
# Hornsea Project Four:

# A4.4.4: Dredging and Disposal (Site Characterisation) (tracked)

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# Glossary

| Term | Definition |
|---|---|
| Benthic | A description for flora and fauna associated with the seabed. Flora and fauna that lie in, on or near the seabed are termed 'benthos'. |
| Biotope | The combination of physical environment (habitat) and its distinctive assemblages of conspicuous species. |
| Commitment | A term used interchangeably with mitigation and enhancement measures. The purpose of Commitments is to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms. Primary (Design) or Tertiary (Inherent) are both embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, Preliminary Environmental Information Report (PEIR) or Environmental Statement (ES)). Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are acceptable. |
| Demersal | Fish living on or near the seabed. |
| Epibenthic | Organisms living specifically on the seabed surface. |
| Epifauna | Animals living on the seabed surface. |
| Habitat | The place in which an animal or plant lives. In the marine environment, this is defined according to geographical location, physiographic features and the physical and chemical environment, including salinity, wave exposure, tidal currents, geology, substrate, biological zone, features and modifiers. |
| Hornsea Project Four Offshore Wind Farm | The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and connection to the electricity transmission network. Hereafter referred to as Hornsea Four. |
| Infauna | Animals living in the seabed sediment. |
| Intertidal | Area of seashore that is covered at high tide and uncovered at low tide. |
| Landings | Quantitative description of the amount of fish returned for sale in terms of value or weight. |
| Order Limits | The limits within which Hornsea Four (the 'authorised project) may be carried out. |
| Orsted Hornsea Project Four Ltd. | The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO). |
| Pelagic | Relating to the open sea. |
| Scour | Local erosion of sediments caused by local flow acceleration around an obstacle and associated turbulence enhancement. |
| Subtidal | Area extending from below low tide to the edge of the continental shelf. |
| Suspended Sediment Concentration | Mass of sediment in suspension per unit volume of water. |

# Acronyms

| Acronym | Definition |
|---|---|
| AfL | Agreement for Lease |
| CCS | Carbon Capture and Storage |
| CAL1 | Cefas Action Level 1 |
| CAL2 | Cefas Action Level 2 |
| Cefas | Centre for Fisheries and Aquaculture Science |
| CFE | Controlled Flow Excavation |
| DCO | Development Consent Order |
| DML | deemed Marine Licence |
| Defra | Department for Environment, Food & Rural Affairs |
| DECC | Department of Energy & Climate Change |
| ECC | Export Cable Corridor |
| EIA | Environmental Impact Assessment |
| ES | Environmental Statement |
| EU | European Union |
| EUNIS | European Nature Information System |
| GBS | Gravity Base Structure |
| HDD | Horizontal Directional Drilling |
| HVAC | High Voltage Alternating Current |
| HVDC | High Voltage Direct Current |
| ICES | International Council for the Exploration of the Sea |
| IHLS | International Herring Larvae Surveys |
| JNCC | Joint Nature Conservation Committee |
| LAT | Lowest Astronomical Tide |
| LSO | Long Sea Outfall |
| MCZ | Marine Conservation Zone |
| MDS | Maximum Design Scenario |
| MHS | Mean High Water |
| MLW | Mean Low Water |
| MMO | Marine Management Organisation |
| MU | Management Unit |
| OSPAR | Oslo-Paris Commission |
| OSS | Offshore Substation |
| PEIR | Preliminary Environmental Information Report |
| PSA | Particle Size Analysis |
| RIAA | Report to Inform Appropriate Assessment |
| SAC | Special Area of Conservation |
| SPA | Special Protection Area |
| SSC | Suspended Sediment Concentration |
| TOC | Total Organic Carbon |
| WFD | Water Framework Directive |
| WTG | Wind Turbine Generator |

# Units

| Unit | Definition |
|---|---|
| £ | Great British Pounds Sterling |
| cm | Centimetre |
| km | Kilometre |
| $km^2$ | Square kilometre |
| l | Litre |
| m | Metre |
| $m^3$ | Cubic metre |
| mg | Milligram |
| nT | Nanotesla |
| s | Seconds |

# 1 Introduction

## 1.1 Project Background

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter 'the Applicant') is proposing to develop the Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four'). Hornsea Four will be located approximately 69 km from the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in the former Hornsea Zone (please see **Volume A1, Chapter 1: Introduction** for further details on the former Hornsea Zone). Hornsea Four will include both offshore and onshore infrastructure, including an offshore generating station (wind farm), export cables to landfall, and connection to the electricity transmission network (please see **Volume A1, Chapter 4: Project Description** for full details of the Project Design).

1.1.1.2 The Hornsea Four Agreement for Lease (AfL) area was 846 $km^2$ at the Scoping phase of project development. In the spirit of keeping with Hornsea Four's approach to Proportionate Environmental Impact Assessment (EIA), the project has due consideration to the size and location (within the existing AfL area) of the final project that is being taken forward to Development Consent Order (DCO) application. This consideration is captured internally as the "Developable Area Process", which includes Physical, Biological and Human constraints in refining the developable area, balancing consenting and commercial considerations with technical feasibility for construction.

1.1.1.3 The combination of Hornsea Four's Proportionality in EIA and Developable Area process has resulted in a marked reduction in the AfL taken forward at the point of DCO application. Hornsea Four adopted a major site reduction from the AfL presented at Scoping (846 $km^2$) to the Preliminary Environmental Information Report (PEIR) boundary (600 $km^2$), with a further reduction adopted for the Environmental Statement (ES) and DCO application (468 $km^2$) due to the results of the PEIR, technical considerations and stakeholder feedback. The evolution of the Hornsea Four Order Limits is detailed in **Volume A1, Chapter 3: Site Selection and Consideration of Alternatives** and **Volume A4, Annex 3.2: Selection and Refinement of the Offshore Infrastructure**.

## 1.2 Scope and Purpose of this Document

1.2.1.1 This document comprises the site characterisation for Hornsea Four as required to permit disposal of seabed and sub-bottom geological material that may arise during the construction of the offshore elements of Hornsea Four.

1.2.1.2 Site characterisation is the process whereby a proposed marine disposal site for spoil material and drill arisings generated by construction activities is described in terms of the existing environment, using all available data sources. It is a requirement that a site characterisation report be submitted to the Marine Management Organisation (MMO), and their scientific advisor, Cefas (the Centre for Environment, Fisheries and Aquaculture Science), to inform the decision-making process and to allow the licensing of the disposal site as well as facilitating the consideration of the need for any relevant conditions in relation to the disposal activity within the Deemed Marine Licences (DMLs) for Hornsea Four. The following information is provided:

- The need for the new disposal site;
- The dredged and/or drilled material characteristics;
- The disposal site characteristics;

- The assessment of potential effects; and
- The reasons for the site selection.

1.2.1.3 This document outlines the site characterisation for the following two proposed Hornsea Four disposal sites that are illustrated in **Figure 1**.

- Array Area Disposal Site: the full extent of the Hornsea Four array area (as defined in **Volume D1, Annex 4.1: Works Plan - Offshore**); and
- Cable Corridor Disposal Site: the full extent of the offshore ECC including the temporary works area and High Voltage Alternating Current (HVAC) booster station search area (as defined in **Volume D1, Annex 4.1: Works Plan - Offshore**).

