the total area of impact of 1,348,200 m^2 it is assumed, for the purposes of this assessment that all habitat loss occurs within one or other of the habitats along the Hornsea Three offshore cable corridor (Table 2.18). Table 2.18 also presents the total maximum losses of these VERs as proportions of the total area of each within the Hornsea Three benthic ecology study area.

2.11.2.7 Table 2.19 presents the maximum design scenario for VER features within the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ. As the exact layout of the Hornsea Three array will depend on technology choice and other decisions made at the procurement stage, maximum design parameters determine that up to 22.2% of array infrastructure will be located within the boundary of the Markham's Triangle rMCZ, in the context of long term habitat loss within the rMCZ (see paragraph 2.11.1.13). This assumes that a maximum of 76 offshore foundations (i.e. turbines, substations and accommodation platforms) could be placed within the part of the rMCZ which coincides with the Hornsea Three array, assuming a 1 km separation between foundations. Long term habitat loss is predicted to affect up to 0.44% of Habitat G and 2.10% of Habitat H within the rMCZ, although the proportion of Habitat H affected is likely to be an overestimate as the majority of the seabed within the rMCZ coinciding with the Hornsea Three array was characterised by Habitat G.

2.11.2.8 For the Cromer Shoal Chalk Beds MCZ, the long term habitat loss areas are based on cable protection being placed over 10% of the up to 15 km of export cables within the MCZ (i.e. the same assumptions as for the rest of the offshore cable corridor; see Table 2.13) and for seven cable crossings which occur within the MCZ boundary. As detailed in section 2.6.4, further site specific surveys within the Hornsea Three offshore cable corridor will provide further detail on the extents of qualifying MCZ habitats within the offshore cable corridor and these will be presented within the final EIA Report. As such, the figures discussed here are indicative for the PEIR. Long term habitat loss is predicted to affect up to 0.12% of Habitat G, 0.37% of Habitat H and 1.00% of Habitat I within the Cromer Shoal Chalk Beds MCZ. Discussions on the effects of Hornsea Three on the Cromer Shoal Chalk Beds are presented in volume 5, annex 2.3: MCZ Assessment.

Table 2.18: Maximum long term habitat loss for VERs within Hornsea Three.

VER	Maximum long term habitat loss within Hornsea Three array area (m²)	Maximum long term habitat loss within Hornsea Three offshore cable corridor (m²)	Total maximum long term habitat loss	
			Area (m²)	% of total area of each VER in Hornsea Three benthic ecology study area
Habitat A	2,907,810	1,348,200	4,256,010	0.21
Habitat B	2,907,810	0	2,907,810	0.27
Habitat C	2,907,810	1,348,200	4,256,010	0.41
Habitat D	0	1,348,200	1,348,200	0.01

Table 2.19: Maximum long term habitat loss of VERs qualifying as features of protected areas within Hornsea Three.

Protected Area	VER	Maximum long term habitat loss within Hornsea Three (m²)	% of total area of each VER within MCZ
Markham's Triangle rMCZ	Habitat G	646,180 [a b]	0.44
	Habitat H	646,180 [a b]	2.10
Cromer Shoal Chalk Beds MCZ	Habitat G	180,600 [c]	0.12
	Habitat H	180,600 [c]	0.37
	Habitat I	180,600 [c]	1.00

a Habitat loss entirely within Hornsea Three array.

b Assumes up to 22.2% of array infrastructure will be placed within Markham's Triangle rMCZ, which is the maximum proportion that can fit within the Hornsea Three array area that overlaps with the rMCZ at minimum spacing.

c Areas are estimates based on project envelope at time of drafting of PEIR. Long term habitat loss numbers to be revised once further information on the baseline environment is collected during site specific surveys.

2.11.2.9 As discussed in paragraph 2.11.2.3, long term habitat loss is not predicted for Habitat F within the North Norfolk Sandbanks SCI. There is potential for cable protection to be used within the boundary of the SCI, all of which is considered Annex I sandbank habitat (i.e. due to the potential for sandbanks to occur in these areas). The potential area affected is predicted to be small in the context of the area of the SCI and even in the maximum design scenario of all cable protection for the Hornsea Three offshore cable corridor being placed within the SCI, along with up to 21 cable/pipeline crossings, this would equate to approximately 0.03% of the overall area of the SCI.

2.11.2.10 As indicated in the baseline characterisation (section 2.7), comparable habitats are widely distributed in the southern North Sea benthic ecology study area and in the vicinity of Hornsea Three (Tappin *et al.*, 2011; see volume 5, annex 2.1: Benthic Ecology Technical Report). Given the small spatial scales of the total long term habitat loss outlined above (i.e. 0.11% of the total Hornsea Three benthic ecology study area and 0.007% of the southern North Sea benthic ecology study area) this loss is not expected to weaken regional ecosystem functions or diminish biodiversity. During decommissioning, if these structures are removed the impacts will be reversible with the affected habitats likely to recover within similar time scales to those outlined in paragraphs 2.11.1.23 to 2.11.1.29.

2.11.2.11 The impact is predicted to be of long term duration, continuous and irreversible during the lifetime of the project. However the effects will be highly localised within Hornsea Three and it is predicted that the impact will affect receptors directly. The magnitude is therefore, considered to be minor.

2.11.2.12 Long term loss on features of the Markham's Triangle rMCZ (i.e. Habitats G and H) is predicted to be localised within the western area of the rMCZ, continuous and irreversible during the lifetime of the project. The impact will affect the receptors directly resulting in a relatively small change in the baseline condition. The magnitude is therefore, considered to be minor.

2.11.2.13 The impact of long term habitat loss within the North Norfolk Sandbanks and Saturn Reef SCI is predicted to be localised to discrete sections of the Hornsea Three offshore cable corridor, affecting a small proportion of the seabed within the SCI, with no predicted effects on qualifying reef habitats (i.e. Habitat F). The impact will be continuous and irreversible during the lifetime of the project and will affect receptors directly. The magnitude is considered to be minor.

2.11.2.14 Long term loss on features of the Cromer Shoal Chalk Beds MCZ (i.e. Habitats G, H and I) is predicted to be localised within the inshore sections of the Hornsea Three offshore cable corridor and will be continuous and irreversible during the lifetime of the project. The impact will affect the receptors directly resulting in a relatively small change in the baseline condition. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

2.11.2.15 The majority of species characterising the VERs that will potentially be affected by long term habitat loss are infaunal. These species would be lost along with the substratum, and therefore are considered to be highly intolerant of, and vulnerable to, complete habitat loss. However none of the VERs likely to be affected are rare or geographically restricted. In addition, the wide distribution of comparable habitats within the wider region suggests that component species and habitats will remain sufficiently represented. Although these habitats typically have high levels of recoverability as outlined in section 2.11.1.31, this is not applicable to this impact during the lifetime of the project.

2.11.2.16 The VERs likely to be affected by permanent habitat loss (i.e. Habitats A, B, C, D, G, H I and Species L) are deemed to be of high vulnerability and regional to national importance and there is no potential for the recoverability of the affected habitats for the lifetime of the project. The sensitivity of the benthic receptors potentially affected is therefore, considered to be high.

Significance of the effect

2.11.2.17 It is predicted that the sensitivity of the receptors is considered to be high and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

2.11.2.18 Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

Colonisation of foundations/cable protection/scour protection may affect benthic ecology and biodiversity.

Magnitude of impact

2.11.2.19 Up to 5,694,330 m² of new hard substrate habitat will be created in the Hornsea Three benthic ecology study area as a result of the installation of gravity base foundations and scour protection associated with up to 342 turbines, 12 offshore high voltage alternating current (HVAC) collector substations, plus surface protection required for up to 2113 km of inter-array, substation interconnector, export cables and cable/pipeline crossings (see Table 2.14).

2.11.2.20 Hard substrate, with the exception of cobbles and boulders, is rare within the Hornsea Three benthic ecology study area. Any increase in hard substrate, and associated increases in biodiversity, will potentially affect Habitats A, B, C, D, E, G, H and I and will be long term, lasting for the duration of the development (i.e. 25 years design life). Any effects, if they occur at all, are likely to be localised to the Hornsea Three array area and the Hornsea Three offshore cable corridor and should not be regarded as mitigation for the loss of soft substrate species associated with the installation of these structures (as described in paragraph 2.11.2.3).

2.11.2.21 The introduction of new hard substrates for the protection of cables within the Cromer Shoal Chalk beds MCZ site is predicted to occur as a result of cable protection and protection for seven cable crossings will be required within the MCZ site (see paragraph 2.11.2.8). Therefore a total 223,347 m² of new hard substrate will be installed within the MCZ. Associated increases in biodiversity will potentially affect Habitats G, H and I.

2.11.2.22 A total of 894,893 m² new hard substrate will be installed within Markham's Triangle rMCZ area. Associated increases in biodiversity will potentially affect the rMCZ features, Habitats G, H, and a total of 1,334,887 m² new hard habitat will be created in the North Norfolk Sandbanks SCI. The area calculated for habitat creation within the SCI conservatively assumes that all cable protection is placed within this area.

2.11.2.23 The impact on Habitats A, B, C, D, E, F, G, H,I, J and K is predicted to be of local spatial extent, long term duration, continuous and irreversible during the lifetime of the project. It is predicted that the impact will affect the receptors indirectly. The magnitude is therefore, considered to be minor.

Sensitivity of the receptor

2.11.2.24 Within Hornsea Three, hard substrate is largely rare and sediments are dominated by sands and coarse sediments. Therefore the introduction of up to 5,694,330 m² of hard substrate will enable the establishment of species previously not present in an environment dominated by soft sediment habitats (Kerckhof *et al*., 2011). Such 'artificial reef' structures have been suggested as having potential to enhance local populations of certain species. For example, lobster have benefitted in the Greater Wash Strategic Environmental Assessment (SEA) (Linley *et al*., 2007). This in turn can have benefits to higher trophic levels as the benthic organisms colonising the structures provide an additional food source for local fish and shellfish species. Studies at the Horns Rev offshore wind farm in Denmark have provided evidence that offshore wind farm structures are used as successful nursery habitats for the edible crab *Cancer pagurus* (BioConsult, 2006). However, any benefits are only likely to occur on a very localised basis (i.e. to habitats in close proximity to the foundation structures). The effects of artificial reef structures upon fish and shellfish receptors are discussed in chapter 3: Fish and Shellfish Ecology.

2.11.2.25 The introduction of new hard substrate will represent a potential shift in the baseline condition within the Hornsea Three benthic ecology study area and the wider southern North Sea benthic ecology study area. Although biodiversity and biomass is likely to increase, as has been observed at the Egmond aan Zee offshore wind farm (OWEZ) (Lindeboom *et al*., 2011), whether any species may be adversely affected is uncertain. Some species which are reported to have benefitted from the introduction of hard substrate due to increased substrate for attachment are those which are typical of rocky habitats and also intertidal environments. Post-construction monitoring of monopiles within the OWEZ using video footage and samples collected by divers recorded colonisation of hard substrate species in two distinct zones. The upper zone (7 to 10 m) was dominated by fast growing mussels *Mytilus edulis* (80-100% surface area coverage) and other fauna including barnacles and starfish. The mussels were estimated to be present in densities of on average 6,725 individuals m^{-2} with a biomass of 1,257 g ash free dry weight (AFDW) m^{-2}. The second, deeper zone (10 m to the seabed) was dominated by a community of anemones together with the small crustacean *Jassa* spp. (Lindeboom *et al*., 2011). The results of the post-construction monitoring surveys at the OWEZ concluded that the colonisation by these species represented an increase in biodiversity and a significant change compared to the situation if no hard substrates were present (Lindeboom *et al*., 2011). The placement of scour material will also increase the structural complexity of the substrata, providing refuge and niche habitats as well as increasing feeding opportunities for a range of larger and more mobile species.

2.11.2.26 An investigation conducted at the research platform Forschungsplattformen in Nord- und Ostsee 1 FINO 1 in the south western German Bight in the North Sea reported similar findings with respect to epifaunal communities colonising offshore foundations (Krone *et al*., 2013) where the blue mussel *M. edulis*, Anthozoa and *Jassa* spp. were found to be the dominant species. The 1 m zone was dominated by a *Mytilus* community, and approximately half of the total biomass (4,300 kg on average) was attached to the 1 m zone (Krone *et al*., 2013). Although *M. edulis* is common in the North Sea, it has generally not been found to settle in significant numbers on entirely submerged shipwrecks; this is in comparison to offshore constructions which have intertidal zones where settlement is much higher. The investigation also found that yearly, 878,000 single shell halves sink onto the seabed from the FINO 1 platform, thereby greatly extending the reef effects created by the construction of the offshore platform structure (Krone *et al*., 2013). In turn, the presence of mussels provides a secondary substrate for the attachment of other epifaunal species (Norling and Kautsky, 2007) and in the long-term the production of shell debris may lead to coarser, shell-dominated sediment and enriched structure diversity. However, the extent to which *Mytilus* colonisation may occur is highly dependent on the nature of the structures installed and site-specific effects. For example, artificial intertidal habitats further offshore and outside the distributional range of *M. edulis* larvae may be colonised less strongly. Although, the higher abundances of the predating *A. rubens* in coastal waters may counteract high larval support and spat fall (i.e. the settling and attachment of bivalves to the substrate) capacity in these areas.

2.11.2.27 Given the presence of epifaunal species and colonising fauna within discrete parts of the Hornsea Three benthic ecology study area already (i.e. associated with coarser sediment habitats), it is predicted that colonisation of hard substrates by common species such as bryozoans and ascidians will occur.

2.11.2.28 The subtidal chalk habitat and peat and clay exposures within the Cromer Shoal Chalk Beds MCZ (Habitats J and K) are not considered to be sensitive to the introduction of new hard substrate. The existing communities associated with the chalk substrate predominantly comprise an epifaunal assemblage, therefore the potential introduction of epifaunal communities associated with the new hard substrate is unlikely to incur a significant impact on the function of the present community. The receptors are not considered vulnerable; the sensitivity of the receptors is therefore considered to be **negligible**.

2.11.2.29 The receptors likely to be affected, Habitats A, B, C, D, are deemed to be of low vulnerability and regional value; the sensitivity of the receptors is therefore, considered to be **low**.

2.11.2.30 Habitats G and H, which are protected features in Cromer Shoal Chalk Beds MCZ and recommended features in Markham's Triangle rMCZ, Habitat I, also a protected feature in Cromer Shoal Chalk Beds MCZ, plus Habitats E and F, the primary features for which North Norfolk Sandbanks and Saturn Reef SCI, are deemed to be of low vulnerability and national to international value. The sensitivity of the receptors is therefore, considered to be **low**.

2.11.2.31 In terms of potential negative effects, the introduction of hard substrate into a predominantly soft sediment area can facilitate the spread of invasive and non-native species (INNS). Effects of introduction of INNS are discussed in paragraph 2.11.2.35 to paragraph 2.11.2.50.

Significance of the effect

2.11.2.32 Any beneficial effects associated with an increase in biodiversity will be highly localised in nature and is not regarded as mitigation for the loss of species associated with the installation of these structures. The species likely to benefit is uncertain. Similarly, whether any negative effects may occur (i.e. from increased competition and predation) is also uncertain.

2.11.2.33 It is predicted that the sensitivity of Habitats J and K is **negligible** and the magnitude of the effect is deemed to be **minor**. The effect will, therefore, be **negligible**, which is not significant in EIA terms.

2.11.2.34 It is predicted that the sensitivity of Habitats A, B, C, D, E, F, G, H, I is **low** and the magnitude of the effect is deemed to be **minor**. The effect will, therefore, be of **minor** adverse or beneficial significance, which is not significant in EIA terms.

Increased risk of introduction or spread of INNS due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity.

2.11.2.35 As discussed in paragraph 2.11.2.19, up to 5,694,330 m² of new hard substrate habitat (foundations, cable protection and scour protection) will be created in the Hornsea Three benthic ecology study area, which will provide new habitat for the potential colonisation by INNS. There will be up to 2,832 round trips to port by operational and maintenance vessels, which will contribute to the risk of introduction or spread of INNS in ballast water (see Table 2.13). Designed-in measures including a biosecurity plan, a PEMMP and vessels complying with the International Maritime Organization (IMO) ballast water management guidelines (Table 2.17) will ensure that the risk of potential introduction and spread of INNS will be minimised.

2.11.2.36 Habitats A, B, C, G and H within the Hornsea Three array area are more likely to be at greater risk of impact by the introduction of INNS for two reasons. Firstly, the majority of the new surface area available for colonisation will be associated with the turbines and array cables within the Hornsea Three array. Secondly, the array will be subjected to higher risk of introduction of INNS by ballast water, as construction vessels will be focussed on the turbines and the majority of up to 11,566 vessel movements during the construction phase to port by construction vessels will to the Hornsea Three array. Similarly, the majority of the 2,832 round trips over 25 years to port by operational and maintenance vessels will to the Hornsea Three array.

2.11.2.37 Habitats A, C, D, E, F, G, H, I, J and K along the Hornsea Three offshore cable corridor, including within North Norfolk Sandbanks and Saturn Reef SCI and Cromer Shoal Chalk Beds MCZ, are likely to be subjected to a lower risk of INNS introduction as only the export cables will be installed along the Hornsea Three offshore cable corridor, which will be buried for the most part. A maximum of 10% of the length of the Hornsea Three offshore cable corridor and up to 37 cable/pipeline crossings will have rock protection; use of cable protection within the SCI and MCZ will be limited, where possible. However, for the North Norfolk Sandbanks and Saturn Reef SCI the parameters of the maximum design scenario comprise habitat creation of a total area of 1,334,887 m², which assumes all cable protection for the offshore cable corridor is located within the SCI and protection for 21 cable crossings of 400 m in length. Within the Cromer Shoal Chalk Beds MCZ the total habitat created would comprise seven cable crossings and would cover a maximum area of 145,435 m².

2.11.2.38 The risk of introduction of INNS by ballast water will be considerably lower than at the Hornsea Three array, as only a limited number of round trips by operational and maintenance vessels will be required for the Hornsea Three offshore cable corridor and over a greater geographic area.

2.11.2.39 The impact on Habitats A, B, C, D, E, F, G, H, I, J and K is predicted to be of local spatial extent (though the introduction of structures may serve as 'stepping stones' and extend the impact on a regional, national, or international scale, however it is not possible to predict such a spread, as such knowledge is currently limited), long term duration, continuous and irreversible. It is predicted that the impact will affect the receptors indirectly. The magnitude is therefore considered to be **negligible**.

Sensitivity of the receptor

2.11.2.40 The introduction of hard substrate into a predominantly soft sediment area can facilitate the spread of non-native species which may predate on, and compete with, existing native species (Inger *et al*., 2009). Recent studies have demonstrated the potential for offshore renewable energy devices to act as ecological 'stepping stones', facilitating the spread of pelagic larval particles that would otherwise have been lost offshore and allowing the transgression of natural biogeographical boundaries (Adams *et al*., 2014). However, there is little evidence from post construction monitoring undertaken to date to suggest that the hard structures associated with offshore wind farms provide any new or unique opportunities for non-indigenous species which could facilitate their introduction (Linley et al., 2007). A study by Kerckhof *et al*. (2011) of colonisation of Belgian offshore wind farm structures found that creating a new intertidal habitat in an offshore environment resulted in non-indigenous species constituting a major part (approximately one third) of the intertidal colonists. All of the non-indigenous species observed, however, were already known to occur in the southern North Sea. These included the barnacles *Elminius modestus* and *Balanus perforatus*, the marine splash midge *Telmatogeton japonicas*, and the amphipod *Jassa marmorata*. Only one non-native species, the invasive American slipper limpet *Crepidula fornicata*, was found subtidally on the turbine columns (Kerckhof *et al*., 2011). *C. fornicata* can be a threat to muddy, mixed and clean sandy biotopes (Blanchard, 1997; De Montaudouin & Sauriau, 1999) though the availability of hard structures and particularly sediments with high gravel or shell content can support high densities of this gastropod (Bohn *et al*., 2015).

2.11.2.41 The carpet sea squirt *Didemnum vexillum*, believed to be native to Japan, was recorded in Holyhead in 2008 and was the first known occurrence of this organism in the United Kingdom (UK). The limited evidence of the distribution of this species within the in the UK suggests that *D. vexillum* is currently restricted to artificial surfaces in the UK. However, while mobile sands are unsuitable for growth, *D. vexillum* may have the potential to colonise and dominate offshore gravel habitats and has been recorded as covering over 50% of the seabed in parts on Georges Bank on the US/Canadian border (Valentine *et al*., 2007). A risk assessment undertaken by the Non-native Species Secretariat in 2011 (www.nonnativespecies.org/index.cfm?sectionid=51) on the threat that this particular organism poses to Great Britain concluded that entry and introduction were very likely, spread would be rapid and the impact would be massive. A biosecurity plan has been adopted as a designed-in measure (Table 2.17) to ensure the likelihood of spreading this organism during the Project, and all other INNS, is limited.

2.11.2.42 Non-indigenous species currently co-exist with indigenous species in the region, as demonstrated by the fact that *C. fornicata* was identified within the Hornsea Three benthic ecology study area. Post-construction monitoring of the monopile structures at the OWEZ using video footage and samples collected by divers recorded colonisation by introduced/non-indigenous species including Japanese oyster *Crassostrea gigas*, slipper limpet and the Titan acorn barnacle *Megabalanus coccopoma* (Lindeboom *et al*., 2011).

2.11.2.43 Post construction monitoring of the Barrow offshore wind farm monopiles found no evidence of invasive or non-native species and similarly, studies of the Kentish Flats monopiles identified only *C. fornicata* (Cefas, 2009). The non-indigenous Japanese skeleton shrimp *Caprella mutica* was recorded at the Horns Rev offshore wind farm and despite its ability to rapidly colonise the turbine structures only negligible effects were observed on native communities and these resulted from an increase in local biodiversity and food availability rather than from negative effects (e.g. competition and predation) associated with the non-indigenous species (Bioconsult, 2006). The capacity for introduced hard substrate to facilitate the introduction and spread of non-indigenous species (e.g. via stepping stone effects) could potentially affect all subtidal VERs within the Hornsea Three benthic ecology study area.

2.11.2.44 Habitats A, B, C, G and H within the Hornsea Three array area are considered more sensitive to impacts by the introduction of INNS as the installation of hard surfaces associated with Hornsea Three will essentially introduce a new type of habitat to the predominantly soft sediments of the Hornsea Three array area. As such, there will only be a limited local epifaunal community which will be able to colonise the new habitat resource, therefore any introduced INNS will face minimal competition and will be more likely to establish local populations. According to MarLIN sensitivity review (De-Bastos and Marshall, 2016; Tillin, 2016a; Tillin, 2016b; Tillin and Rayment, 2016) some biotopes within these habitats are sensitive to colonisation by INNS, including *Caprella mutica*, *D. vexillum* and in particular *C. fornicata*.

2.11.2.45 Habitats F, J and K are generally not considered sensitive to impacts by INNS, according to MarLIN sensitivity information (Tillin and Marshall, 2015; Tillin and Hill, 2016). Habitats J and K within the Cromer Shoal Chalk Bed MCZ are less likely be affected by the introduction of hard surfaces as some of the epifaunal species associated with these habitats are likely to compete with, and possibly dampen, efforts by INNS to colonise the newly available habitat resource; many of the species found on chalk and clay are commonly associated with other habitats and are mobile or rapid colonisers (Tillin and Hill, 2016). The communities of soft substrates within Habitats J and K tend to have a low biodiversity as the substrate is too hard for species normally associated with sediments, and too soft for epiphytic flora and fauna to attach to (Tillin and Hill, 2016).

2.11.2.46 Habitats A, B, C, D, E, G, H and I and Species L are deemed to be of medium vulnerability and regional to national value. The sensitivity of these receptors is therefore, considered to be medium.

2.11.2.47 Habitats F, J and K are deemed to be of low vulnerability and national to international value. The sensitivity of these receptors is therefore, considered to be low.

Significance of the effect

2.11.2.48 There is little evidence from other offshore wind farm developments within the North Sea of non-indigenous species having any adverse effects on key species and habitats. It is predicted that the sensitivity of Habitats A, B, C, D, E, G, H and I and Species L is medium and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

2.11.2.49 It is predicted that the sensitivity of Habitats F, J and K is considered to be low and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

2.11.2.50 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

Alteration of seabed habitats arising from effects on physical processes, including scour effects and changes in the wave and tidal regimes resulting in potential effects on benthic ecology.

Magnitude of impact

2.11.2.51 See chapter 1: Marine Processes for assessments of changes to waves (both in isolation and cumulatively), scour and tidal currents. In this section, the term 'local scour' refers to the local response to individual structure members. 'Global scour' refers to a region of shallower but potentially more extensive scour associated with a multi-member foundation resulting from the change in flow velocity through the gaps between members of the structure and turbulence shed by the entire structure. Global scour does not imply scour at the scale of the wind farm array (chapter 1: Marine Processes).

2.11.2.52 The presence of Hornsea Three would result in near-field current effects only (i.e. primarily within the offshore wind farm footprint), largely spatially limited to within the Hornsea Three array area and a narrow region just outside of the boundary (in the order of 4 km; see chapter 1: Marine Processes) with predicted maximum changes in current speeds varying from +0.04 ms^{-1} to -0.1 ms^{-1}. Baseline tidal currents across the former Hornsea Zone vary from approximately 0.6 ms^{-1} (at High Water) to 1 ms^{-1} (at Low Water) for peak mean spring tides and as such the existing tidal strength can be classified as moderately strong (McLeod, 1996). As outlined in volume 1, chapter 3: Project Description, scour protection will be installed around foundations to reduce scour. Cables and cable protection along the offshore cable corridor and within the Hornsea Three array area will only exert a highly localised influence on the tidal regime.

2.11.2.53 Scour development within the Hornsea Three array area is expected to be dominated by the action of tidal currents, and wave action is considered insufficient for scour around monopiles and jacket foundations. Of all of the turbine foundation options, scour effects (vertical and horizontal) are predicted to be greatest for a 15 m diameter monopile structure (without scour protection), with a local scour depth of 19.5 m and local scour extent of 31.2 m in non-cohesive soil (31.2 m; see chapter 1: Marine Processes). Note that the maximum depth of scour is calculated using all maximum design assumptions about the development of scour and is the result of applying standard formulae. The scour dimensions described above will not necessarily manifest in real terms.

2.11.2.54 The greatest individual foundation global scour extent is predicted to be 40.0 m, which is associated with the larger (40 m base length) piled jacket structure (see chapter 1: Marine Processes).

2.11.2.55 For GBFs, the maximum predicted scour depth under currents alone for 41 m diameter design is 1.6 m. Scour due to waves is likely to result in a scour depth of 2.1 m scour for the same diameter structure, while a combined wave and current scour depth is predicted to be 3.4 m. For the 41 m diameter gravity bases, the scour hole extent is estimated to be 2.5 m (chapter 1: Marine Processes).

2.11.2.56 For the Hornsea Three array area as a whole, the greatest total turbine foundation local scour footprint is associated with an array of 160 (15 m diameter) monopile foundations (724,801 m^2, equivalent to approximately 0.1% of the array area).

2.11.2.57 For the Hornsea Three array area as a whole, the greatest total turbine foundation global scour footprint is associated with an array of 342 smaller (32 m base diameter) piled jacket foundations (1,091,787 m^2, equivalent to approximately 0.16% of the array area).

2.11.2.58 The presence of the turbine foundations and associated infrastructure also has the potential to affect the wave regime which could lead to potential impacts on coastal habitats and offshore sandbanks such as those associated with Habitat G (Annex I 'sandbanks which are slightly covered by seawater all the time' within an SAC) found within the North Norfolk Sandbanks and Saturn Reef SCI. However, the results of wave assessment presented in volume 5, annex 1.1: Marine Processes Technical Report, indicates that although the presence of Hornsea Three will cause a localised reduction in wave heights, under all the wave conditions tested (magnitudes and directions), predicted measurable changes to wave heights due to the operational presence of Hornsea Three do not extend to the adjacent coastlines. Therefore, no effects are predicted on habitats within The Wash and North Norfolk Coast SAC or the North Norfolk Coast SAC. With respect to offshore sandbanks the results of the wave modelling predict a general reduction in wave height in the region of the north Norfolk sandbanks when waves are coming from the north, north northeast and north east, which is about 15% of the time. During these conditions, there may be a small reduction in wave height of up to 15% % within the vicinity of the Indefatigable Bank system and up to ~2.5% in the vicinity of sandbanks closer inshore (e.g. Ower Bank; see chapter 1: Marine Processes). Whilst impacts to sandbanks could theoretically occur throughout the operational lifetime of Hornsea Three (i.e. be of long term duration), any impacts would be intermittent in nature.

2.11.2.59 Within the Hornsea Three array, although the impact from a change in marine processes is predicted to be of long term duration, continuous, and irreversible for the lifetime of the project, it is expected to be of local spatial extent (i.e. restricted to Hornsea Three array and the immediate surrounding area). It is predicted that the impact will affect the benthic receptors (Habitats A, B, C, G and H and Species L) directly. The magnitude within Hornsea Three array is therefore, considered to be minor.

2.11.2.60 Predicted impacts along the Hornsea Three offshore cable corridor will be similar to the Hornsea Three array, but of a significantly reduced extent. Again, the impact is predicted to be of long term duration, continuous and irreversible for the lifetime of Hornsea Three, but of highly localised extent. It is predicted that the impact will affect the benthic receptors (Habitats A, B, C, D, E, F, G, H, I, J, K and Species L) directly. The magnitude along the Hornsea Three offshore cable corridor is therefore, considered to be negligible.

Sensitivity of receptor

2.11.2.61 All VERs are likely to be affected by changes to flow rate, wave regime and increased scour found within, and immediately adjacent to, the boundary of Hornsea Three array and along the Hornsea Three offshore cable corridor (i.e. Habitats A, B, C, D, E, F, G, H, I, J, K and Species L).

2.11.2.62 Habitats A, C, G and H are characteristic of areas subject to physical disturbance by weak to moderately strong tidal streams or as a result of wave action and have typically intermediate to high intolerance to large increases and decreases in flow rates. In very strong currents little sediment deposition will take place resulting in coarse sediments that retain little organic matter. The polychaete species characteristic of these habitats are less likely to be affected by increased water flow rate as these species burrow deeper and hunt infaunally (Budd 2008a). Burrowing species, such as the amphipod *Bathyporeia pilosa* and key species such as the bivalve *F. fabula* and the polychaetes *Magelon*a sp. are deposit feeders and show a preference for finer sediments. As such, these species may be lost with a shift in the community to one representative of coarser sediments (Rayment, 2008a). Decrease in water flow, may lead to increased fine sediment deposition, also changing the nature of the substrate to one which favours deposit feeders, therefore resulting in changes to species composition (Budd, 2008a; Rayment, 2008a). Recoverability of these habitats is likely to be high to very high on return to prior conditions, but this is not considered relevant for the duration of the operation period. Species L, due to the depths in the sediment in which this species lives, has low intolerance and high recoverability to changes in flow rate (Sabatini *et al*., 2008).

2.11.2.63 The brittlestar dominated communities of Habitat B, which was found in deeper waters, are typically associated with areas of weak or very weak tidal streams and so are likely to have high intolerance to changes in water flow. Characterising species such as *A. filiformis* are suspension feeders with no self-produced feeding current, as such; water flow rate is likely to be of primary importance to these species. In increased flow rates *A. filiformis* may be unlikely to maintain their arms vertically in the feeding position and over the long term the nature of the top layers of sediment may become coarser and therefore possibly unsuitable for shallow burrowing species such as brittlestars. Reduced flow rates can impede feeding because it may reduce the transport of organic particles (Hill, 2004). Recoverability of these habitats is likely to be high to very high on return to prior conditions, but this is not considered relevant for the duration of the 25 year design life.