1.2.1.4 The disposal activity will involve the deposit of inert, native sedimentary material originating from the following activities associated with the construction of Hornsea Four within the proposed Hornsea Four Order Limits:

- Construction drilling;
- Seabed preparation for foundation works;
- Cable installation preparation; and
- Excavation of horizontal directional drilling (HDD) exit pits.

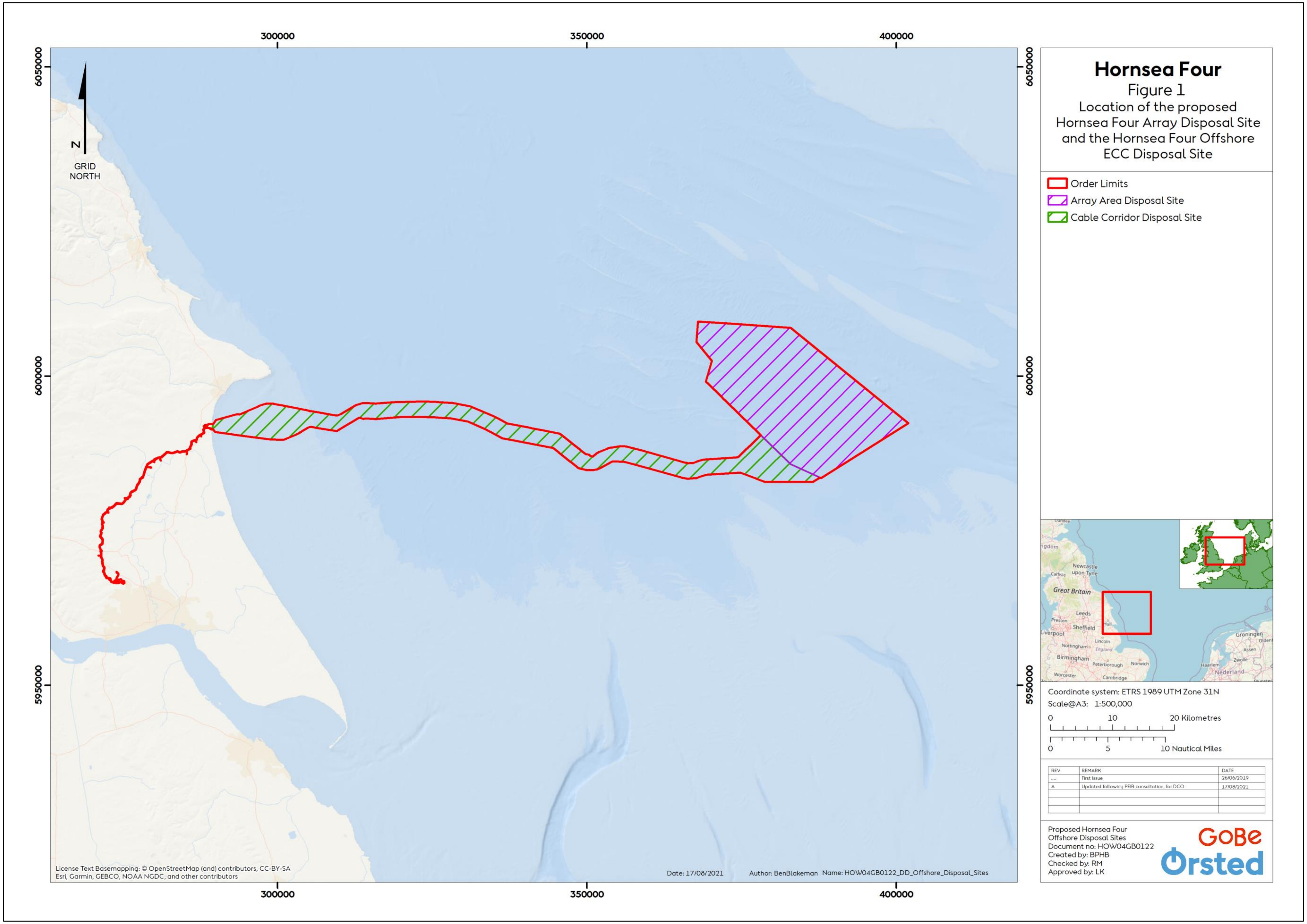


**Figure 1: Location of the proposed Hornsea Four Array Disposal Site and the Hornsea Four Offshore ECC Disposal Site.**

### 1.3 Project Overview

1.3.1.1 Hornsea Four will have a maximum of 180 wind turbine generators (WTGs). These will be connected to offshore substations (OSSs) via array cables, and then to offshore export cables. Up to six offshore export cables will transfer power from the Hornsea Four array area to the landfall. At landfall, the offshore export cables will be joined to onshore export cables at transition joint bays.

1.3.1.2 With the Hornsea Four array area, up to six offshore transformer substations, up to three offshore High Voltage Direct Current (HVDC) converter substations and one offshore accommodation platform may be constructed. Additionally, up to three offshore HVAC booster stations would be located in the Hornsea Four offshore ECC, rather than in the Hornsea Four array area. Offshore HVDC converter substations are mutually exclusive with HVAC booster stations in a single transmission system and as such, the total numbers of each of these structure types should not be combined in the total number of structures.

1.3.1.3 The following foundation types for WTGs, OSSs, booster stations and the accommodation platform are being considered:

- Monopile (all structures);
- Mono-suction bucket (all structures);
- Piled jacket (WTG-type) (all structures);
- Gravity Base Structure (GBS) (WTG-type) (all structures);
- GBS (Box-type) (OSS and platforms);
- Suction bucket jacket (WTG-type) (all structures);
- Suction bucket jacket (Small OSS) (OSS and platforms);
- Piled jacket (Small OSS) (OSS and platforms);
- Piled jacket (Large OSS) (offshore HVDC converter substation/HVAC substations only);
- Suction bucket jacket (Large OSS) (offshore HVDC converter substation/HVAC substations only);
- Box-type GBS (Large OSS) (offshore HVDC converter substation/HVAC substations only); and
- Pontoon GBS (offshore HVDC converter substation/HVAC substations only).

1.3.1.4 The final selection of foundation type(s) will be dependent on a range of factors including turbine and platform size, seabed conditions, water depth, environmental considerations and supply chain considerations. Therefore, the type of foundations will not be confirmed until the final design phase that will occur post-consent. Some form of seabed preparation may also be required for each foundation type. Seabed preparations may include seabed levelling and removing surface and subsurface debris, as detailed in **Volume A1, Chapter 4: Project Description**. If debris are present below the seabed surface, then excavation may be required for access and removal.

## 2 Consultation

2.1.1.1 A Dredging and Disposal (Site Characterisation) Report was prepared and submitted as part of the PEIR to be reviewed as part of the Section 42 consultation process. A summary of the key issues raised during consultation, specific to this report is provided in **Table 1**, together with how these issues have been considered in the production of this report.

**Table 1: Consultation responses.**

| Consultee | Date, Document, Forum | Comment | Where addressed in the ES |
|---|---|---|---|
| MMO | 23 September 2019 Section 42 Consultation | The MMO requested presentation of the two Hornsea Four disposal sites on a figure. The MMO also noted that no open disposal site can overlap with another open site. | The proposed Hornsea Four disposal sites are presented in **Figure 1**. The Applicant can confirm that there is no overlap of these proposed sites with any other open disposal sites. The proposed Hornsea Four offshore ECC disposal site does overlap with the Dogger Bank A & B export cable corridor but disposal for Dogger Bank A & B is only permitted within the Dogger Bank A & B array area (of which there is no overlap with the Hornsea Four proposed disposal sites). |
| MMO | 23 September 2019 Section 42 Consultation | The MMO agreed with the conclusions of the Dredging and Disposal (Site Characterisation Report) but noted that the Applicant should continue to investigate alternative uses of the material to be disposed of within the two proposed disposal sites. | Noted. Alternative uses of the material has been considered in **Section 4** of this report. |
| MMO | 23 September 2019 Section 42 Consultation | Article 1, Work No. 10(c) should stipulate maximum parameters for disposal from seabed levelling, boulder clearance and drill arisings respectively. | Work No.10 relates to works above MHWS. Work No.1-5 relates to works below MHWS. Maximum total values are presented for Work No.1-5 within the DCO. The constituent parts of the maximum parameters presented in the DCO for disposal, seabed levelling, boulder clearance and drill arisings are presented within **Volume A4, Annex 4.8: Pro-Rata Annex.** |
| Natural England | 15 October 2019 Section 42 Consultation | Natural England noted discrepancies between the receptor sensitivity to temporary localised increases in Suspended Sediment Concentration (SSC) and smothering presented in the Dredging and Disposal (Site Characterisation Report and the Fish and Shellfish Chapter. Natural England also noted their disagreement on the conclusion of the significance of this effect. | This report has been updated in line with the assessment presented within **Volume A2, Chapter 3: Fish and Shellfish Ecology** which has, in turn, also been updated following PEIR comments and consultee comments on an updated draft ES chapter.<br><br>The Applicant has considered further mitigation options through discussions with stakeholders within the Evidence Plan process and has committed to a seasonal piling restriction for the HVAC booster stations during the herring spawning season. This is secured by commitment |

| Consultee | Date, Document, Forum | Comment | Where addressed in the ES |
| --- | --- | --- | --- |
| | | | (Co190 – see further details in **Volume A4, Annex 5.2: Commitment Register**). |
| Natural England | 15 October 2019 Section 42 Consultation | Natural England noted that the Draft DCO and DMLS should detail the maximum volumes of hard and soft substrate to be disposed of, i.e. maximum volumes of seabed levelling and volumes of boulder clearance/drill arisings. | Work No.1-5 relates to works below MHWS. Maximum total values are presented for Work No.1-5 within the DCO. The constituent parts of the maximum parameters presented in the DCO for disposal, seabed levelling, boulder clearance and drill arisings are presented within **Volume A4, Annex 4.8: Pro-Rata Annex**. The differentiation of hard and soft substrate types will be presented in the final dredging and disposal site characterisation report. |

# 3 Predicted source of spoil and estimated quantities for disposal

## 3.1 Sources of spoil

### 3.1.1 Foundation installation – seabed preparation and drilling

3.1.1.1 Spoil will be generated from the installation of each of the WTG, OSS and offshore accommodation platform foundation types that are included in the project design (either through seabed preparatory works and/or from drilling).

3.1.1.2 For those foundation types that may require seabed preparation (i.e. all foundation types excluding monopiles), any soft mobile or unlevel sediment in the area of installation may need to be removed to create a firm, stable and level seabed prior to foundation installation. Initial investigations (see **Volume A5, Annex 1.1: Marine Processes Technical Report**) have shown some variability in the seabed topography with sandwaves and associated megaripples evident across the majority of the offshore array area apart from the southerly region, and areas of megaripples are evident in the vicinity of the HVAC booster station search area. Typically, surface sediments (sands and gravels) will be removed by a suction hopper dredger which will subsequently release the dredged sediment from its hopper either at the water surface or via discharge pipes, within the array area, usually adjacent to the foundation locations.

3.1.1.3 Depending on ground conditions within the Hornsea Four array area and the HVAC booster station search area, drilling may be required to install piles to their target depth for those WTG and OSS foundation types involving piling (i.e. monopiles or piled jackets). It is assumed that up to 10% of pile locations or up to 10% of pile depths across the array may require drilling.

3.1.1.4 Spoil created by drilling will normally be disposed of adjacent to the foundation location (i.e. the drilling location) and will be discharged at the sea surface settling rapidly to the seabed. Drill arisings typically comprise inert sub-bottom geological material; as a result, it will not result in the introduction of contaminants of anthropogenic origin to the marine environment. Disposal of drill arisings adjacent to installed foundations has been used on existing UK offshore wind farms including, for example, London Array and Hornsea Project One, amongst others. Monitoring of benthic communities associated with offshore wind farm drill arisings has indicated no long-term adverse effects on the overall benthic ecology of the study area (Joint Nature Conservation Committee (JNCC) 2013).

### 3.1.2 Cable installation preparation – sandwave clearance and pre-trenching

3.1.2.1 Prior to the installation of cables (array, export and interconnector cables), seabed preparation in the form of sandwave clearance and pre-trenching may be required to facilitate the use of cable installation equipment within its operational tolerances and to reduce stress on the cable by maximising the bending radius. These activities also reduce the chance of unsuccessful cable installation and increases the likelihood of installation to the maximum target burial depth.

3.1.2.2 As with seabed preparation described above, sandwave clearance may be undertaken by suction hopper dredger, which will subsequently release material at the sea surface or via discharge pipes and will be composed of surficial sediments. Alternatively, the seabed may be levelled by the use of Controlled Flow Excavation (CFE).

### 3.1.3 Excavation of HDD exit pits

3.1.3.1 For the installation of HDD ducts to connect the offshore export cables to the onshore export cables at landfall, up to eight HDD exit pits will be excavated in the shallow subtidal area, at a minimum of 400 m and a maximum of up to 1,500 m from the onshore transition joint bay, although the final locations will be confirmed post-consent. The HDD exit pit ~~may be located above mean high water (MHW), within the Hornsea Four intertidal area (intertidal punch out) or~~ will be below mean low water (MLW). Exit pits will be excavated or dredged to the required depth.

3.1.3.2 The jack up barge or lay barge will be located behind the punch out location and the exit pit will be excavated using a long reach excavator located on the jack up or lay barge. There will be up to three exit pits open at any given time ( . Material will either be taken away to a designated disposal site or stored adjacent to the exit pit prior to backfilling.

## 3.2 Volumes of spoil for disposal

### 3.2.1 Hornsea Four array disposal site

3.2.1.1 The Maximum Design Scenario (MDS) volumes of material to be disposed in the array area from seabed preparation for foundation works, pile drilling and cable installation preparation are summarised in **Table 2**.

3.2.1.2 It is important to note that it is possible that piled jacket foundations may require seabed preparation as well as drilling. In this case, the total volume for disposal for this foundation type will not exceed the total volume for the MDS of seabed preparation for non-piled foundations.