2.11.2.64 Habitat D has high intolerance to increases and decreases in flow rate. The tubes of *S. spinulosa* would likely be broken up and redistributed along with much of the infauna and epifaunal species attached to the *S. spinulosa* aggregations in areas of flow increase. As a result, many of the species would be at increased risk of predation at the surface and declines in species richness may be observed (Marshall, 2008). Decreases in flow rate are likely to hinder growth and repair of *S. spinulosa* tubes and reduce food availability for suspension feeders and deposit feeders. However, recovery of this habitat is likely to be high on return to prior conditions, as discussed in paragraph 2.11.1.28, but this is not considered relevant for the duration of the 25 year design life. Changes to the hydrodynamic regime may also affect sediment and/or *S. spinulosa* larval supply, however, this is considered unlikely due to the small predicted changes to current flow across the Hornsea Three array area.

2.11.2.65 Habitats J and K have low to no sensitivities to flow rates (depending on the particular biotopes considered) and are not sensitive to wave exposure changes (De-Bastos and Hill, 2016; Tillin and Hill, 2016). The CR.MCR.SfR.Pid: 'Piddocks with a sparse associated fauna in sublittoral very soft chalk or clay' biotope has been recorded in locations with tidal flow rates ranging from 0.5 to 1.5 ms^{-1} (Connor *et al*., 2004), which is within the baseline tidal current for the Hornsea Three benthic ecology study area (see paragraph 2.11.2.52), and taking into account the maximum changes in current speeds resulting from Hornsea Three. These habitats are also typically located in extremely sheltered to moderately wave exposed locations (Connor *et al*., 2004, De-Bastos and Hill, 2016; Tillin and Hill, 2016), indicating that these habitats are not susceptible to minor changes in wave regimes.

2.11.2.66 It is important to note that the predicted changes in water flow rates as a result of Hornsea Three (see chapter 1: Marine Processes) are much lower than the MarLIN benchmark used to inform the assessment summarised above. The benchmark is a change of two categories of water flow rate for one year and, as this is not predicted to occur (see paragraph 2.11.2.58), significant effects on communities, such as some of the effects described above, are not likely to occur.

2.11.2.67 Habitats A, B, C and D and Species L are deemed to be of low to medium vulnerability and regional value. The sensitivity of the receptors to the magnitude of changes predicted is therefore, considered to be **low**.

2.11.2.68 By definition, subtidal mobile sandbanks are subject to continued reworking of the sediment by wave action and tidal streams and thus are dominated by species capable of tolerating severe changes in the hydro-physical regime (Elliott *et al*., 1998). Sensitivity of the benthic communities associated with Habitats E and F are considered to be identical to Habitat A and D, respectively, however these features are of international importance and are therefore considered to be of **medium** sensitivity. This reflects the assessment of the Annex I sandbank features of the North Norfolk Sandbanks and Saturn Reef SCI in chapter 1: Marine Processes, for changes to the wave regime impact.

2.11.2.69 Sensitivity of the features of the Markham's Triangle rMCZ, i.e. Habitats G and H, are considered to be identical to Habitats A and C, respectively, as noted in paragraph 2.11.1.33. However these habitats are of national importance and therefore are considered to be of **medium** sensitivity.

2.11.2.70 Sensitivity of Habitats G, H and I, which are features of the Cromer Shoal Chalk Beds MCZ, are considered to be identical to Habitats A, C and D, respectively, as noted in paragraph 2.11.1.35. However these habitats are of national importance and therefore are considered to be of **medium** sensitivity.

2.11.2.71 Sensitivity of Habitats J and K of the Cromer Shoal Chalk Beds MCZ are deemed to be of low vulnerability and are of national value. The sensitivity of the receptor is therefore, considered to be **low**.

<u>Significance of the effect</u>

2.11.2.72 The predicted changes to flow rate are small and below the MarLIN benchmark levels used to assess the sensitivity of the receptors. Although effects may be observed they are likely to be more subtle than those described above. Benthic species in the area are tolerant to a certain degree of instability, as well as fluctuating levels of suspended sediments and variable sediment deposition rates, arising from scour and/or small changes in the local wave and tide regime. The effect on all subtidal VERs (including features of the SCI, MCZ and rMCZ sites) is therefore considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.11.2.73 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

Maintenance operations may result in temporary seabed disturbances and potential effects on benthic ecology.

<u>Magnitude of impact</u>

2.11.2.74 The operation and maintenance phase is assumed to involve up to 87 jack-up operations per year over the 25 year design life of Hornsea Three (total of 2,175 jack-up operations (87 x 25)), which will lead to a total area of temporary habitat disturbance of up to 2,218,500 m^2 (Table 2.13), equating to 0.06% of the Hornsea Three benthic ecology study area. Impacts will be limited to the immediate area around the turbine foundations, where spud-can legs will come into contact with benthic habitats. The spatial extent of this impact is very small in relation to the total area of Hornsea Three. Similarly, subtidal cable reburial/repair works (if and when necessary) will affect habitats in the immediate vicinity of cable reburial operations. As outlined in volume 1, chapter 3: Project Description, it is expected that, on average, the subsea cables will require up to two visits per year for the first three years, reducing to yearly thereafter for preventative maintenance including routine inspections to ensure the cable is buried to an adequate depth. Additional visits may be required by specialised vessels should remedial measures be required, although it is not possible to accurately quantify the area potentially affected.

2.11.2.75 As described in paragraph 2.11.1.7, the VERs that would be affected by operational jack-up and cable reburial operations are restricted to those within the boundary of the Hornsea Three array area and along the Hornsea Three offshore cable corridor (i.e. Habitats A, B C, D, E, G, H, I) and also Species L. During the construction phase, the maximum design scenario for jack-up operations in relation to benthic VERs is that all of this temporary habitat loss/disturbance (i.e. 2,218,500 m^2) occurs wholly within either Habitat A (0.11%), B (0.44%), C (0.21%), D (2.09%), E (0.22%), G (0.76%), H (4.55%), I (4.53%), of the total area of these VERs in the Hornsea Three benthic ecology study area. The temporary disturbance to habitats along the Hornsea Three offshore cable corridor as a result of cable reburial will be of a much smaller magnitude than that described in paragraph 2.11.1.7 for the construction phase.

2.11.2.76 With respect to available habitat for Species L, the total area of temporary habitat loss during the operational phase represents a very small percentage loss (0.0003%) of the total area of the OSPAR Region II within which *A. islandica* is listed as under threat and/or decline.

2.11.2.77 Temporary seabed disturbance will be avoided where possible to minimise any direct impacts on Habitats F. Pre-construction surveys are to be undertaken along the Hornsea Three offshore cable corridor to identify these discrete benthic habitats of conservation importance, and appropriate mitigation will be discussed and agreed with statutory consultees to avoid direct impacts on these features (see Table 2.17).

2.11.2.78 The impact on Habitats A, B C, D and E and Species L is predicted to be of local spatial extent, short term duration (i.e. individual maintenance operations would occur over the period of days to weeks), intermittent and reversible. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be **negligible**.

2.11.2.79 The impact on the features of Markham's Triangle rMCZ (i.e. Habitats G and H) in the western area of the rMCZ is predicted to be of local spatial extent, short term duration (i.e. individual maintenance operations would occur over the period of days to weeks), intermittent and reversible. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be **negligible**.

2.11.2.80 The impact on the features of Cromer Shoal Chalk Beds MCZ (i.e. Habitats G, H and I) is predicted to be of local spatial extent, short term duration (i.e. individual maintenance operations would occur over the period of days to weeks), intermittent and reversible. No impact is predicted on Habitat J and K due to this operational impact, as any cable installation effects in these habitats during the construction phase will be irreversible. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be **negligible**.

Sensitivity of receptor

2.11.2.81 As discussed in paragraphs 2.11.1.25 to 2.11.1.31, Habitats A to D have typically low to intermediate intolerance to physical disturbance as the characterising species are predominantly infaunal. However, recovery in all respects is likely to be high as the component species are highly mobile, tolerant of sediment movement and would accompany the influx/re-settlement of disturbed material (Budd, 2008a; Rayment, 2008a; Rayment 2008b). As such, nothing more than minor localised declines in species richness are predicted as a result of maintenance jack-up and cable re-burial operations. In addition, the frequency of maintenance jack-up operations (i.e. approximately six over the lifetime of a turbine) will allow for the recovery of benthic communities between these events.

2.11.2.82 No direct impacts as a result of temporary seabed disturbance are predicted on Habitats F. Pre-construction surveys are to be undertaken along the Hornsea Three offshore cable corridor to identify these discrete benthic habitats of conservation importance, and appropriate mitigation will be discussed and agreed with statutory consultees to avoid direct impacts on these features (see Table 2.17).

2.11.2.83 Habitats A, B, C, D are deemed to be of low to medium vulnerability, high recoverability and regional value. The sensitivity of the receptor is therefore, considered to be **low**.

2.11.2.84 Habitats G and H, which are protected features in Cromer Shoal Chalk Beds MCZ and recommended features in Markham's Triangle rMCZ, Habitat I, also a protected feature in Cromer Shoal Chalk Beds MCZ, plus Habitat E, the primary feature for which North Norfolk Sandbanks and Saturn Reef SCI, are deemed to be of low to medium vulnerability, high recoverability and national to international value. The sensitivity of the receptor is therefore, considered to be **medium**.

2.11.2.85 As discussed in paragraph 2.11.1.32, Species L (*A. islandica*) has intermediate intolerance to displacement and abrasion/physical disturbance but would be expected to bury itself back into the sediment quickly and as such recoverability is predicted to be high (Sabatini *et al*., 2008). In addition, the historic benthic ecology surveys did not suggest that the Hornsea Three area is particularly important for this species. *A. islandica* is deemed to be of medium vulnerability, medium to high recoverability and national value. The sensitivity of this receptor is therefore, considered to be **low**.

Significance of the effect

2.11.2.86 The area of benthic habitat affected by operational jack-up operations and cable reburial on Habitats A, B, C and D and Species L, will be very small and highly localised in nature. The VERs affected have low to medium sensitivity to, and medium to high recoverability from, jack-up operations and physical disturbance. The effect is therefore considered to be of negligible significance, which is not significant in EIA terms.

2.11.2.87 It is predicted that the sensitivities of Habitats A, B, C, D and Species L are **low** and the magnitude of the effect is deemed to be **negligible**. The effect will, therefore, be of **negligible** significance, which is not significant in EIA terms.

2.11.2.88 It is predicted that the sensitivities of Habitats E, G, H, I are **medium** and the magnitude of the effect is deemed to be **negligible**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

2.11.2.89 Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.

Magnitude of impact

2.11.2.90 The magnitude of the impact is entirely dependent on the nature of the pollution incident but the SEA carried out by DECC (2011c) recognised that, "renewable energy developments have a generally limited potential for accidental loss of containment of hydrocarbons and chemicals, due to the relatively small inventories contained on the installations (principally hydraulic, gearbox and other lubricating oils, depending on the type of installation)".

2.11.2.91 A typical turbine (nominal output 7 MW) is likely to contain approximately 1,300 l of grease, 20,000 l of hydraulic oil, 2000 l of gear oil, 80,000 l of liquid nitrogen, 7,000 kg of transformer silicon/ester oil, 2,000 l of diesel and 13,000 l of coolant. The nacelle, tower, and hub will be designed to retain any leaks, thus reducing the risk to the marine environment. With respect to leachate from anodes, dissolved zinc from anodes is toxic to marine life at low concentrations; the Environmental Quality Standard (EQS) is 40 µg/l (annual mean value), but no such EQS currently exists for aluminium. The concentrations of zinc and aluminium released into the marine environment from sacrificial anodes are likely to be minimal and well below the EQS for zinc.

2.11.2.92 A potential for accidental spills will also occur as a result of the 2,382 round trips to port by maintenance and operational vessels and up to 25,234 round trips by helicopter over the 25 year design life of the project (Table 2.21). However, as the majority of these vessels will be crew/supply vessels and helicopters, these will be typically small and will therefore be carrying only limited amounts of potential contaminants. Although larger operational and maintenance vessels may contain larger quantities of potential pollutants (e.g. jack up vessels) such as diesel oil, movements of these vessels will be far fewer in comparison to smaller vessels.

2.11.2.93 Throughout operation there will be the requirement to store fuel offshore for the purposes of refuelling crew transfer vessels and/or helicopters, this storage will be on up to three of the offshore accommodation platform barges (Table 2.21). An impact upon benthic ecology receptors would only be realised if an incident occurs where the fuel is accidentally released. The historical frequency of pollution events in the southern North Sea benthic ecology study area is low considering the density of existing marine traffic in the area. Given the designed-in mitigation (see Table 2.17) which is proposed (i.e. a PEMMP), it is considered that the likelihood of accidental release is extremely low. Furthermore, the likelihood of a collision between vessels resulting in an accidental spill during the operation and maintenance period will be further reduced by the HSE MS which will be developed and implemented by DONG Energy which incorporates the elements of the ASMS, as required by MGN 371 (see chapter 7: Shipping and Navigation).

2.11.2.94 The risk of an accidental pollution event upon subtidal benthic receptors is predicted to be of local to regional spatial extent, short term duration (i.e. in the unlikely event that a spillage occurs, the impact would last hours to days), intermittent and reversible. It is predicted that the impact would affect benthic receptors directly and/or indirectly, but that the likelihood of an accidental pollution incident occurring is small. The magnitude is therefore, considered to be **negligible**.

Sensitivity of receptor

2.11.2.95 All of the subtidal VERs that would be potentially affected by the accidental release of pollutants (i.e. Habitats A, B, C, D, E, F, G, H, I, J and K and Species L) are identified as having intermediate to high intolerance to synthetic compound and hydrocarbon contamination, with localised declines in species richness likely as a result of this type of contamination, as discussed in paragraph 2.11.1.63. The recoverability of these communities is however likely to be moderate to high due to the life history characteristics of the component species (see paragraphs 2.11.1.23 to 2.11.1.29), although this is based on limited experimental data (see paragraph 2.11.1.63). Recoverability is likely to be assisted by the hydrodynamic regime in the offshore parts of Hornsea Three which would lead to rapid dispersion of pollutants, reducing the probability of a severe pollution event (Elliott *et al*., 1998).

2.11.2.96 Habitats A to D are deemed to be of medium vulnerability, high recoverability and regional value. However, due to the high potential for dilution and dispersal offshore, the sensitivity of the subtidal receptors is therefore, considered to be **low**.

2.11.2.97 Habitats E to K and Species L are deemed to be of medium vulnerability, high recoverability and national and international value. The sensitivity of the receptors is therefore, considered to be **medium**.

Significance of the effect

2.11.2.98 Provided published guidelines, best working practices and the mitigation measures outlined in Table 1.19 (i.e. implementation of a PEMMP) are adhered to, the likelihood of an accidental spill is extremely low and, in the event of a spill, the volumes of potential contaminants released would be small and rapidly dispersed to concentrations below which deleterious effects would be expected.

2.11.2.99 Therefore the effect of accidental release of pollutants on subtidal benthic receptors (Habitats A, B, C, D E, F, G, H, I, J and K and Species L) is considered to be of **negligible** significance, which is not significant in EIA terms.

2.11.2.100 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

2.11.3 Decommissioning phase

2.11.3.1 The impacts of the offshore decommissioning of Hornsea Three have been assessed on benthic ecology. The environmental effects arising from the decommissioning of Hornsea Three are listed in Table 2.13 along with the maximum design scenario against which each decommissioning phase impact has been assessed.

2.11.3.2 A description of the potential effect on benthic ecology receptors caused by each identified impact is given below.

Temporary loss of habitat due to operations to remove array cables, substation interconnector cables and export cables, and jack-up operations to remove foundations, resulting in potential effects on benthic ecology.