**Table 2: Summary of MDS spoil volumes associated with seabed preparation, pile drilling and cable installation in the Hornsea Four array area disposal site.**

| Source | Volume ($m^3$) | |
|---|---|---|
| | Drilling for piled foundations | Seabed preparation for non-piled foundations |
| *Foundations* | | |
| WTG Foundations (180) | 127,235 $m^3$ (assuming 10% of sites require drilling to full pile depth) (Monopiles) | 1,012,226 $m^3$ (80 x GBS (WTG type) and 100 x suction bucket jacket (WTG type)) |
| OSS Foundations (six small offshore transformer substations and three large offshore converter substations) | 13,854 $m^3$ (assuming drilling of all piles to 10% of pile depth) (Piled Jacket (Small OSS)) | 737,130 $m^3$ (Suction Caisson Jacket (Small OSS) and GBS (Large OSS)) |
| Offshore Accommodation Platform (one small OSS) | 1,539 $m^3$ (assuming drilling of all piles to 10% of pile depth) (piled jacket) | 57,245 $m^3$ (Suction Caisson Jacket (Small OSS)) |
| ***Foundation subtotal*** | ***142,628 $m^3$*** | ***1,806,601 $m^3$*** |
| *Cables (Sandwave Clearance)* | | |
| Array cables | 727,000 $m^3$ | |
| Interconnector cables | 110,000 $m^3$ | |
| Export cable (part within array) | 68,000 $m^3$ | |
| ***Cables subtotal*** | ***905,000 $m^3$*** | |
| *Cables (Trenching)* | | |
| Array cables | 3,600,000 $m^3$ | |
| Interconnector cables | 540,000 $m^3$ | |
| Export cable (part within array) | 360,000 $m^3$ | |
| ***Cables subtotal (see footnote)*** | ***4,500,000 $m^3$*** | |
| **Total** | **5,547,628 $m^3$** (in the case of piled foundations) | **7,211,601 $m^3$** (in the case of seabed preparation for non-piled foundations) |

**FOOTNOTE**: Hornsea Four may apply for permission for pre-lay trenching (trench cut and material sidecast, cable laid and then natural infill of trench). Hornsea Project One previously sought such permission from the MMO, who confirmed that this process was not disposal. The Hornsea Four application and approval would therefore reduce the disposal volumes accordingly.

### 3.2.2 Hornsea Four Offshore ECC disposal site

3.2.2.1 The MDS for the offshore ECC includes sandwave clearance, export cable installation, the excavation of HDD exit pits, as well as seabed preparation and drilling for HVAC booster station foundations. These are described in Table 3. It is noted that piled jacket foundations may require seabed preparation as well as drilling. In this case, the total volume for disposal for this foundation type will not exceed the total volume for MDS of seabed preparation for non-piled foundations.

**Table 3: Summary of MDS spoil volumes associated with seabed preparation, pile drilling and cable installation in the Hornsea Four cable corridor disposal site.**

| Source | Volume ($m^3$) | |
|---|---|---|
| | Drilling for piled foundations | Seabed preparation for non-piled foundations (as MDS volumes) |
| *Foundations* | | |
| HVAC Booster Stations (3) | 4,617 $m^3$ (assuming drilling of all piles to 10% of pile depth) (Piled Jacket (Small OSS)) | 171,735 $m^3$ (Suction Caisson Jacket (Small OSS)) |
| *Cables (Sandwave Clearance)* | | |
| Export cable (ECC only) | 371,000 $m^3$ | |
| *Cables (Trenching)* | | |
| Export cable (ECC only) | 3,543,000 $m^3$ | |
| *HDD Exit Pits* | | |
| HDD Exit Pits (8) | 20,000 $m^3$ | |
| **Total** | **3,938,617 $m^3$** (in the case of piled foundations) | **4,105,735 $m^3$** (in the case of seabed preparation for non-piled foundations) |

### 3.2.3 Total

3.2.3.1 As a worst-case, the total volume of material that may require disposal would be up to 11,317,336 $m^3$ (if non-piled foundations are used for all foundations), of which up to 7,211,601 $m^3$ may be disposed of in the array area disposal site and up to 4,105,735 $m^3$ in the cable corridor disposal site.

3.2.3.2 If piled foundations are used and require drilling (without the need for seabed preparation), the worst-case total would be up to 9,486,245 $m^3$, with up to 5,547,628 $m^3$ in the array area disposal site and up to 3,938,617 $m^3$ in the cable corridor disposal site.

# 4 Alternative options for disposal

4.1.1.1 Once drilled or dredged material has been produced, it is classified as a waste material. Once a material has entered the waste stream it is strictly controlled.

4.1.1.2 Disposal of dredged and drilled material is controlled under the London Convention 1972, the Oslo-Paris Commission (OSPAR) Convention 1992, and the European Union (EU) Waste Framework Directive 2008/98/EC. At the core of the Waste Framework Directive is the Waste Hierarchy (Department for Environment, Food & Rural Affairs (Defra) 2011) which comprises:

- Prevention;
- Re-use;
- Recycle;
- Other recovery; and
- Disposal.

4.1.1.3 Where prevention or minimisation is not possible, management options for dealing with waste material must consider the alternative options in the order of priority indicated above (i.e. re-use, recycle, other recovery and then disposal).

4.1.1.4 The consideration of alternative solutions to the disposal of drilled and/or dredged material within the array and offshore ECC is therefore an important part of the site characterisation process and is required in order to inform the decision-making process required of the MMO and their advisors. The following sections of this document present information on potential alternative to the disposal of drilled and dredged material from Hornsea Four.

## 4.2 Prevention

4.2.1.1 The Waste Hierarchy places a strong emphasis on waste prevention or the minimisation of waste. However, consent is being sought for Hornsea Four for the use of a range of foundation options and cable installation methodologies. Further information is required before the design of Hornsea Four can be finalised and it is possible, for example, that more than one foundation type may be used across the project.

4.2.1.2 For piled foundations, if percussive piling alone does not achieve full pile penetration due to the presence of hard ground conditions, the material inside the monopile/pin piles may need to be drilled out before the pile can be driven to the required depth. If drilling is required, the generation of spoil arising from the drilling will be unavoidable. For piled foundations, the MDS is that up to 10% of the foundations may require drilling to assist with installation.

4.2.1.3 If non-piled foundations are chosen, seabed preparation works including dredging and disposal will be unavoidable in order to achieve the flat and stable seabed that is required to seat these particular foundation types, although the volumes of spoil generated will depend on the size of foundations needed and the seabed conditions at each installation location.

4.2.1.4 Sandwave clearance is expected to be required in areas where sandwave gradients are in excess of the working limits for standard cable installation equipment, to avoid unnecessary strain on the cables through bending, and to maximise ploughing efficiency and reduce the chances of burial failure. Additionally, the cable must be buried to a depth where it may be expected to stay buried for the duration of the project lifetime. Sandwaves are generally mobile in nature therefore the cable must be buried beneath the level where natural sandwave movement would uncover it. Sometimes this can only be done by removing the mobile sediments before installation takes place. Therefore, to install the cables for Hornsea Four, sandwave clearance and the associated dredging and disposal works will in some cases be unavoidable.

4.2.1.5 As a result, the safe and effective installation of the Hornsea Four infrastructure may involve installation techniques that give rise to spoil. Whilst volumes of spoil will be minimised to that necessary for safe and effective installation, it is not possible to prevent spoil generation.

## 4.3 Re-use

4.3.1.1 Where prevention is not possible, the re-use of dredged and drilled material is the preferred option. Potential options for the re-use of dredged and drilled material can include:

- Beach nourishment/replenishment schemes;
- Land reclamation schemes; and
- Habitat enhancement schemes.

4.3.1.2 The material for disposal within the array and offshore ECC could potentially have alternative uses. Transfer of the volume of spoil material to another location where material could be re-used would consist of the movement of up to 7,211,601 $m^3$ from the array area (see **Table 2** for the detailed breakdown) and up to 4,105,735 $m^3$ from the offshore ECC (see **Table 3** for the detailed breakdown). Alternative uses are most likely to be based on land, which would require a total of up to approximately 656 and 374 dredging cycles for the array area and ECC disposal, respectively (assuming a hopper capacity of 11,000 $m^3$). Each cycle would form a round trip from the closest port (for example, in the Humber).

4.3.1.3 Collection of drill arisings would be costly due to the need for suction dredging vessels in addition to drilling vessels and the limited material produced at each foundation site means collection would not be viable.

4.3.1.4 Dredger movements would lead to additional environmental impacts due to increased vessel emissions that could be avoided if dredged material were disposed of *in situ* (i.e. close to the source of production). Barges for transporting material away from Hornsea Four may also require four-point anchoring systems at each loading point, which would also result in an additional environmental impact which the disposal of material *in situ* would preclude.

4.3.1.5 At the time of writing, no projects have been identified that could accept the type and volume of spoil material that might be generated during the construction of Hornsea Four. Therefore, even if it were technically and economically feasible to re-sue the spoil material, at present there are no known projects to facilitate its re-use.

4.3.1.6 In conclusion, the assessments undertaken have not identified any significant adverse (in EIA terms) impacts on receptors as a result of the proposed disposal activity. It is concluded that whilst potential alternative options for use of this material may exist in theory and at some point in the future, disposal *in situ* remains the most viable option. *In situ* disposal also has the advantage of retaining sediment within the local sedimentary system.

## 4.4 Recycle

4.4.1.1 Recycling of drilled and dredged material would involve transforming the material into a different form, for example to produce bricks or aggregate material. As outlined in the MMO guidance (MMO 2011), these are generally land-based solutions with any material produced used in onshore construction projects. As such, the same issues with respect to vessel movements to transport the dredged material to land, as discussed above, would apply. The disposal of drilled and dredged spoil material *in situ* would preclude the additional environmental impacts that would arise.

### 4.5 Other recovery

4.5.1.1 There are currently very few examples of recovery from dredged and drilled material (MMO 2011) and no such options have been identified for the spoil material from Hornsea Four.

### 4.6 Disposal

4.6.1.1 With regards to the potential to dispose of the produced spoil at an existing marine disposal site, the closest open marine disposal site is for Hornsea Project Two Offshore Wind Farm (Hornsea Project Two), located to the east of Hornsea Four.

4.6.1.2 Disposal sites are generally licensed to enable the disposal of material from specific locations and activities. It is not considered desirable to use an existing disposal site since they are not generally designated for additional volumes beyond those necessary for the specific purpose for which they were licensed.

4.6.1.3 In addition, the use of another site, such as the Hornsea Project Two licensed disposal site, would require the transport of the Hornsea Four spoil material away from Hornsea Four to another disposal site, resulting in additional vessel movements. The receiving seabed environment at an alternative location may also be characterised by a somewhat different sediment composition. Disposal of the spoil material *in situ* within the Hornsea Four project boundary, and close to the point of production, ensures that the spoil will be returned into a broadly similar sedimentary environment (and in the case of drill arisings, ensures that the spread of material away from the point of production is minimised). Disposal of material at another disposal site may also require hydrodynamic and sediment transport modelling studies to determine the capacity of the site to accommodate the additional spoil type and volumes.

4.6.1.4 Therefore, it is concluded that disposal at an existing marine disposal sites does not represent the most efficient or environmentally robust approach to disposal of material from Hornsea Four array area and the offshore ECC.

## 5 Characteristics of the Hornsea Four disposal sites

### 5.1 Physical characteristics

5.1.1.1 This section provides a summary of the physical characteristics of the Hornsea Four array area and offshore ECC. Further details on the physical environment are set out in **Volume A5, Annex 1.1: Marine Processes Technical Report** and **Volume A2, Chapter 1: Marine Geology, Oceanography and Physical Processes**.

#### 5.1.2 Array area disposal site

*Tide and wave regime*

5.1.2.1 Tidal flows across the array area occur at velocities of 0.5 – 0.6 m/s, though this is limited to peak flows during spring tides. Tidal ellipses are generally aligned north-west on the ebb tide and south-east on the flood tide.

5.1.2.2 Waves across the array have periods in the range of 3 – 6 s, typically around 4 s. Significant wave heights are typically less than 1 m but can reach up to 4.5 m during storm events. Wave directions are predominantly from the north-west. Due to local water depths of more than 32 m, even the largest waves are not capable of stirring local sediments alone. This means peak tidal currents during spring tides are the main mechanism for developing sediment transport across the offshore array area.

*Seabed geology*

5.1.2.3 Holocene deposits are generally less than 1 m thick across the array, varying with the presence of thick sandwave and sand ridge features. Beneath the surface layer of Holocene sands, there is a firm to stiff clay till of the Bolders Bank Formation. There are instances where the Bolders Bank Formation layer becomes very thin and, at times, absent leaving the Holocene sediments directly overlying the Cretaceous Chalk and pre-chalk sediments. Sub-surface chalk appears to be absent in the northern and western parts of the offshore array area, as well as some of the eastern part, but most evident in the central to southern parts with increasing depths below seabed from around 3 to 100 m.

5.1.2.4 The seabed lithology of the offshore array area is mainly sandy with a few patches of gravelly sand (Holocene sands at the sea surface). There is also an area bordering the Outer Silver Pit with gravelly muddy sand.

*Bedforms and sediment transport*

5.1.2.5 The general seabed profile across the array area shelves into deeper water in a northerly direction from around 40 m to 55 m below Lowest Astronomical Tide (LAT). The Outer Silver Pit, a large geological "tunnel valley" depression, establishes the north-westerly / south-easterly alignment of the eastern boundary of the offshore array area. The shallowest parts of the array are associated with large bedform structures. The shallowest depth is approximately 34 m, associated with the ridge of a sandbank feature known as 'The Hills' in the north-west of the array.

5.1.2.6 Sandwave crests are evident across much of the array, except in the southern extents, and are generally aligned perpendicular to the axis of tidal flows. The asymmetric cross-section of sandwaves suggests a net transport direction in a north-westerly direction driven by a flood dominant tidal flow.

*Suspended sediments*

5.1.2.7 Surface turbidity is relatively low across the offshore array area, with monthly averaged concentrations typically less than 5 mg/l across the whole year, with minimal seasonal variation. The relatively low concentrations are due to a low content of fine material in the seabed sediments and the area being distant from any terrestrial sources such as the Humber Estuary and the Holderness Cliffs.

### 5.1.3 Cable corridor disposal site

*Tide and wave regime*

5.1.3.1 In open water, tidal flows are generally to the south-east on the flood tide and north-west on the ebb tide. Closer inshore flows become more aligned with the orientation of the coastline, especially around Flamborough Head where flows become strongest. Regional mapping shows tidal flows tend to reduce from west to east along the offshore ECC, with the most sheltered conditions in the lee of the headland.