2.11.3.3 The nature and extent of temporary habitat loss/disturbance during decommissioning (i.e. from cable removal operations and working areas etc.) is likely to be similar or the same as that described for the same activities during the construction phase in paragraphs 2.11.1.3 to 2.11.1.39 (i.e. cable installation, anchor placements and jack-up operations). However it should be noted that this approach is considered precautionary as there is no statutory requirement for decommissioned cables to be removed. Therefore, cables may be left buried in place or alternatively partially removed by pulling the cables back out of the ducts (see volume 1; chapter 3: Project Description). Such details will be included within the Decommissioning Programme which will be developed to minimise environmental disturbance and will be updated throughout the lifetime of Hornsea Three to account for changing best practice.

2.11.3.4 Decommissioning operations to remove array cables, accommodation platform power cables, export cables (subtidal and intertidal), including associated anchor placements, and jack-up operations to remove all foundations have the potential to cause temporary loss of, or disturbance to, benthic habitats within Hornsea Three, similar to those described during the construction phase. However, as seabed preparation works would not be required, the magnitude of this impact will be lower than during the construction phase, as described below in paragraph 2.11.3.6 to 2.11.3.14.

Magnitude of impact

2.11.3.5 The total maximum area of intertidal temporary direct habitat loss/disturbance that may be affected by cable removal is approximately 271,914 m^2. This is the area predicted for maximum impact during construction, so decommissioning works are likely to be substantially lower than this. As no VERs were recorded at the Hornsea Three landfall, due to the barren nature of the sediments (see section 1.7.2), the effect of intertidal habitat loss on benthic ecological receptors is not considered further for this impact.

2.11.3.6 The magnitude of subtidal temporary habitat loss/disturbance is predicted to be lower than that described for the construction phase in paragraphs 2.11.1.3 *et seq.*, as seabed preparation works and/or drilling will not be required. The total maximum area of subtidal temporary direct loss/disturbance due to the decommissioning activities described above and in Table 2.13 is predicted to be 27,377,024 m^2. This equates to 0.04% of the total seabed area within the southern North Sea benthic ecology study area and 0.74% of the Hornsea Three benthic ecology study area. The impacts on subtidal habitats will occur intermittently throughout the decommissioning phase.

2.11.3.7 The subtidal benthic VERs likely to be affected by decommissioning activities are the same as described in paragraph 2.11.1.10. The total maximum potential temporary losses of each VER as a result of subtidal operations are therefore as follows:

- Habitat A – 31,922,342 m^2 (1.08% of Habitat A within Hornsea Three benthic ecology study area);
- Habitat B – 12,201,312 m^2 (2.40% of Habitat B within Hornsea Three benthic ecology study area);
- Habitat C – 14,706,612 m^2 (1.40% of Habitat C within Hornsea Three benthic ecology study area); and
- Habitat D – 2,949,382 m^2 (2.78% of Habitat D within Hornsea Three benthic ecology study area).

2.11.3.8 The total area of temporary habitat loss represents a very small percentage loss (0.004%) of the total area of the OSPAR Region II within which *A. islandica* is listed as under threat and/or decline.

2.11.3.9 As discussed in paragraph 2.11.1.15, there are uncertainties with regard to the distribution and extents of protected features of the Cromer Shoal Chalk Beds MCZ within the Hornsea Three offshore cable corridor, with further site-specific data to be collected to address these data uncertainties (see section 2.6.4) and therefore this assessment should be considered preliminary. Approximately 15 km of export cables will be located within the boundary of the MCZ. The maximum habitat loss/disturbance predicted to occur within the MCZ is 1,026,000 m^2, with all of this habitat loss/disturbance predicted to occur within one of the subtidal coarse, sandy or mixed sediment areas within the MCZ (i.e. Habitats G, H and I, respectively). This would represent 0.69% of Habitat G, 5.7% of Habitat H or 2.09% of Habitat I within the MCZ.

2.11.3.10 As detailed in paragraph 2.11.1.16, direct impacts as a result of cable installation within Habitats J (subtidal chalk) and K (peat and clay exposures) within the Cromer Shoal Chalk Beds MCZ would be permanent and irreversible and therefore decommissioning of cables would not lead to further loss of these habitats. Anchor placement within these areas during decommissioning would lead to habitat loss/disturbance, although as detailed in paragraph 2.11.1.16, the extent of disturbance and therefore the potential for recovery of communities would be dependent on the structural complexity of these features, e.g. presence of gullies, pinnacles etc. Anchor placement during decommissioning is predicted to affect up to 18,470 m^2 during the decommissioning phase, or approximately 0.06% of Habitat J (subtidal chalk) within the Cromer Shoal Chalk Beds MCZ. The proportion of Habitat K (peat and clay exposures) which may be affected by anchor placements during decommissioning is more difficult to quantify due to the patchy distribution within the Cromer Shoal Chalk Beds MCZ.

2.11.3.11 The impact of temporary loss/disturbance to Habitats A, B, C, D and Species L is predicted to be localised to Hornsea Three, of short to medium term duration (i.e. the duration of the decommissioning phase) and intermittent in nature. It is predicted that the impact will affect the receptors directly, resulting in a very slight change in the baseline condition. The magnitude is therefore, considered to be minor.

2.11.3.12 As discussed in section 2.6.4, there are uncertainties with regard to the distribution and extents of Habitat F within the Hornsea Three offshore cable corridor, with further site-specific data to be collected to address these data uncertainties. As outlined in section 2.10, direct impacts on Habitat F will be mitigated by avoiding them, where possible.

2.11.3.13 The impact of temporary loss/disturbance on Habitat E of the North Norfolk Sandbanks and Saturn Reef SCI and features of Markham's Triangle rMCZ (i.e. Habitats G and H) and Cromer Shoal Chalk Beds MCZ (i.e. Habitats G, H and I) is predicted to be localised, of short to medium term duration (i.e. the duration of the decommissioning phase) and intermittent in nature. It is predicted that the impact will affect the receptors. The magnitude is therefore, considered to be minor. For Habitats J and K of the Cromer Shoal Chalk Beds, the proportion of habitat affected is predicted to be small, with some recovery expected to occur since anchor placements will not remove the substrate, allowing for recolonisation by associated communities. The magnitude is therefore considered to be minor.

2.11.3.14 As discussed in paragraph 2.11.1.11, no VERs were recorded at the Hornsea Three landfall and therefore no impact assessment has been undertaken for intertidal habitat loss on benthic ecological receptors.

Sensitivity of receptor

2.11.3.15 The sensitivity of benthic receptors will be the same as described in paragraphs 2.11.1.23 to 2.11.1.35 for subtidal receptors. Based on information available at time of writing, the expected sensitivity of Habitats A, B and C is low, while sensitivity for Habitats D, E, G, H, I and species L is considered to be medium. Sensitivity of Habitats J and K were considered to be very high due to cable laying during the construction phase, however during the decommissioning phase substrates affected by anchor placements will be left in place, allowing for recovery of associated communities. The sensitivity of these habitats is therefore considered to be high.

Significance of the effect

2.11.3.16 The magnitude of the impact on Habitat A, Habitat B and Habitat C is minor, the sensitivity of these VERs is low and therefore the effect of temporary habitat loss/disturbance is considered to be of minor adverse significance, which is not significant in EIA terms.

2.11.3.17 The magnitude of the impact on Habitats D, E, G, H, I and species L is minor, the sensitivity of these VERs is medium and therefore the effect of temporary habitat loss/disturbance is considered to be of minor adverse significance, which is not significant in EIA terms.

2.11.3.18 The magnitude of the impact on Habitats J and K is minor with a high sensitivity and therefore the effect of cable removal during the decommissioning phase is considered to be of minor adverse significance, which is not significant in EIA terms. However, as noted in paragraph 2.11.1.40, this assessment is considered to be very precautionary and Hornsea Three is currently investigating the feasibility of avoiding these features and will seek to use this to mitigate these potential impacts, where possible, as the project evolves.

2.11.3.19 Conclusions on the effect of this impact on the site integrity of the North Norfolk Sandbanks and Saturn Reef SCI are beyond the scope of this PEIR and a full account of the screening and appropriate assessment is presented within the Draft Report to Inform Appropriate Assessment for Hornsea Three. Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

Temporary increases in suspended sediment concentrations and deposition from removal of array cables, export cables and foundations resulting in potential effects on benthic ecology.

Magnitude of impact

2.11.3.20 The magnitude of the impact on subtidal receptors will be substantially less as a result of decommissioning activities when compared to construction activities as works such as seabed preparation prior to gravity base installation (Table 2.13). The impact of increased SSC in the subtidal from cable and foundation removal is predicted to be of local to regional spatial extent, medium term duration (i.e. the duration of the decommissioning phase), intermittent, reversible following cessation of activities and within the natural variability of the area. It is predicted that the impact will affect benthic receptors indirectly. Based on information available at time of writing, the expected magnitude of impact is **minor**.

Sensitivity of receptor

2.11.3.21 The sensitivity of benthic receptors to increased SSC and sediment deposition are detailed in paragraphs 2.11.1.50 to 2.11.1.55.

2.11.3.22 The benthic ecology VERs Habitats A to I and Species L are considered to be of low vulnerability, high to immediate recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be **low**.

2.11.3.23 The Habitats J and K of the Cromer Shoal Chalk Beds MCZ are considered to be of low to medium vulnerability, medium to high recoverability and of national importance. The sensitivity of these receptors is therefore considered to be **medium**.

Significance of effect

2.11.3.24 The magnitude of the impact on benthic VERs Habitats A to I and Species L is of limited spatial extent, temporary and reversible and therefore of **low** magnitude. The sensitivity of these VERs is **low** and therefore the effect of increases in SSC and associated sediment deposition on these benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.11.3.25 The magnitude of the impact on Habitats J and K (habitat features of the Cromer Shoal Chalk Beds MCZ) is of limited spatial extent, temporary and reversible and therefore of **low** magnitude. The sensitivity of these VERs is **medium** and therefore the effect of temporary habitat loss/disturbance on all benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.11.3.26 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

Removal of foundations and cable protection leading to loss of species/habitats colonising these structures.

Magnitude of impact

2.11.3.27 The removal of foundations during the decommissioning phase of Hornsea Three would result in the long-term loss of 1,595,792 m² of hard substrate. The VERs which would be affected by these operations are restricted to those within Hornsea Three array, in the vicinity of the offshore HVAC substations and high voltage direct current (HVDC) substations, and offshore accommodation platforms (i.e. Habitats A, B, C, D, G and H).

2.11.3.28 The impact is predicted to be of long term duration (i.e. the colonising species will be permanently lost) and irreversible but it will be of highly localised spatial extent. It is predicted that the impact will affect receptors directly. Based on information available at time of writing, the expected magnitude of impact is **minor**.

Sensitivity of receptor

2.11.3.29 The removal of this substrate would result in localised declines in biodiversity. However, areas of bare sediment will be exposed and it is expected that the soft substrate benthic communities in these areas will recover and revert to their pre-construction state within the time frames outlined in paragraphs 2.11.1.25 to 2.11.1.31. Recovery of the VERs affected is likely to be high and to occur within five years as a result of a combination of recruitment from surrounding unaffected areas, adult migration and larval dispersal.

2.11.3.30 Subtidal benthic receptors (i.e. Habitats A, B, C, D, G and H) are deemed to be of overall high vulnerability to complete removal, however recovery to pre-construction conditions will be high. Based on information available at time of writing, the expected sensitivity of receptors is **low**.

Significance of effect

2.11.3.31 The loss of species colonising the hard substrate will be highly localised, and given the high recoverability of the subsequently exposed substrate and communities back to their pre-construction state (i.e. within five years), the effects on subtidal benthic is therefore considered to be of **negligible** significance, which is not significant in EIA terms.

2.11.3.32 Conclusions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in full within volume 5, annex 2.3: Marine Conservation Zone Assessment.

Permanent habitat loss due to presence of scour/cable protection left *in situ* post decommissioning, and potential effects on benthic ecology.

2.11.3.33 As discussed in Table 2.13, the assessment of impacts during the decommissioning phase assumes that all offshore infrastructure will be removed from the seabed during decommissioning (i.e. all turbines, offshore substations and subsea cables), with the exception of scour protection and cable protection which will be left *in situ*. It should be noted, however, that this approach is considered highly precautionary and the precise programme to be followed will use the best available advice and guidance at the time and as per the Decommissioning Programme to be agreed with the MMO as per conditions to the Deemed Marine Licence. Hornsea Three will continue to discuss the need for, and feasibility of, removal of cable and scour protection in certain sensitive areas as the project progresses.

Magnitude of impact

2.11.3.34 The removal of all structures during decommissioning, with the exception of cable and scour protection will result in a proportion of the long term habitat loss predicted to occur during the operational phase (see paragraphs 2.11.2.4 *et seq.*) continuing post decommissioning. This is predicted to result in the permanent loss of up to 3,592,038 m^2 of benthic habitats within Hornsea Three which equates to 0.097% of the Hornsea Three benthic ecology study area and 0.006% of the southern North Sea benthic ecology study area.

2.11.3.35 As discussed in paragraph 2.11.2.10, comparable habitats are widely distributed in the southern North Sea benthic ecology study area and in the vicinity of Hornsea Three (Tappin *et al.*, 2011; see volume 5, annex 2.1: Benthic Ecology Technical Report). Given the small spatial scales of the permanent habitat loss, it is not expected that this loss will weaken regional ecosystem functions or diminish the region's biodiversity.

2.11.3.36 The impact is predicted to be permanent (i.e. continuous and irreversible) and will affect benthic receptors directly. The effects will, however, be highly localised to within Hornsea Three. The magnitude of the impact is therefore, considered to be **minor**.

Sensitivity of receptor

2.11.3.37 The sensitivities of benthic receptors to permanent habitat loss through leaving scour/cable protection measures *in situ* post decommissioning are highlighted in paragraphs 2.11.2.15 and 2.11.2.16.

2.11.3.38 The VERs likely to be affected by permanent habitat loss (i.e. Habitats A, B, C, D, G, H and I and Species L) are deemed to be of high vulnerability and regional to national value and there is no potential for recovery. However, all of the habitats potentially affected are widely distributed in the Hornsea Three benthic ecology study area and wider southern North Sea benthic ecology study area. The sensitivity of the benthic receptors potentially affected is considered to be **high**.

Significance of effect

2.11.3.39 There will be a direct permanent negative impact upon Habitats A, B, C, D, G, H I and on habitat available for Species L (*A. islandica*) as discussed in paragraph 2.11.2.17. The effect of permanent habitat loss is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.11.3.40 Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.

2.11.3.41 The effects of decommissioning activities are expected to be the same or similar to the effects from construction. The significance of effect is therefore **negligible** (see paragraph 2.11.1.68).

2.12 Cumulative Effect Assessment methodology

2.12.1 Screening of other projects and plans into the Cumulative Effect Assessment

2.12.1.1 The Cumulative Effect Assessment (CEA) considers the impact associated with Hornsea Three together with other projects and plans. The projects and plans selected as relevant to the CEA presented within this chapter are based upon the results of a screening exercise undertaken as part of the 'CEA long list' of projects (see volume 4, annex 5.2: Cumulative Effects Screening Matrix and volume 4, annex 5.3: Location of Schemes). Each project on the CEA long list has been considered on a case by case basis for scoping in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

2.12.1.2 In undertaking the CEA for Hornsea Three, it is important to bear in mind that other projects and plans under consideration will have differing potential for proceeding to construction and an operational stage and hence a differing potential to ultimately contribute to a cumulative impact alongside Hornsea Three. For example, relevant projects and plans that are already under construction are likely to contribute to cumulative impact with Hornsea Three (providing effect or spatial pathways exist), whereas projects and plans not yet approved or not yet submitted are less certain to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors. For this reason, all relevant projects and plans considered cumulatively alongside Hornsea Three have been allocated into 'Tiers', reflecting their current stage within the planning and development process. This allows the CEA to present several future development scenarios, each with a differing potential for being ultimately built out. Appropriate weight may therefore be given to each Tier in the decision-making process when considering the potential cumulative impact associated with Hornsea Three (e.g. it may be considered that greater weight can be placed on the Tier 1 assessment relative to Tier 2). An explanation of each tier is included below:

- Tier 1: Hornsea Three considered alongside other project/plans currently under construction and/or those consented but not yet implemented, and/or those submitted but not yet determined and/or those currently operational that were not operational when baseline data was collected, and/or those that are operational but have an on-going impact;

- Tier 2: All projects/plans considered in Tier 1, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information). Specifically, this Tier includes all projects where the developer has submitted a Scoping Report; and
- Tier 3: All projects/plans considered in Tier 2, as well as those on relevant plans and programmes likely to come forward but have not yet submitted an application for consent (the PINS programme of projects is the most relevant source of information). Specifically, this Tier includes all projects where the developer has advised PINS in writing that they intend to submit an application in the future but have not submitted a Scoping Report.

2.12.1.3 It is noted that Tier 1 includes projects, plans and activities that are operational, under construction, consented but not yet implemented and submitted but not yet determined. The certainty associated with other projects, plans and activities, in terms of the scale of the development and the likely impacts, increase as they progress from submitted applications to operational projects. In particular, offshore wind farms seek consent for a maximum design scenario and the as built offshore wind farm will be selected from the range of consented scenarios. In addition, the maximum design scenario quoted in the application (and the associated Environmental Statement) are often refined during the determination period of the application. For example, it is noted that the Applicant for Hornsea Project One has gained consent for an overall maximum number of turbines of 240, as opposed to 332 considered in the Environmental Statement. Similarly, Hornsea Project Two has gained consent for an overall maximum number of turbines of 300, as opposed to 360 considered in the Environmental Statement.

2.12.1.4 It should be noted that the CEA presented in this Benthic Subtidal and Intertidal Ecology chapter has been undertaken on the basis of information presented in the Environmental Statements for the other projects, plans and activities. The level of impact on Benthic Subtidal and Intertidal Ecology would likely be reduced from those presented here. In addition, Hornsea Three is currently considering how the different levels of certainty associated with projects in Tier 1 can be reflected in the CEA and an update, in terms to the approach to tiering, will be presented in the Environmental Statement.

2.12.1.5 The specific projects scoped into this CEA and the Tiers into which these have been allocated, are outlined in Table 2.20. The projects included as operational in this assessment have been commissioned since the baseline studies for this project were undertaken and as such were excluded from the baseline assessment.

2.12.2 Maximum design scenario

2.12.2.1 The maximum design scenarios identified in Table 2.21 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. The cumulative impact presented and assessed in this section have been selected from the details provided in the Hornsea Three project description (volume 1, chapter 3: Project Description), as well as the information available on other projects and plans, in order to inform a 'maximum design scenario'. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope (e.g. different turbine layout), to that assessed here be taken forward in the final design scheme.

2.12.2.2 A number of impacts set out in Table 2.21 have not been considered in the CEA due to the highly localised nature of some of the impacts (i.e. within the Hornsea Three boundary only) and/or where the potential significance of impact has been assessed as negligible for Hornsea Three offshore wind farm alone. These impacts are:

- Construction Phase:
  - Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology; and
  - Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.
- Operation and Maintenance Phase:
  - Increased risk of introduction or spread of invasive and non-native species (INNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity;
  - Maintenance operations may result in temporary seabed disturbances and potential effects on benthic ecology; and
  - Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.

Table 2.20: List of other projects and plans considered within the CEA.

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
1	*Offshore wind farms*							
	Under construction	Dudgeon Offshore Wind Farm	87 km	11 km	Up to 168 turbines consented	2015 to 2017	No	Yes
		Race Bank	114 km	28 km	Up to 206 turbines consented, 91 constructed	2015 to 2017	No	Yes
		Hornsea Project One	7 km	14 km	Up to 240 turbines consented	2017 to 2018	No	Yes
	Approved	Hornsea Project Two - Optimus Wind	7 km	20 km	Up to 300 turbines	2017 to 2019	No	Yes
		Triton Knoll offshore wind farm	100 km	44 km	Up to 288 turbines consented	2017 to 2021	Yes	Yes
	Aggregate extraction and disposal sites							
	Operational (with on-going effects)	Humber 3 - 484	43 km	0 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 481/1-2	126 km	41 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 481/1-2	127 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 481/1-2	126 km	41 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 481/1-2	127 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Outer Dowsing - 515/1-2	102 km	41 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Outer Dowsing - 515/1-2	88 km	38 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Humber 4 - 490	19 km	13 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction	Yes
		Humber 7 - 491	4 km	0 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
		Inner Dowsing - 481	125 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 481	125 km	38 km	Operational until end 2023	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		West of Inner Dowsing Bank disposal site	77 km	32 km	Operational	N/A	Yes (operational activity overlapping with Hornsea Three construction	Yes
	Application	Humber 4 and 7 - 506	131 km	48 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Humber 5 - 483	13 km	8 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
		Inner Dowsing - 439	131 km	48 km	Application for operation sought up to 31 December 2029	N/A	Yes (operational activity overlapping with Hornsea Three construction	No
	Cables and pipelines							
	Pre-commission	PL2237 - SATURN TO MIMAS	33 km	22 km	3 inch Pre-commission CHEMICAL pipeline operated by CONOCOPHILLIPS	2017 to 2018	No	*Yes*
	Pre-commission	PLU3122 - JULIET TO PICKERILL A UMBILICAL	89 km	50 km	138 mm Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	2017 to 2018	No	Yes
	Pre-commission	PL3088 - CYGNUS TO ETS GAS PIPELINE	48 km	64 km	24 inch Pre-commission GAS pipeline operated by ENGIE	2017 to 2018	No	Yes
	Pre-commission	PL2894 - KATY TO KELVIN GAS EXPORT PIPELINE	39 km	53 km	10 inch Pre-commission GAS pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
	Pre-commission	PL2895 - KELVIN TO KATY METHANOL PIPELINE	39 km	53 km	2 inch Pre-commission METHANOL pipeline operated by CONOCOPHILLIPS	2019 to 2021	Yes	Yes
	Pre-commission	PL3121 - JULIET TO PICKERILL A GAS PIPELINE	50 km	89 km	12 inch Pre-commission MIXED HYDROCARBONS pipeline operated by ENGIE	2019 to 2021	Yes	Yes
	Under-construction	PL0219_PR K4-Z to K5-A	20 km	35 km	6-inch Under construction Gas pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
	Under-construction	PL0219_UM K4-Z to K5-A	20 km	35 km	5-inch Under construction Control pipeline operated by Total E&P Nederland B.V.	2017 to 2018	No	Yes
	Proposed	PL0221_HS D18-A to D15-FA-1	19 km	45 km	2-inch Proposed Methanol pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes

Tier	Phase	Project/Plan	Distance from Hornsea Three array area	Distance from Hornsea Three offshore cable corridor	Details	Date of Construction (if applicable)	Overlap of construction phase with Hornsea Three construction phase	Overlap of operation phase with Hornsea Three operation phase
	Proposed	PL0221_PR D18-A to D15-FA-1	19 km	45 km	8-inch Proposed Gas pipeline operated by GDF SUEZ E&P Nederland B.V.	2019 to 2021	Yes	Yes
2	*Cables and pipelines*							
	Proposed	Viking Interconnector	13 km	18 km	High voltage (up to 500 kV) Direct Current (DC) electricity interconnector	2019 to 2022	Yes	Yes

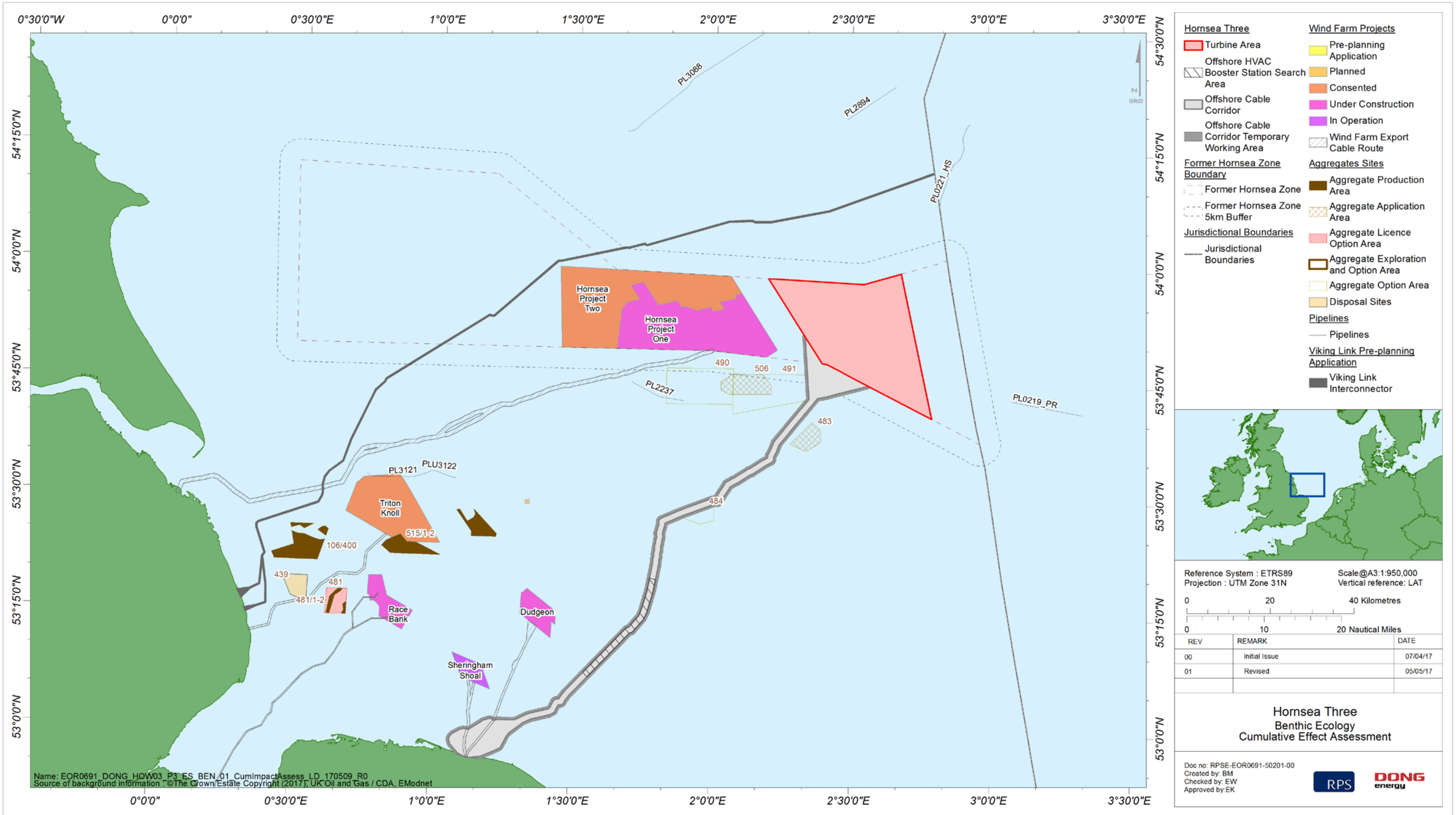

Figure 2.8: Offshore project/plans/activities screened into the Hornsea Three cumulative effect assessment for benthic ecology.

Table 2.21: Maximum design scenario considered for the assessment of potential cumulative impacts on benthic ecology.

Potential impact	Maximum design scenario	Justification
Construction phase		
Cumulative temporary habitat loss/disturbance of benthic ecology VERs as a result of offshore wind farm construction, aggregate extraction activities, and cable and pipeline installation.	165.49 km² total cumulative temporary habitat loss/disturbance of benthic ecology VERs (see Table 2.23). Maximum design scenario as described for construction phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of the Hornsea Three boundary: *Tier 1* • All licensed aggregate extraction areas (assuming an average of 10% of the total licensed area is dredged at any one time); • All application aggregate extraction areas; • Cables and pipelines (i.e. PL2237 – Saturn to Mimas, PLU3122 and PL3121 – Juliet to Pickerill A gas pipeline and umbilical, PL3088 – Cygnus to ETS gas pipeline, PL2894 – Katy to Kelvin gas export pipeline, PL2895 – Kelvin to Katy methanol pipeline, PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical, PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1); • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank Hornsea Project One - Heron Wind); and Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). Tier 2 and • Cables and pipelines (i.e. Viking Interconnector). Tier 3: • No Tier 3 projects.	Maximum additive temporary habitat loss is calculated within a representative 50 km buffer of Hornsea Three as this area is a fair representation of benthic habitats within the wider southern North Sea benthic ecology study area due to its proximity to Hornsea Three. Areas of temporary habitat loss for other offshore wind farms have been taken from the respective Environmental Statement chapters, were available. An average of 10% of the total licensed aggregate extraction areas is assumed to be dredged at any one time. This is based on Annual Reports produced by the Crown Estate for the Humber region which report that for at least the last five years, dredging each year has taken place within 5 to 10% of the total licensed area (Crown Estate, 2012). Therefore, as a precautionary approach, 10% has been assumed for this assessment.
Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.	*Maximum design scenario as described for construction phase of Hornsea Three (for both foundation and cable installation) assessed cumulatively with the following Tier 1 licensed/consented/ aggregate extraction areas:* • *Humber 3 (484);* • *Humber 4 and 7 (506); and* • *Humber 5 (483).* Tier 2 and Tier 3: • No Tier 2 or Tier 3 projects.	Maximum potential for interactive effects from increases in suspended sediment concentrations and consequent deposition (chapter 1: Marine Processes).
Operation and maintenance phase		
Cumulative long term loss of benthic ecology VERs through presence of offshore wind farm foundations and related infrastructure (e.g. cable protection, substations) and oil and gas and interconnector installations.	15.36 km² total cumulative long term habitat loss of benthic ecology VERs (see Table 2.24). Maximum design scenario as described for operation and maintenance phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of the Hornsea Three boundary: *Tier 1* • Cables and pipelines (i.e. PL2237 – Saturn to Mimas, PLU3122 and PL3121 – Juliet to Pickerill A gas pipeline and umbilical, PL3088 – Cygnus to ETS gas pipeline, PL2894 – Katy to Kelvin gas export pipeline, PL2895 – Kelvin to Katy methanol pipeline, PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical, PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1); • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank Hornsea Project One - Heron Wind); and Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). Tier 2 and • Cables and pipelines (i.e. Viking Interconnector). Tier 3: • No Tier 3 projects.	Maximum cumulative long term habitat loss is calculated within a representative 50 km buffer of Hornsea Three as this area is considered to be a fair representation of benthic habitats within the wider southern North Sea benthic ecology study area due to its proximity to Hornsea Three.

Potential impact	Maximum design scenario	Justification
Cumulative introduction of subtidal hard substrates (i.e. from offshore wind farm structures) and associated colonisation.	Maximum design scenario as described for operation and maintenance phase assessed cumulatively with the full development of the following marine projects within a representative 50 km buffer of the Hornsea Three boundary: *Tier 1* • Cables and pipelines (i.e. PL2237 – Saturn to Mimas, PLU3122 and PL3121 – Juliet to Pickerill A gas pipeline and umbilical, PL3088 – Cygnus to ETS gas pipeline, PL2894 – Katy to Kelvin gas export pipeline, PL2895 – Kelvin to Katy methanol pipeline, PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical, PL0221_HS D18-A to D15-FA-1 and PL0221_PR D18-A to D15-FA-1); • Offshore wind farm projects under construction (i.e. Dudgeon, Race Bank, Hornsea Project One - Heron Wind); and • Consented offshore wind farm projects (i.e. Triton Knoll and Hornsea Project Two). Tier 2 and Tier 3: • No Tier 2 or Tier 3 projects.	Maximum cumulative habitat creation is calculated within a representative 50 km buffer of Hornsea Three as this area is considered to be a fair representation of benthic habitats within the wider southern North Sea benthic ecology study area due to its proximity to Hornsea Three.
Alteration of seabed habitats arising from effects on physical processes, wave and tidal regimes resulting in potential effects on benthic ecology.	Maximum design scenario as described for the operation and maintenance phase of Hornsea Three assessed cumulatively with the following Tier 1 offshore wind farms: • Lincs; • Sheringham Shoal; • Humber Gateway; • Westermost Rough; • Lynn and Inner Dowsing; • Triton Knoll; • Dudgeon; • Race Bank; • Hornsea Project One; and • Hornsea Project Two. Tier 2 and Tier 3: • No Tier 2 or Tier 3 projects.	Maximum potential cumulative effects on the tidal and wave regimes (see chapter 1: Marine Processes).