5.1.3.2 The general pattern across the offshore ECC is for lower wave heights and wave periods closer to shore due to local sheltering from northerly waves by Flamborough Head and the commencement of shallow water shoaling of larger waves. Wave heights and periods increases further offshore, and this also varies seasonally. Wave periods along the offshore ECC are typically in the region 3 to 6 s, and occasionally up to 7 to 8 s. These periods are typical of wind generated seas without a strong influence of swell. Average wave heights in the inshore section of the ECC are 1.20 m in winter and 0.79 m in summer. In the HVAC booster station search area, this increases to 1.84 m in winter and 1.06 m in summer. This increases towards the array area.

*Seabed geology*

5.1.3.3 Surficial sediment cover along the offshore ECC indicates an increasing sand content from inshore to offshore. From the landfall, the surficial sediments comprise sands with patches of gravelly sand, becoming sands across the shallower Smithic Bank, then sandy gravels onto gravelly sands, slightly gravelly sands and finally sands once into the array area.

*Bedforms and sediment transport*

5.1.3.4 The offshore ECC commences from the seaward extent of the landfall area with depths approximately 7 m below LAT onto a relatively flat seabed profile. This flat area is the seaward end of an ebb tidal channel that extends to Flamborough Head and defines the inshore flank of Smithic Bank[1]. From this location, the offshore ECC gently shallows onto the southern part of Smithic Bank where depths reduce to around 5 m below LAT. Approximately 9 km from the coastline, the offshore ECC reaches the eastern edge of the bank, which also aligns with the seaward limit of Flamborough Head to the north. Further to the east, the headland no longer provides direct sheltering from north and north-easterly waves, or strong tidal flows, and the seabed drops to around 20 m below LAT. The profile of the seabed continues to deepen in an easterly direction and reaches around 51 m at the HVAC booster station search area (approximately 35 km offshore).

5.1.3.5 East from the HVAC booster station search area, the offshore ECC passes just to the south of The Hills, a series of sinuous inter-related sandbank features with near symmetrical sandwaves. When the offshore ECC reaches the offshore array area depths are around 40 m below LAT.

5.1.3.6 Waves in deeper sections of the offshore ECC have too short a wave period to influence the seabed so these pathways are driven mainly by tides and surge currents. In shallower areas,

[1] https://data.gov.uk/dataset/d19f631c-27c0-4c74-804f-d76a4632b702/annex-i-sandbanks-in-the-uk-v2-public

waves begin to exert a stirring effect on the seabed which can increase sediment mobility rates and associated transport.

*Suspended sediments*

5.1.3.7 Surface turbidity in the nearshore section of the offshore ECC exhibits a high level of seasonal variation. Surface concentrations are highest in the first 10 km and are highest in winter. July is typically the month with the lowest concentrations. Concentrations range from 2 – 14 mg/l close to shore, reducing to 2 or 3 mg/l further offshore. This is mainly due to sediments from coastal erosion in winter, shallower water and stronger local flows maintaining the material in suspension and inhibiting local deposition.

## 5.2 Biological characteristics

5.2.1.1 This section provides a summary of the biological characteristics of the disposal sites. Full details are provided in **Volume A2, Chapter 2: Benthic and Intertidal Ecology, Volume A2, Chapter A3: Fish and Shellfish Ecology, Volume 2, Chapter 4: Marine Mammals** and **Volume A2, Chapter 5: Offshore and Intertidal Ornithology** and their associated Technical Report annexes.

### 5.2.2 Benthic and intertidal ecology

5.2.2.1 Across the Hornsea Four array area, a total of 2,678 individuals representing 163 taxa were recorded from the 21 macrofaunal samples acquired. The macrofaunal community was found to be relatively sparse with 54 taxa appearing at a single station and 34 of those taxa represented by a single individual.

5.2.2.2 Analysis of benthic grab samples obtained across the Hornsea Four array area revealed that benthic subtidal communities across the array area were generally dominated by Annelida, Mollusca and Echinodermata, all of which contributed c.30% of the total individuals identified. The Mollusca group was dominated by the bivalve *Abra* which contributed 60% of total Mollusc individuals whilst the Echinodermata group was dominated by the brittle star *A. filiformis*, which contributed 72% of the total Echinoderm individuals. The Annelida group was not dominated by a single taxon rather the group was represented by a diverse range of taxa. Review of the biomass data revealed an equally variable data set which was dominated by single large specimens of Arthropoda, Mollusca and Echinodermata particularly at stations which recorded larger biomass values.

5.2.2.3 Seabed imagery corroborated the findings of particle size and faunal sample data, indicating a relatively heterogenous benthos across the Hornsea Four Order Limits, which ranged from muddy sand to sandy gravel. Typical epifauna observed included hydroids, bryozoans, molluscs, anthozoans and echinoderms. Free swimming megafauna were limited to demersal teleosts (bony fish) including pleuronectiforms and dragonets. The potential habitats 'seapen and burrowing megafauna community' and 'stony reef' were identified in the data. Across the offshore ECC, Particle Size Analysis (PSA) was more variable than in the array, demonstrating variations in the proportions of silts, sands and gravels across the large spatial extent. According to the Folk classification, the dominant sediment types throughout the offshore ECC were 'muddy sand' and 'sand', although sands with gravel were also present, particularly towards the inshore portion of the offshore ECC.

5.2.2.4 Across the offshore ECC, a total of 2,813 individuals representing 259 taxa were recorded from 26 macrofaunal samples acquired. The greater stability and broader range of ecological niches offered by the mixed substrates that characterise these portions of the offshore ECC are likely to be the main factors driving the elevated diversity indices. The benthic subtidal communities were dominated by Annelida, Arthropoda, Mollusca and Echinodermata whilst all other phyla accounted for the remaining seven taxa (2% of individuals).

5.2.2.5 Predictive habitat modelling revealed that a few additional biotopes to the ones identified through site- specific surveys are predicted to potentially occur across Hornsea Four benthic subtidal ecology study area, albeit showing varying degrees of modelled coverage.

5.2.2.6 A wide range of European Nature Information System (EUNIS) habitat classifications were documented across the offshore array and ECC, supporting the conclusion that the habitats across Hornsea Four Order Limits vary in accordance with the heterogenous sandy sediments encountered. In the intertidal, the biotope that characterised area during the Phase I walkover survey along the Holderness Coast between Bridlington and Skipsea was coarse littoral sand (LS.Lsa.MoSa.Bar.Sa), which is typical of clean sands in areas of high hydrodynamic energy, as seen along this portion of coastline.

5.2.2.7 Although individuals of *Sabellaria spinulosa* were identified within the benthic grab samples at five stations across the offshore ECC (see Appendix C of **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report**), these were not recorded in numbers that would constitute reef and the only aggregation observed in the video footage was a small patch encrusting a pebble that would not itself be classified an Annex I reef. Detailed review of the side scan sonar and multibeam bathymetry datasets found no evidence of the distinctive signatures which would be typically associated with the presence of biogenic reefs.

5.2.2.8 Four discrete patches of stony reef habitat were recorded as present across a portion of the offshore ECC, although were scored as 'low' resemblance to stony reef, as per the qualifying criteria set out in regulatory guidance. Guidance suggests that the patches identified during this survey would not be considered as contributing to the national site network unless there is strong justification. Based on these results and evidence from geophysical studies across the site, the area of 'Sandy gravel with boulders' encompassing stations ECC_22 and ECC_23 is expected to comprise a patchy mosaic of stony substrate surrounded by gravels and coarse sands, rather than extensive areas of unbroken stony reef. This habitat is typical of the wider region and has been recorded within several other development projects in the region including Dogger Bank A & B (Forewind, 2013) and the Tolmount to Easington Pipeline (Premier Oil 2018).