2.13 Cumulative Effect Assessment

2.13.1.1 A description of the significance of cumulative effects upon benthic ecology receptors arising from each identified impact is given below.

2.13.2 Construction phase

Cumulative temporary habitat loss/disturbance of benthic ecology VERs as a result of offshore wind farm construction, aggregate extraction activities, and cable and pipeline installation.

2.13.2.1 There is the potential for cumulative temporary habitat loss as a result of construction activities associated with Hornsea Three and other Round 2 and Round 3 offshore wind farms (i.e. from cable/pipeline burial, anchor placements and seabed preparation for the installation of GBFs) and aggregate extraction activities (see Figure 2.8). For the purposes of this PIER, this additive impact has been assessed within a representative 50 km buffer of Hornsea Three using the tiered approach outlined above in paragraph 2.12.1.2 and in Table 2.21. The 50 km buffer area is considered to be a fair representation of benthic habitats within the wider southern North Sea benthic ecology study area in proximity to Hornsea Three.

2.13.2.2 Almost all plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. Tier 1). One Tier 2 project has been identified within the representative 50 km buffer, while no Tier 3 projects have been identified.

Tier 1

Magnitude of impact

2.13.2.3 Predicted cumulative temporary habitat loss/disturbance from each of the Tier 1 plans/projects/activities is presented in Table 2.22 together with a breakdown of the sources of this data from the relevant Environmental Statements and any assumptions made where necessary information was not presented in these Environmental Statements. Table 2.22 shows that for all projects/plans/activities in the Tier 1 assessment, the cumulative temporary habitat loss/disturbance is estimated at 173.10 km^2. However, as discussed in paragraph 2.12.1.3, these areas are likely to be highly precautionary.

2.13.2.4 The maximum total temporary habitat loss/disturbance associated with all offshore wind farms within a representative 50 km buffer is 110.48 km^2. For licensed and application aggregate extraction areas (assuming an average of 10% of the total licensed areas is dredged at any one time) the maximum total temporary habitat loss/disturbance is approximately 56.84 km^2 and for cable and pipeline installation it is 3.92 km^2. The values of temporary habitat loss for Hornsea Three, Hornsea Project One and Hornsea Project Two are comparably larger than for other offshore wind farms presented in Table 2.3, as the Hornsea Three, Hornsea Project One and Hornsea Project Two areas include habitat affected as a result of seabed preparation and also consider the installation of up to six and eight export cable trenches, respectively, for the HVAC Maximum design scenario.

2.13.2.5 The assumption that an average of 10% of the total licensed areas will be dredged at any one time is based on annual reports produced by The Crown Estate for the Humber region which state that recent dredging has taken place within 5 to 10% of the total licensed area each year; in 2012, 9.9% of the total licensed area was dredged (Crown Estate, 2012). The estimate of temporary habitat loss resulting from aggregate extraction activities is also likely to be an over-estimation as only a proportion of the active licence areas are dredged at any one time allowing for recovery between dredging events.

2.13.2.6 The benthic subtidal habitats likely to be affected by cumulative temporary habitat loss will be similar to those described in paragraph 2.11.1.5 for Hornsea Three (i.e. Habitats A, B and C). These habitats are typical of, and widespread throughout, the southern North Sea benthic ecology study area (see volume 5, annex 2.1: Benthic Ecology Technical Report).

2.13.2.7 The cumulative impact of temporary habitat loss is predicted to be of regional spatial extent, medium term duration (i.e. Hornsea Three construction phase of up to 11 years; see Table 2.13), intermittent and reversible but with a relatively small amount of the loss described occurring at any one time. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be minor.

Table 2.22: Cumulative temporary habitat loss for Hornsea Three and other plans/projects/activities in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Total predicted temporary habitat loss (km^2)	Source
Tier 1		
Offshore wind farms		
Hornsea Three	31.73	See Table 2.13.
Dudgeon Offshore Wind Farm	1.23	Values taken from Environmental Statement (Royal Haskoning, 2009): 1.2 km^2 from cable installation and 0.0315 km^2 from jack-up barges.
Race Bank Offshore Wind Farm	1.02	Values taken from Environmental Statement (Centrica Energy, 2009): 0.01236 km^2 from jack-up barges, 0.8641 km^2 from export cable installation and 139 km of array cables (1 m width disturbance).
Triton Knoll Offshore Wind Farm	2.45	Values taken from Environmental Statement (TKOWFL, 2012): 0.53 km^2 from inter-array and inter-substation cable installation, 0.60 km^2 from jack-up barges and 1.319 km^2 from seabed preparation.
Hornsea Project One Offshore Wind Farm	28.52	Values taken from Environmental Statement (SMart Wind, 2013): 0.143 km^2 from jack-up barges, 5.3 km^2 from inter-array and inter-connector cable burial, 6 km^2 from export cable burial, 16.8 km^2 from seabed preparation and 0.279 km^2 from anchor placements.
Hornsea Project Two Offshore Wind Farm	45.53	Values taken from Environmental Statement (SMart Wind, 2015): 0.466 km^2 from jack up barges, 8.47 km^2 from inter-array and inter-connector cable burial, 17.498 km^2 from export cable burial, 18.162 km^2 from seabed preparation and 0.930 km^2 from anchor placements.
Total Offshore Wind Farms	110.48 km^2	
Cables and Pipelines		
PL2237 - Saturn to Mimas	0.28	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 13.4 km pipeline length.
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	0.46	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	1.33	Values taken from Environmental Statement (GDF Suez, 2011).
PL2894 - Katy to Kelvin Gas Export Pipeline	0.29	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 14 km pipeline length.
PL2895 - Kelvin to Katy Methanol Pipeline	0.29	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 14 km pipeline length.
PL0219_PR and PL0219_UM K4-Z to K5-A pipeline route and umbilical	0.36	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 17.2 km pipeline and umbilical length.
PL0221_HS D18-A to D15-FA-1	0.45	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 17.2 km pipeline length.
PL0221_PR D18-A to D15-FA-1	0.45	Assumptions made for the cumulative assessment: trench width of 21 m along the entire 17.2 km pipeline length.
Total Cables and Pipelines	3.92 km^2	
Aggregate extraction and disposal areas		
Application areas	10.57	10% of total application areas of 105.7 km^2.
Licenced areas	43.65	10% of total licenced areas of 436.5 km^2.
Licenced disposal areas (West of Inner Dowsing Bank)	2.62	10% of total licenced areas of 26.2 km^2.
Total aggregate extraction	56.84 km^2	
Total Tier 1	173.10 km^2	
Tier 2		
Cables and Pipelines		
Viking Interconnector.	1.86	Assumptions made for the cumulative assessment: trench width of 10 m for up to 2 cable circuits along the 93 km interconnector length in UK waters within a 50 km buffer of Hornsea Three.
Total Tier 2	168.86 km^2	

Sensitivity of receptor

2.13.2.8 The sensitivity of benthic subtidal habitats to offshore wind farm related impacts will be as described for the construction phase impacts in paragraphs 2.11.1.23 to 2.11.1.35. With respect to marine aggregate dredging, research has shown that the recovery of marine benthic communities to such activities appears to be largely site specific, reflecting complex interactions between the intensity of dredging and the level of screening, the composition of sediments at the site and the extent to which the resident organisms are adapted to environmental disturbance (Hill *et al*., 2011). A relevant study in Licence Area 408 in the central North Sea has provided evidence that restoration of species composition and population density is accomplished rapidly by recolonisation of small individuals, even within the boundaries of the dredged area (Newell *et al*., 2002). A study investigating the effects of sustained dredging at the Cross Sands dredge site (5 to 25 km off the east coast of Great Yarmouth and Lowestoft), similarly demonstrated that even though variables such as abundance and species richness were found to depart significantly from an equitable state during the eight year study period, the effect did not persist from one year to the next and the potential for short term partial recovery of the assemblage was not compromised (at least in terms of abundance and species richness) (Barrio Froján *et al*., 2008). The rapid restoration of community structure by active recolonisation of mobile, opportunistic species is characteristic of shallow marine environments. These environments are subject to the influences of tide and wave action, such as those associated with Habitats A and C within the Hornsea Three benthic ecology study area, and the species typically inhabiting them, such as polychaetes. As such, the vulnerability of habitats is considered to be low to high, but with high recoverability with most recovery occurring within months and full recovery within five years.

2.13.2.9 Habitats A to C are deemed to be of low to medium vulnerability, high recoverability and regional to regional value. The sensitivity of the receptor is therefore, considered to be **low**. Habitat D is deemed to be of medium to high vulnerability, high recoverability and regional value. Although *S. spinulosa* is likely to recover quickly, the associated high biodiversity may take longer to recover and, as such, the sensitivity of Habitat D is considered to be **medium**. Species L (*A. islandica*) is deemed to be of medium vulnerability, medium recoverability and national value, and the sensitivity of this receptor is considered to be **medium**.

2.13.2.10 Sensitivity of the features of the Markham's Triangle rMCZ, i.e. Habitats G and H, are considered to be identical to Habitats A and C, although these are of national importance and therefore are considered to be of **medium** sensitivity. Sensitivity of Habitat E, the Annex I sandbank feature of the North Norfolk Sandbanks and Saturn Reef SCI is considered to be identical to Habitat A, although this is of international importance and is therefore considered to be of **medium** sensitivity. Sensitivity of the features of the Cromer Shoal Chalk Beds MCZ which may be affected by temporary habitat loss/disturbance, i.e. Habitats G, H and I, are considered to be identical to Habitats A, C and D, respectively, although these are of national importance and therefore are considered to be of **medium** sensitivity.

Significance of the effect

2.13.2.11 Overall, it is predicted that the sensitivity of the receptors is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Tier 2

Magnitude of impact

2.13.2.12 The Tier 2 assessment includes all Tier 1 projects and the proposed Viking Interconnector. There is currently no detailed information on the impact of temporary habitat loss during cable installation for this project and therefore the same assumptions have been made as for Hornsea Three (see Table 2.22). If further detailed information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

2.13.2.13 The cumulative impact of temporary habitat loss from Tier 2 projects is predicted to be of regional spatial extent, medium term duration (i.e. Hornsea Three construction phase of up to 11 years; see Table 2.13), intermittent and reversible but with a relatively small amount of the loss described occurring at any one time. It is predicted that the impact will affect the receptors directly. The magnitude is therefore, considered to be **minor**.

Sensitivity of the receptor

2.13.2.14 As detailed in paragraph 2.13.2.9, the habitats characterising this part of the southern North Sea are expected to have low, medium and high vulnerabilities, medium to high recoverability and regional to regional value. The sensitivity of the receptor is therefore, considered to be **low** to **medium**.

Significance of the effect

2.13.2.15 Overall, it is predicted that the sensitivity of the receptors is considered to be **low** to **medium** and the magnitude is deemed to be **minor**. The effect of Tier 2 projects will, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.

Tier 1

2.13.2.16 There is potential for cumulative impacts from increased SSC and associated sediment deposition to occur during the construction of Hornsea Three and similar from aggregate extraction activities and the construction of other offshore wind farms within one tidal excursion (see chapter 1: Marine Processes).

2.13.2.17 All plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. Tier 1). No Tier 2 or Tier 3 projects have been identified. The maximum design scenario is as described in Chapter 1: Marine Processes.

Magnitude of impact

2.13.2.18 The Tier 1 assessment includes Hornsea Three together with licensed and application aggregate extraction areas within one tidal excursion, which been considered in chapter 1: Marine Processes.

2.13.2.19 The licensed aggregate extraction areas 484, 506 and 483 are located 43, 13 and 14 km from the Hornsea Three array area, respectively, and 0, 8 and 2 km from the Hornsea Three offshore cable corridor, respectively (see Figure 2.8).

2.13.2.20 The target material at these marine aggregate areas is sands and gravels. The aggregate deposits in this region are generally understood to contain <5% fines (silt and clay) and therefore the concentrations of this fraction in the overflow from the dredging vessels are anticipated to be relatively low. Aggregate extraction operations may release sediment into the water column through overspill and/or screening. The spatial extent of this plume will largely be determined by the sediments being extracted and the local hydrodynamic regime: heavier gravel-sized particles will settling rapidly at the discharge point, whilst sand-sized particles typically settle within about 250 m to 500 m, and within 5 km where tidal currents are strong (chapter 1: Marine Processes).

2.13.2.21 Plume dispersion modelling results for Application Areas 484 and 483 showed that the maximum extent of a turbid plume resulting from dredging activity would be 17.0 and 15.5 km, at 483 and 484, respectively (ABPmer, 2013b). Maximum increases in near-seabed concentrations could exceed 600 mg/l in close proximity to the dredger within the application areas for a period of 1 hour, before reducing to approximately 50 to 150 mg/l for the remainder of the dredging period. It is expected that a return to near background concentrations would take approximately four days during spring tides or slightly longer during neap tides. The maximum sedimentation thickness resulting from the dredge plumes is expected to be approximately 1 mm in very close proximity to the dredge location, though the settled material will be transitory with the changing flood/ebb and spring/neap variations in the tidal currents (ABPmer, 2013b). Deposition of dispersed sediment resulting from cable laying activities in Hornsea Three at aggregate dredging areas is considered to be low, as levels of deposition resulting from cable laying is predicted to be approximately 0.06 m within 100 m from the Hornsea Three offshore cable corridor (chapter 1: Marine Processes).

2.13.2.22 The turbid plume arising from the proposed dredging activities at Application Area 506 (see Figure 2.8) is predicted to extend between 2.5 to 4 km to the north-northwest and between 2 to 3 km to the south-southwest of the area (ABPmer, 2010). Depth averaged increases in SSC of between 50 and 70 mg/l above background levels would be likely to occur within the dredging area and in the streamline of a dredger at Area 506 (ABPmer, 2010). Outside of the dredging area SSC of 50 mg/l above background levels would be likely to occur. The plume was predicted to extend no further than 4 km north-northwest or 3 km south-southwest and at this point the predicted increase in suspended sediment was less than 10 mg/l. In terms of deposition the dredging footprint based on the Maximum design scenario was predicted to extend up to 2 km (ABPmer, 2010).

2.13.2.23 The plumes arising from both the aggregate extraction-related dredging activity and the Hornsea Three extraction activity are generally predicted to coalesce together, creating a larger plume with concentrations similar to the alone activities, as opposed to an additive plume with a higher concentration (chapter 1: Marine Processes). It is considered that activities would mostly likely cause an additive plume of higher concentrations only if cable installation for Hornsea Three took place at the same time and in the vicinity of the western margin of 483 and eastern margin of 506 aggregate extraction areas, though this is predicted to cause a maximum additive plume of a few 10's mg/l over the construction of Hornsea Three alone, as described in paragraphs 2.11.1.44 to 2.11.1.49 (chapter 1: Marine Processes).

2.13.2.24 The cumulative impact of increased SSC and sediment deposition on subtidal benthic receptors (i.e. Habitats A, B, C, D, E, F, G, H, I, J and K and Species L) from dredging at aggregation extraction areas 483, 484 and 506, and activities relating to the development of Hornsea Three, is predicted to be of regional spatial extent (i.e. within kilometres of Hornsea Three), of medium term (i.e. construction phase of up to 11 years; Table 2.13) and intermittent duration, and reversible to baseline conditions following cessation of activities. It is also predicted that the impact will affect benthic receptors indirectly and therefore, the magnitude is considered to be low.