### 5.2.3 Fish and shellfish ecology

5.2.3.1 The fish communities within the study area broadly comprised of demersal species, with high abundances of whiting (*Merlangius merlangus*), dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), solenette (*Buglossidium luteum*) and grey gurnard (*Eutrigula gurnardus*) present. Spatial variability could be a factor influencing species composition across the study area, with deeper offshore areas, including the array area having increased abundances of whiting, and shallower inshore areas, proximal to the nearshore section of the ECC having higher occurrences of dab and crustaceans.

5.2.3.2 Pelagic species recorded within the study area included sprat (*Sprattus sprattus*), herring (*Clupea harengus*) and mackerel (*Scomber scombrus*), with sprat and herring being a key characterising species of the otter and beam trawl surveys. All three species showed seasonal variability in abundance, with sprat and herring having higher abundances in spring, and mackerel being more abundant in autumn within the array area.

5.2.3.3 Sandeel (*Hyperoplus lanceolatus* and *Ammodytes tobianus)* were generally recorded at low abundances during otter and bream trawl surveys proximal to the array area, compared to many of the other characterising species. It should be noted, however, that these survey methods are not specifically designed to sample sandeel. Sandeel abundances as recorded during trawl surveys across the study area were generally found to be highest to the west of the Hornsea Four array area.

5.2.3.4 Data from Coull et al. (1998) suggests that the Hornsea Four ECC lies near herring spawning grounds. Data from the International Herring Larvae Surveys (IHLS) supports this, showing that the main area for herring spawning is located to the north of Flamborough Head and the ECC. The array area has minimal spatial interaction with the spawning grounds. Data from Ellis et al. (2010) showing indicative extents of sandeel spawning habitats suggests that the Hornsea Four Order Limits overlap a high intensity spawning area, and a low intensity nursery site.

5.2.3.5 A number of migratory fish species have the potential to occur in the southern North Sea fish and shellfish study area, migrating to and from rivers and other freshwater bodies in the area which these species use either for spawning habitat (e.g. sea lamprey (*Petromyzon marinus)*, river lamprey (*Lampetra fluviatilis*), twaite shad (*Alosa fallax*), allis shad (*Alosa alosa*), Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*), or growth and development to the adult phase with spawning occurring at sea (i.e. European eel (*Anguilla Anguilla*)).

5.2.3.6 Shellfish of commercial importance to the region include brown crab (*Cancer pagurus*), (*Nephrops norvegicus*), European lobster (*Homarus gammarus*), velvet swimming crab (*Necora puber*), common whelk (*Buccinum undatum*), brown and pink shrimp (*Crangon crangon* and *Pandulus montagui*) and king scallop (*Pecten maximus*). European common squid (*Alloteuthis subulate*) were identified as the most common cephalopod in the region, and velvet swimming crab were recorded in the greatest abundance in potting surveys carried out in the nearshore section of the ECC. The European common squid and the velvet swimming crab are both widespread across the North Sea.

### 5.2.4 Marine mammals

5.2.4.1 The Hornsea Four site specific surveys suggested that the area may be important for harbour porpoise (*Phocoena phocoena*), with higher average densities here than in the rest of the reference population Management Unit (MU) (North Sea). This is reflected by a number of other data sets describing harbour porpoise abundance and distribution of harbour porpoise in the North Sea. The Hornsea Four array area is located within the Southern North Sea Special Area of Conservation (SAC) designated for harbour porpoise.

5.2.4.2 The marine mammal species which are most likely to occur in the Hornsea Four marine mammal study area are: harbour porpoise, minke whale (*Balaenoptera acutorostrata*), white-beaked dolphin (*Lagenorhynchus albirostris*), bottlenose dolphin (*Tursiops truncatus*), harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*).

### 5.2.5 Offshore Ornithology

5.2.5.1 Twenty-four offshore aerial digital surveys have been conducted across Hornsea Four between April 2016 and March 2018. A total of 23 bird species were recorded, with the key species recorded in the greatest abundance/density within the array area (and 4 km buffer) being fulmar (*Fulmarus glacialis*), gannet (*Morus bassanus*), kittiwake (*Rissa tridactyla*), great black-backed gull (*Larus marinus*), guillemot (*Uria aalge*), razorbill (*Alca torda*) and puffin (*Fratercula arctica*).

5.2.5.2 In the intertidal, a desktop study was undertaken to derive the baseline of intertidal birds, which includes several species such as common scoter, red-throated diver, cormorant, shag, curlew, turnstone and numerous gull species. In general, the landfall area is not considered to be of particular importance for intertidal birds.

5.2.5.3 A number of Special Protection Areas (SPAs) were identified as having potential connectivity to Hornsea Four, the closest being the Greater Wash SPA and the Flamborough and Filey Coast SPA. Potential effects on these sites are considered separately within the Report to Inform Appropriate Assessment (RIAA) (**B2.2: Report to Inform Appropriate Assessment**).

### 5.2.6 Designated sites

5.2.6.1 The Hornsea Four Order Limits is in close proximity to a number of sites designated for nature conservation and water quality, including the Flamborough Head SAC, the Flamborough and Filey Coast SPA, the Greater Wash SPA, the Holderness Inshore Marine Conservation Zone (MCZ) and the Holderness Offshore MCZ. The only site designated for nature conservation that the Hornsea Four Order Limits overlaps with is the Southern North Sea SAC. The inshore section of the offshore ECC runs through the Yorkshire South waterbody and is in close proximity to two designated Bathing Waters (BWs) at Wilsthorpe and Fraisthorpe.

5.2.6.2 Further information and assessment of impacts to designated sites can be found in the RIAA (**B2.2: Report to Inform Appropriate Assessment**) which considers effects on sites within the national site network (SACs, SPAs and Ramsar sites), the MCZ Assessment (**Volume A5, Annex 2.3: Marine Conservation Zone Assessment**) and the Water Framework Directive (WFD) Assessment (**Volume A5, Annex 2.2: Water Framework Directive Assessment**).

## 5.3 Human environment characteristics

5.3.1.1 This section summarises the human environment of the Hornsea Four array area and offshore ECC. Further detail can be found in the Commercial Fisheries, Shipping and Navigation, Marine Archaeology and Infrastructure and Other Users ES chapters (**Volume A2**, **Chapter 6**; **Chapter 7**; **Chapter 9;** and **Chapter 11**, respectively) and their associated annexes.

### 5.3.2 Commercial fisheries

5.3.2.1 The Hornsea Four array area and offshore ECC overlaps International Council for the Exploration of the Sea (ICES) rectangles 37E9, 37F0, 37F1, 36F0 and 36F1, which have an annual average value of £23.5 million for all UK vessels for the years 2015 to 2019 (MMO 2020), with key fisheries of brown crab (*Cancer pagurus*), king scallop (*Pecten maximus)*, whelk (*Buccinum undatum)* and European lobster (*Homarus gammarus*).