Sensitivity of receptor

2.13.2.25 The sensitivities of the benthic ecology VERs to temporary increases in suspended sediments and associated deposition from construction activities are discussed in paragraphs 2.11.1.50 to 2.11.1.55.

2.13.2.26 The benthic ecology VERs Habitats A to I and Species L are considered to be of low vulnerability, high to immediate recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be low.

2.13.2.27 The Habitats J and K of the Cromer Shoal Chalk Beds MCZ are considered to be of low to medium vulnerability, medium to high recoverability and of national importance. The sensitivity of these receptors is therefore considered to be medium.

Significance of the effect

2.13.2.28 The magnitude of the impact on benthic VERs Habitats A to I and Species L is of limited spatial extent, temporary and reversible and therefore of **minor** magnitude. The sensitivity of these VERs is **low** and therefore the effect of increases in SSC and associated sediment deposition on these benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.13.2.29 The magnitude of the impact on Habitats J and K (habitat features of the Cromer Shoal Chalk Beds MCZ) is of limited spatial extent, temporary and reversible and therefore of **low** magnitude. The sensitivity of these VERs is **medium** and therefore the effect of temporary habitat loss/disturbance on all benthic VERs is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.13.2.30 Discussions on the effects of Hornsea Three on the Markham's Triangle rMCZ and the Cromer Shoal Chalk Beds MCZ are presented in volume 5, annex 2.3: Marine Conservation Zone Assessment.

Operation and maintenance phase

Cumulative long term loss of benthic ecology VERs through presence of offshore wind farm foundations and related infrastructure (e.g. cable protection, substations) and oil and gas and interconnector installations.

Cumulative long term habitat loss is predicted to occur as a result of the presence of Hornsea Three, all other offshore wind farms which are consented, submitted or under construction within a representative 50 km buffer of Hornsea Three and cables and pipelines (see Table 2.21 and Figure 2.8). Long term habitat loss may result from the physical presence of foundations, scour protection and cable protection. All plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. Tier 1). One Tier 2 project has been identified within the representative 50 km buffer, while no Tier 3 projects have been identified.

Tier 1

Magnitude of effect

2.13.2.31 The predicted cumulative long term habitat loss from each of the Tier 1 offshore wind farm and cable/pipeline projects is presented in Table 2.23. Long term habitat loss areas associated with offshore wind farms, pipeline and cable corridors within 50 km of Hornsea Three have been taken from Environmental Statements, where available. Where such information has not been available it has not been possible to estimate the cable/pipeline protection that might be left on the seabed after decommissioning. The proportion of cable protection is site specific and depends on local ground conditions for each project. Therefore it is not possible to estimate the percentage of a cable that might require cable protection (e.g. 10% or 90% of a cable length). As such, areas of long term habitat loss have not been included in the Tier 1 assessment for many of the cable and pipelines within 50 km of Hornsea Three. See Table 2.23 for the data available.

Table 2.23: Cumulative long term habitat loss for Hornsea Three and other plans/projects in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Total predicted long term habitat loss (km^2)	Source
Tier 1		
Offshore wind farms		
Hornsea Three	4.26	See Table 2.13.
Dudgeon Offshore Wind Farm	0.42	Values taken from Environmental Statement (Royal Haskoning, 2009).
Race Bank Offshore Wind Farm	0.10	Values taken from Environmental Statement (Centrica Energy, 2009).
Triton Knoll Offshore Wind Farm	0.88	Values taken from Environmental Statement (TKOWFL, 2012).
Hornsea Project One Offshore Wind Farm	4.23	Values taken from Environmental Statement (SMart Wind, 2013).
Hornsea Project Two Offshore Wind Farm	5.45	Values taken from Environmental Statement (SMart Wind, 2015).
Total Offshore Wind Farms	15.34 km^2	
Cables and pipelines		
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	0.01	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	0.01	Values taken from Environmental Statement (GDF Suez, 2011).
Total Cables and Pipelines	0.02 km^2	
Total Tier 1	15.36 km^2	

2.13.2.32 These habitat loss areas are derived from project-specific documents, such as Environmental Statements, where available. Where such sources of information have not be available, areas have not been estimated regarding habitat loss associated with cable/pipeline protection.

2.13.2.33 Table 2.23 shows that for all projects/plans/activities in the Tier 1 assessment, the cumulative long term habitat loss within a 50 km buffer of Hornsea Three is estimated to be 15.36 km^2. This equates to 0.063% of the total area of subtidal habitat within a 50 km buffer of Hornsea Three. Comparable habitats are however, widely distributed in the southern North Sea benthic ecology study area (see volume 5, annex 2.1: Benthic Ecology Technical Report) so this loss is not predicted to diminish regional ecosystem functions.

2.13.2.34 If during decommissioning these offshore wind farm structures and the pipelines are removed, the impacts will be reversible with recoverability of the affected habitats likely, within time scales similar to those outlined in paragraphs 2.11.1.23 to 2.11.1.32, following removal of the structures.

2.13.2.35 The cumulative impact of long term habitat loss will affect benthic subtidal receptors directly. It is predicted to be of regional spatial extent (but highly localised within each offshore wind farm), long term duration (i.e. for the lifetime of the projects), continuous and reversible. The magnitude for the Tier 1 assessment is therefore, considered to be minor.

Sensitivity of receptor

2.13.2.36 As the majority of the species likely to be affected are infaunal and would therefore be lost along with the substratum, these species are all considered to be highly intolerant of, and therefore vulnerable to, complete habitat loss. However, none of the habitats likely to be affected are rare, geographically restricted or of specific conservation importance (e.g. mitigation will be discussed with statutory consultees, where necessary, to avoid impacts to Annex I habitats should these be identified during the pre-construction surveys of the Hornsea Three offshore cable corridor). The wide distribution of comparable habitats within the wider region suggests that component species and habitats will remain sufficiently represented. Although these habitats typically have high levels of recoverability as outlined in paragraphs 2.11.1.23 to 2.11.1.32, recoverability is not considered to be applicable to this impact as there will be no recoverability during the lifetime of the project.

2.13.2.37 Benthic subtidal receptors are deemed to be of high vulnerability and regional to international value (recoverability is not deemed applicable for this impact). The sensitivity of the benthic receptors potentially affected is therefore, considered to be high.

Significance of effect

2.13.2.38 There will be a direct, negative impact, of long term duration (i.e. for the lifetime of the project) but of relatively limited spatial extent, upon benthic subtidal habitats. However, all of the habitats potentially affected are widely distributed in the southern North Sea benthic ecology study area and this loss is not considered likely to affect ecosystem functionality.

2.13.2.39 Overall, it is predicted that the sensitivity of the receptors is considered to be high and the magnitude is deemed to be minor. The effect will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Tier 2

Magnitude of impact

2.13.2.40 The Tier 2 assessment includes all Tier 1 projects and the proposed Viking Interconnector. There is currently no detailed information on the long term habitat loss from placement of cable protection for this project and due to this requirement being specific to the project and ground conditions across the interconnector route, it this has not been possible to provide a reasonable estimate for this. If further detailed information becomes available prior to the compilation of the Hornsea Three Environmental Statement, this will be included in the CEA.

2.13.2.41 The cumulative impact of long term habitat loss from Tier 2 projects will affect benthic subtidal receptors directly. It is predicted to be of regional spatial extent (but highly localised within each offshore wind farm), long term duration (i.e. for the lifetime of the projects), continuous and reversible. The magnitude for the Tier 2 assessment is therefore, considered to be minor.

Sensitivity of the receptor

2.13.2.42 Benthic subtidal receptors are deemed to be of high vulnerability and regional to international value (recoverability is not deemed applicable for this impact). The sensitivity of the benthic receptors potentially affected is therefore, considered to be high.

Significance of the effect

2.13.2.43 Overall, it is predicted that the sensitivity of the receptors is considered to be high and the magnitude is deemed to be minor. The effect of long term habitat loss from Tier 2 projects will, therefore, be of minor adverse significance, which is not significant in EIA terms.

Cumulative introduction of subtidal hard substrates (i.e. from offshore wind farm structures) and associated colonisation.

2.13.2.44 As discussed in paragraphs 2.11.2.24 and 2.11.2.31, the introduction of hard substrate into areas of predominantly soft sediments has the potential to alter community composition and biodiversity and to facilitate the spread/introduction of non-indigenous species. The latter may be particularly important with regards to cumulative effects as several offshore structures in relatively close proximity could enable the 'stepping stone effect'.

2.13.2.45 All plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. Tier 1). No Tier 2 or Tier 3 projects have been identified within the representative 50 km buffer.

Tier 1

Magnitude of impact

2.13.2.46 It is difficult to accurately quantify the total area of hard substrate that will be introduced within a 50 km buffer of Hornsea Three, particularly since this is not quantified in the majority of the assessments for the other offshore wind farms included within the Tier 1 assessment (see Table 2.20). The extent of habitat creation will depend on the exact foundation size, and scour protection and cable armour requirements which will vary for each site. However, from a review of the relevant Environmental Statements and information acquired from developers' websites, it is estimated that approximately 1,696 turbines may be constructed from all projects included within Tier 1 (Table 2.24). It should be noted however, that this assessment is considered to be precautionary as the Maximum design scenario has assumed the habitat created as a result of the installation of the maximum number of turbines consented for each offshore wind farm project which may, in reality, be greater than the number of turbines actually constructed.

2.13.2.47 For the purposes of this assessment, it has been assumed that for all other projects where habitat creation numbers are not specified in the relevant Environmental Statement, the area of introduced hard substrate per turbine is the same as for the Hornsea Three foundations (i.e. 7,533 m^2 including scour protection). The total cumulative hard substrate associated with offshore wind farms which could be introduced within a 50 km buffer of Hornsea Three is estimated to be approximately 21,781,303 m^2. This is considered to be a highly precautionary maximum design scenario as in many cases smaller turbines than those assumed for the Hornsea Three assessment will be installed for the other offshore wind farms, and also fewer turbines may actually be constructed than the number consented (see paragraph 2.12.1.3). Therefore, although an estimation of substrate introduced as a result of the installation of cable protection for the other offshore wind farms within the Tier 1 assessment has not been included (except for Hornsea Project One and Hornsea Project Two) due to the difficulty in quantifying these areas, given the precaution included in the assessment these areas are likely to be well within the total cumulative estimate of 21,781,303 m^2.

2.13.2.48 The total maximum habitat creation resulting from cable/pipeline protection is estimated to be 124,000 m^2 (Table 2.24). As such, the total habitat creation is considered to be 21,905,303 m^2. The maximum cumulative introduction of hard substrate equates to less than 0.0899% of the subtidal habitat within a 50 km buffer of Hornsea Three.

2.13.2.49 The impact will extend over the regional area but will be highly localised within this area, will be of long term duration, continuous and irreversible during the lifetime of the projects. The magnitude of the impact is therefore, considered to be minor.

Table 2.24: Cumulative habitat creation for Hornsea Three and offshore wind farms in the Tier 1 assessment within a representative 50 km buffer of Hornsea Three.

Project	Maximum number of turbines	Total predicted habitat creation (m^2)	Source
Tier 1			
Offshore wind farms			
Hornsea Three	342	5,694,330	See Table 2.13.
Dudgeon Offshore Wind Farm	168	1,265,544	168 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Race Bank Offshore Wind Farm	206	1,551,798	206 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Triton Knoll Offshore Wind Farm	288	2,169,504	288 turbines (consented) x 7,533 m^2 (i.e. predicted habitat creation per turbine as per Hornsea Three assumptions as value not specified in Environmental Statement).
Hornsea Project One Offshore Wind Farm	332	4,860,136	Values taken from Environmental Statement (SMart Wind, 2013)
Hornsea Project Two Offshore Wind Farm	360	6,239,991	Values taken from Environmental Statement (SMart Wind, 2015)
Total Offshore Wind Farms		21,781,303 m^2	
PLU3122 and PL3121 Juliet to Pickerill A Gas Pipeline and Umbilical	N/A	10,000	Values taken from Environmental Statement (GDF Suez, 2012).
PL3088 - Cygnus to ETS Gas Pipeline	N/A	114,000	Values taken from Environmental Statement (GDF Suez, 2011).
Total cable/pipeline protection		124,000 m^2	
Total habitat creation		21,905,303 m^2	

Sensitivity of receptor

2.13.2.50 The sensitivity of subtidal receptors will be as described in paragraphs 2.11.2.24 to 2.11.2.31. Naturally occurring hard substrate in this part of the southern North Sea benthic ecology study area is rare and therefore the introduction of a maximum of approximately 21.78 km^2 of artificial hard substrate represents a large shift in the baseline condition of the pre-construction area. Whether this effect is viewed as positive or negative for benthic receptors is subjective. For example, an increase in the abundance of a commercially important invertebrate (e.g. lobster) resulting from new habitat and shelter may be beneficial to commercial fisheries, although from an ecological perspective this may be perceived as a slight negative impact. Negative effects may also occur if non-indigenous species become established. Precisely which, if any, species may benefit is unknown and conversely which species may be adversely affected is also uncertain; INNS which have been recorded to date associated with offshore wind farm structures are discussed in paragraphs 2.11.2.40 to 2.11.2.44. There is generally very little information concerning the intolerance of different benthic biotopes to invasion by INNS, but as discussed in paragraph 2.11.2.24, monitoring of existing offshore wind farms has not demonstrated any significant negative impacts.

2.13.2.51 The VERs likely to be affected by an increase in hard substrate species diversity and INNS (Habitats A, B, C, D, G, H, I) are deemed to be of low vulnerability and regional to national value. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of the effect

2.13.2.52 Overall, it is predicted that the sensitivity of the receptors is considered to be **high** and the magnitude is deemed to be **minor**. The effect of cumulative hard habitat creation resulting in community change and facilitating the spread of INNS is considered, therefore, be of **minor** adverse significance, which is not significant in EIA terms.

Alteration of seabed habitats arising from effects on physical processes, wave and tidal regimes resulting in potential effects on benthic ecology.

2.13.2.53 The cumulative presence of offshore structures associated with Hornsea Three and other offshore wind farms may introduce changes to the local hydrodynamic and wave regime, resulting in cumulative changes to the sediment transport pathways and associated effects on benthic ecology.

2.13.2.54 All plans/projects/activities screened into the assessment for cumulative effects from temporary habitat loss/disturbance are either on-going activities (i.e. licensed and application aggregate extraction areas) or other offshore wind farms which are consented, submitted or under construction (i.e. Tier 1). No Tier 2 or Tier 3 projects have been identified. The maximum design scenario is as described in chapter 1: Marine Processes.

Tier 1

Magnitude of impact

2.13.2.55 The Tier 1 assessment includes Hornsea Three together with Hornsea Project One – Heron Wind, Hornsea Project Two – Optimus Wind, Triton Knoll, Dudgeon and Race Bank offshore wind farms. With respect to currents, the cumulative presence of offshore wind farm structures is likely to result in near-field effects only (i.e. primarily within each offshore wind farm footprint). The presence of Hornsea Three alone is predicted to result in localised changes of approximately +0.04 ms^{-1} to -0.1 ms^{-1}. These are expected to be largely confined to within 4 km of the offshore wind farm footprint (see paragraph 2.11.2.52). The Hornsea Project One – Heron Wind assessment (SMartWind, 2013) predicted localised changes to flow rates of up to approximately ±0.05 ms^{-1}, though these were expected to be largely confined to the immediate vicinity of the foundation structures with some reduction in flow speed within approximately 4 km of the boundary of the array area. As for Project Two, the Hornsea Project Two – Optimus Wind assessment (SMartWind, 2015) predicted changes of approximately +0.04 ms^{-1} to -0.1 ms^{-1}. The Triton Knoll EIA (TKOWFL, 2012) predicted changes in currents ranging between -0.1 to +0.07 ms^{-1}, but for the majority of time there would be a slight reduction in current speed. Cumulative effects to current, as assessed in chapter 1: Marine Processes are predicted to be negligible.

2.13.2.56 Scour effects associated with the presence of offshore wind farm structures are also likely to be highly localised and spatially restricted to the immediate vicinity of the structures within the offshore wind farm arrays. For example, the Triton Knoll assessment predicted a maximum scour extent from foundations of 6.2 m (TKOWFL, 2012). Cumulative effects resulting from scour are therefore considered to be negligible.

2.13.2.57 The cumulative presence of the turbine foundations and associated infrastructure also has the potential to affect the wave regime which could lead to potential impacts on coastal habitats; this is fully assessed in chapter 1: Marine Processes. The predicted changes to wave heights resulting from the operational presence of Hornsea Project One, Hornsea Project Two and Hornsea Three are expected to be very small (less than ~2.5%) as far west as Humber Gateway and Westermost Rough for any of the wave directions tested. Moreover, potential wave interactions between the offshore wind farms in the former Hornsea Zone, Westermost Rough offshore wind farm and Humber Gateway offshore wind farm will only occur for waves coming from an easterly direction. Waves from this sector only occur for approximately 15% of the time and the majority of these waves are shorter period wind waves which will have recovered in height before reaching the Humber Gateway and Westermost Rough offshore wind farms. Accordingly, the duration of time over which potential wave interaction could occur is very small (volume 5, annex 1.1: Marine Processes Technical Report). The assessment presented in volume 5, annex 1.1 Marine Processes Technical Report concludes that the cumulative reduction in wave height predicted due to the operational presence of Hornsea Three, Hornsea Project One – Heron Wind, Hornsea Project Two – Optimus Wind, Triton Knoll and the other offshore wind farms presented above are considered to be of very small magnitude and are not predicted to have any measurable effects on sediment transport. Therefore, cumulative effects on benthic coastal habitats along the Lincolnshire and North Norfolk coastlines are not predicted.

2.13.2.58 With respect to effects on offshore sandbanks in the North Norfolk Sandbanks and Saturn Reef SCI, the closest sandbanks to the Hornsea Three array area are the Indefatigable Banks which are located approximately 10 km to the southwest of the Hornsea Three array area. Owing to the (east – west) alignment of the Hornsea Three array area relative to Hornsea Project One and Hornsea Project Two, there is very limited potential for a cumulative reduction in wave energy at these nearby banks. Moreover, as the Indefatigable Banks are understood to be largely relict features, it is extremely unlikely that any reductions in wave activity over the bank crests would result in a corresponding morphological change.

2.13.2.59 For sandbanks (i.e. Habitats E and F), the cumulative impact is predicted to be of regional spatial extent, long-term duration, intermittent and reversible. It is predicted that the impact will affect the receptor indirectly. The magnitude is therefore, considered to be **negligible**.

2.13.2.60 Cumulative impacts will extend over the regional area but will, on the whole, be highly localised to within the individual offshore wind farm areas, of long term duration, continuous and irreversible during the lifetime of the projects. The magnitude of the impact is therefore, considered to be **minor**.

Sensitivity of receptor

2.13.2.61 The sensitivities of subtidal receptors likely to be affected by cumulative effects associated with changes to marine processes are as described in paragraphs 2.11.2.61 to 2.11.2.71, and are summarised below.

2.13.2.62 Habitats A, B, C and D and Species L are deemed to be of low to medium vulnerability and regional value. The sensitivity of the receptors to the magnitude of changes predicted is therefore, considered to be **low**.

2.13.2.63 Sensitivity of the benthic communities associated with Habitats E and F (the Annex I sandbank features of the North Norfolk Sandbanks and Saturn Reef SCI) are considered to be identical to Habitat A and D, respectively as noted in paragraph 2.11.2.68, however these features are of international importance and are therefore considered to be of **medium** sensitivity.

2.13.2.64 As discussed in paragraph 2.11.1.35, the sensitivity of Habitats G and H, features of the Markham's Triangle rMCZ and Cromer Shoal Chalk Beds MCZ, and sensitivity of Habitat I, also a feature of Cromer Shoal Chalk Beds MCZ, are considered to be identical to Habitats A, B and C, respectively, However these habitats are of national importance and therefore are considered to be of **medium** sensitivity.

2.13.2.65 Sensitivity of Habitats J and K of the Cromer Shoal Chalk Beds MCZ are deemed to be of low vulnerability and are of national value. The sensitivity of the receptor is therefore, considered to be **low**.

Significance of the effect

2.13.2.66 The magnitude of the impact on Habitats E and F is **negligible** magnitude. The sensitivity of these VERs is **medium** and therefore the effect is considered to be of **minor** adverse significance, which is not significant in EIA terms.

2.13.2.67 The magnitude of impact on Habitats A, B, C, D, G, H, I, J and K and Species L is predicted to be **minor** and sensitivity of these features is **low** to **medium**. The effect is therefore considered to be **minor** adverse, which is not significant in EIA terms.

2.14 Transboundary effects

2.14.1.1 A screening of transboundary impacts has been carried out and is presented in annex 5.5: Transboundary Impacts Screening Note. This screening exercise identified that there was [no] potential for significant transboundary effects with regard to benthic ecology from Hornsea Three upon the interests of other European Economic Area (EEA) States.

2.14.1.2 The only transboundary impact that may result for Hornsea Three is increased SSC that may reach Klaverbank SCI. The Klaverbank SCI is 11 km from the Hornsea Three array area, within the Dutch jurisdiction. This site is designated for Annex I 'reefs', which is the primary reason for the designation of the site. However, as discussed in paragraph 2.11.1.45, elevations in SSC above background levels at distances of hundreds of metres to a few kilometres are predicted to be relatively low (i.e. less than ~20 mg/l) and within the range of natural variability and after 24 hours, elevations in SSC are predicted to typically be less than 5 mg/l. Therefore by the time that a plume might reach Klaverbank SCI, the SSC and any associated deposition are predicted to be at background levels, and are therefore likely to have negligible effects on the benthic receptors. As such, any transboundary effects on Klaverbank SCI are predicted to be not **significant**.

2.15 Inter-related effects

2.15.1.1 Inter-relationships are considered to be the impacts and associated effects of different aspects of the proposal on the same receptor. These are considered to be:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the project (construction, operational and maintenance, and decommissioning), to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g. subsea noise effects from piling, operational turbines, vessels and decommissioning); and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on benthic ecology such as direct habitat loss or disturbance, sediment plumes, scour, jack-up vessel use etc., may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

2.15.1.2 A description of the likely inter-related effects arising from Hornsea Three on benthic ecology is provided in chapter 12: Inter-Related Effects (Offshore).

2.16 Conclusion and summary

2.16.1.1 A number of potential impacts on benthic ecology, associated with the construction, operation and decommissioning of Hornsea Three, have been identified and are summarised in Table 2.25. With the proposed mitigation measures in place, all of these impacts result in effects of either negligible or minor adverse significance. Temporary and long term habitat loss/disturbance was deemed to be of minor adverse significance to benthic receptors in the Hornsea Three benthic ecology study area, with the proportion of habitat lost predicted to be small in the context of available habitats in the southern North Sea benthic ecology study area. Temporary increases in SSC and associated deposition were also deemed to be of minor adverse significance due to the short term nature of the impact and the generally low sensitivity of the receptors.

2.16.1.2 The effects on the habitats in the North Norfolk Sandbanks and Saturn Reef SCI, Cromer Shoal Chalk Beds MCZ and Markham's Triangle rMCZ, including the effects of temporary habitat loss/disturbance, increased SSC, deposition and associated contaminant resuspension, were assessed as being not relevant (as in the case of Annex I *Sabellaria* reefs for some impacts), negligible significance or minor adverse significance. The exception was the potential loss of subtidal chalk and peat and clay exposures within the Cromer Shoal Chalk Beds MCZ from cable installation during the construction phase, where a moderate significant impact was predicted, based on the information available to inform the PEIR. It should be noted, however, that the assumptions within this assessment were highly precautionary and that Hornsea Three is currently investigating the feasibility of avoiding these features and will seek to use this to mitigate these potential impacts, where possible, as the project evolves. This part of the impact assessment will therefore be revisited ahead of the Environmental Statement.

2.16.1.3 Cumulative impacts from plans, projects and activities screened into the assessment have been assessed using a tiered approach. These impacts are predicted to result in effects of negligible or minor adverse significance upon subtidal benthic communities within a representative 50 km buffer of Hornsea Three for additive effects (where applicable), and within one tidal excursion for synergistic effects. Subject to designed in measures (Table 2.17), including avoidance of *Sabellaria* Annex I reefs, subtidal chalk and clay and peat exposures, where possible, cumulative impacts of Hornsea Three and other projects on key features of Norfolk Sandbanks and Saturn Reef SCI, Cromer Shoal Chalk Beds MCZ and Markham's Triangle rMCZ, have also been assessed and are predicted to result in effects of mainly minor adverse significance.

2.17 Next Steps

2.17.1.1 As discussed in paragraph 2.6.4.3, a further Hornsea Three specific survey of the Hornsea Three offshore cable corridor is planned for Quarter Two 2017. The purpose of this survey is to further characterise the sediment properties and habitats along the Hornsea Three offshore cable corridor, particularly those within the SCI and, MCZ sites. Together with the existing data, this survey will be used to establish a robust and up-to-date characterisation of the baseline environment in the Hornsea Three offshore cable corridor. The results will be used to inform the final EIA report benthic ecology chapter.

Table 2.25: Summary of potential environmental effects, mitigation and monitoring.

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Construction Phase							
Temporary habitat loss/disturbance due to cable laying operations (including anchor placements), spud-can leg impacts from jack-up operations and seabed preparation works for gravity base foundations (GBFs), may affect benthic ecology.	Pre-construction surveys of the cable route corridor to be undertaken to identify habitats of conservation and ecological importance prior to construction. Should Annex I reef habitat be identified during pre-construction surveys of the export Hornsea Three offshore cable corridor, appropriate mitigation will be discussed with statutory consultees to avoid direct impacts to these features (where appropriate this may include micro-siting).	Minor (Habitats A to E, G, H, I, J and K and Species L)	Low (Habitats A, B and C) Medium (Habitats D, E, G, H and I and species L) Very high (Habitats J and K)	Minor adverse (Habitats A to E, G, H and I and Species L) Moderate adverse (Habitats J and K)	Hornsea Three is currently investigating the feasibility of avoiding Habitats J and K within the Cromer Shoal MCZ and will seek to use this to mitigate these potential impacts, where possible, as the project evolves.	To be confirmed in Environmental Statement	N/A
Temporary increases in suspended sediment concentrations and associated sediment deposition from cable and foundation installation and seabed preparation during the construction phase may affect benthic ecology.	N/A	Minor (Habitats A to K and Species L)	Low (Habitats A to I and Species L) Medium (Habitats J and K)	Minor adverse (Habitats A to K and Species L)	N/A	N/A	N/A
Seabed disturbances within the offshore cable corridor leading to the release of sediment contaminants and resulting in potential effects on benthic ecology.	N/A	To be determined in the final EIA	To be determined in the final EIA	To be determined in the final EIA	N/A	N/A	N/A
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Development of, and adherence to, a CoCP.	Negligible (Habitats A to K and Species L)	Low (Habitats A to D) Medium (Habitats E to K and Species L)	Negligible (Habitats A to K and Species L)	N/A	N/A	N/A
Operation Phase							
Long term loss of seabed habitat through presence of foundations, scour protection and cable protection, resulting in potential effects on benthic receptors.	Pre-construction surveys of the cable route corridor to be undertaken to identify habitats of conservation or ecological importance prior to construction. Should Annex I reef habitat be identified during pre-construction surveys of the export Hornsea Three offshore cable corridor, appropriate mitigation will be discussed with statutory consultees to avoid direct impacts to these features (where appropriate this may include micro-siting).	Minor (Habitats A to D, G, H and I and Species L)	High (Habitats A to D, G, H and I and Species L)	Minor adverse (Habitats A to D, G, H and I and Species L)	N/A	N/A	N/A
Colonisation of foundations/cable protection/scour protection may affect benthic ecology and biodiversity.	N/A	Minor (Habitats A to K)	Negligible (Habitats J and K) Low (Habitats A to I)	Negligible (Habitats J and K) Minor adverse (Habitats A to I)	N/A	N/A	N/A
Increased risk of introduction or spread of invasive and non-native species (INNS) due to presence of subsea infrastructure and vessel movements (e.g. ballast water) may affect benthic ecology and biodiversity.	Development of a Biosecurity Plan.	Negligible (Habitats A to K and Species L)	Medium (Habitats A, B, C, G and H and Species L) Low (Habitats F, J and K)	Minor adverse (Habitats A to K and Species L)	N/A	N/A	N/A

Description of impact	Measures adopted as part of the project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Alteration of seabed habitats arising from effects on physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic ecology.	N/A	Minor (Habitats A, B, C, G and H and Species L) Negligible (Habitats D, E, F, I, J and K)	Low (Habitats A, B, C, D, J and K and Species L) Medium (Habitats E, F, G, H and I)	Minor adverse (Habitats A to K and Species L)	N/A	N/A	N/A
Maintenance operations may result in temporary seabed disturbances and potential effects on benthic ecology.	N/A	Negligible (Habitats A to I and Species L)	Low (Habitats A, B, C, D and Species L) Medium (Habitats E, G, H and I)	Negligible (Habitats A, B, C, D and Species L) Negligible (Habitats E, G, H and I)	N/A	N/A	N/A
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Implementation of an appropriate PEMMP.	Negligible (Habitats A to K and Species L)	Low (Habitats A to D) Medium (Habitats E to K and L)	Negligible (Habitats A to K and Species L)	N/A	N/A	N/A
Decommissioning Phase							
Temporary loss of habitat due to operations to remove array cables, substation interconnector cables and export cables, and jack-up operations to remove foundations, resulting in potential effects on benthic ecology.	Should Annex I reefs (*Sabellaria* reefs) be identified in surveys undertaken prior to decommissioning, appropriate mitigation will be discussed with statutory consultees to avoid direct impacts to these features. Should Annex I reef habitat be identified during pre-construction surveys of the export Hornsea Three offshore cable corridor, appropriate mitigation will be discussed with statutory consultees to avoid direct impacts to these features (where appropriate this may include micro-siting).	Minor (Habitats A to K and Species L)	Low (Habitats A, B and C) Medium (Habitats D, E, G, H and I and species L) High (Habitats J and K)	Minor adverse (Habitats A to E, G to K and Species L)	Hornsea Three is currently investigating the feasibility of avoiding Habitats J and K within the Cromer Shoal MCZ and will seek to use this to mitigate these potential impacts, where possible, as the project evolves.	To be confirmed in Environmental Statement	
Temporary increases in suspended sediment concentrations and deposition from removal of array cables, export cables and foundations resulting in potential effects on benthic ecology.	N/A	Minor (Habitats A to E, G, H and I and Species L)	Low (Habitats A B, C) Medium (Habitats D, E, G, H, I and species L)	Minor adverse (Habitats A to E, G, H and I and Species L)	N/A	N/A	N/A
Removal of foundations and cable protection leading to loss of species/habitats colonising these structures.	N/A	Minor (Habitats A, B, C, D, G and H)	Low (Habitats A, B, C, D, G and H)	Negligible (Habitats A, B, C, D, G and H)	N/A	N/A	N/A
Permanent habitat loss due to presence of scour/cable protection left in situ post decommissioning, and potential effects on benthic ecology.	N/A	Minor (Habitats A, B, C, D, G, H and I and Species L)	High (Habitats A, B, C, D, G, H and I and Species L)	Minor adverse (Habitats A, B, C, D, G, H and I and Species L)	N/A	N/A	N/A
Accidental release of pollutants (e.g. from accidental spillage/leakage) may affect benthic ecology.	Development of a Decommissioning Programme.	Negligible (Habitats A to K and Species L)	Low (Habitats A to D) Medium (Habitats E to K and Species L)	Negligible (Habitats A to K and Species L)	N/A	N/A	N/A

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