5.3.2.2 For non-UK vessels, the commercial fisheries study area is dominated by landings of herring (*Clupea harengus)* by Dutch and German vessels in particular, and of sandeels (*Ammodytes marinus)*, predominantly by Danish vessels. The significant landings are reflective of the industrial scale of these fisheries. The average annual value of herring landings between 2012 and 2016 was in excess of approximately £5.67 million, and for sandeel landings the equivalent value was approximately £1.75 million. Data shows notable fluctuations in annual landings for both species, indicative of the opportunistic nature of the fisheries. Herring, caught mainly by pelagic trawl, are primarily landed from ICES rectangle 37F0, which overlaps with the offshore ECC and a small portion of the array area. Highly mobile pelagic species, that move in shoals and are not associated with specific seabed habitats, are assumed to be available to catch across large areas i.e., if a shoal of herring cannot be caught within Hornsea Four array area or offshore ECC, this shoal is expected to move to an area where they can be caught.

5.3.2.3 Sandeels, caught mainly by otter trawl, are primarily landed from ICES rectangle 37F1, which overlaps with a large portion of the array area and the offshore ECC to a lesser extent. North Sea sandeel grounds are well-mapped, and data indicates that whilst the array area does partially overlap with some grounds, the majority of grounds within ICES rectangle 37F1 are to the north of the array area.

5.3.2.4 Excluding herring and sandeel fisheries, the key species are brown crab and king scallop, targeted primarily by UK potters and dredgers respectively. Brown crab represent the most significant landings by weight across the inshore and southern portion of the study area in ICES rectangles 37E9, 36F0 and 36F1. Landings have steadily increased over the five-year study period, peaking at over 5,500 tonnes in 2016. Scallop landings originate primarily from inshore ICES rectangle 37E9, and annual landings fluctuate markedly over the five-year study period, peaking in 2015 at over 2,800 tonnes. Other species of importance based on landings weight include whiting, lobsters, whelks, plaice and mackerel.

### 5.3.3 Shipping and navigation

5.3.3.1 Hornsea Four array area is positioned in the North Sea, approximately 69 km from shore and is near to a number of major shipping routes, with a number of these shipping routes passing through the Hornsea Four array area. These are principally vessels transiting northeast/southwest between the Humber Estuary and the entrance to the Baltic Sea. Other routes passing through the site run between northeast England and Scottish / European ports in the southern North Sea. A greater amount of traffic passes across the offshore ECC. Commercial shipping is also recorded at anchor near to the offshore ECC landfall.

5.3.3.2 A total of 14 main routes were identified within the Hornsea Four array area shipping and navigation study area, with the highest traffic volume routes between one and two transits per day between Immingham and Esbjerg, Immingham and Gothenburg, Immingham and Hamburg, and Newcastle and Amsterdam. These were the four main routes featuring commercial ferries operated by DFDS Seaways with the others operating between North Shields and Ijmuiden and Immingham and Oslo. Cargo vessels, tankers and fishing vessels were the main vessel types recorded within the Hornsea Four offshore ECC throughout the winter survey period. Recreational vessel and fishing vessel activity was low outwith the nearshore area.

5.3.3.3 The principal activity near to Hornsea Four are those vessels engaged in the oil and gas industry. In particular, offshore supply vessels are active at the fields located near to the study area and pass through the Hornsea Four array area. The Babbage and Ravenspurn gas fields are located adjacent to the southwestern corner of the Hornsea Four array area. The Hyde and West Sole gas fields are located to the south and the Garrow and Kilmar gas fields to the north. Significant activity by these vessels has also been recorded across the offshore limits of the offshore ECC.

### 5.3.4 Marine archaeology

5.3.4.1 The geoarchaeological potential within the deposits present is high and it is likely that the general area contains important prehistoric archaeological material and paleoenvironmental evidence. Specifically, there is likelihood of surviving remains of Mesolithic activity and settlement on the Mesolithic shoreline identified in the northern part of the array area.

5.3.4.2 The sedimentary sequence assessment identified deposits of archaeological potential within the Hornsea Four marine archaeology study area, including: Bolders bank, Swarte bank and Yarmouth Roads, which lie on top of chalk, or pre-chalk, bedrock. In some areas, a unit of interest which underlies the Holocene deposits and overlies the basal deposit has been identified.

5.3.4.3 Within the Hornsea Four Order Limits there are 18 known wrecks with 13 classified as LIVE (wreck considered to exist as a result of detection through survey). In addition, there are five fouls and seabed obstructions and reports of six fishermen's fasteners. The majority of the known wrecks are dated to the 20$^{th}$ century.

5.3.4.4 In terms of geophysical data, the following contacts of archaeological potential have been identified: 139 features of low potential, 41 magnetic anomalies over 100 nT but with no seabed contact, five features of medium potential, and two features of high potential.

### 5.3.5 Infrastructure and other users

5.3.5.1 There are currently four licenced blocks for oil and gas exploration and two gas fields coincident with the Hornsea Four array area (and a 1 km buffer); licences are held by Bridge Petroleum, Harbour Energy[2], and Perenco. There are seven unlicensed blocks coincident with the Hornsea Four array.

5.3.5.2 There are currently nine licenced blocks for oil and gas exploration and six gas fields coincident with the Hornsea Four ECC (and associated 1 km buffer); licences are held by Dana Petroleum, Perenco, Harbour Energy[1] and NEO Energy. There are currently nine unlicensed blocks within the Hornsea Four ECC.

5.3.5.3 There are 19 wells located within 1 km of the Hornsea Four array area and 32 wells within 1 km of the offshore ECC. There is a total of 10 permanent surface platforms within 9 nautical miles of the Hornsea Four array area, although none of these are within 1 km of the array area. There are three platforms within 1 km of the offshore ECC, with one inside the ECC boundary (Tolmount Main platform).

[2] Previously held by Premier Oil. At the end of March 2021, Premier Oil merged with Chrysaor to become Harbour Energy plc.

5.3.5.4 There are six oil and gas associated pipelines located within the Hornsea Four array area and the associated 1 km buffer area, and seven oil and gas pipelines which cross the offshore ECC. There are no existing cables that cross the Hornsea Four array area or ECC, although the export cable corridor for Dogger Ban A & B crosses the ECC with construction of these projects scheduled for between 2021 and 2024.

5.3.5.5 There are plans in place for a pipeline operated by Dana Petroleum that will cross the offshore ECC. Two wells within the Hornsea Four array are set to be decommissioned over the next few years. More information on these future plans and projects can be found within **Volume A2, Chapter 11: Infrastructure and Other Users**, **Annex 5.3: Offshore Cumulative Effects** and **Annex 5.4: Locations of Offshore Cumulative Schemes**.

5.3.5.6 The proposed Endurance Carbon Capture and Storage (CCS) saline deposit reservoir overlaps in part with the northern part of the Hornsea Four array area and there are two planned CCS projects that propose to make use of the Endurance reservoir, with a pipeline proposed to cross the ECC.

# 6 Characteristics of the material for disposal

## 6.1 Physical characteristics

### 6.1.1 Array area

*Drilled material*

6.1.1.1 The spoil material derived from drilling activities will be different in nature to that disposed of via seabed preparation/dredging as these drilled materials will include predominantly sediment/rock from deeper in the soil profile.

6.1.1.2 Beneath the veneer of surficial sediments (sands), sub surface geology consists of a firm to stiff clay till (the Bolders Bank formation) and below that, chalk bedrock. In some areas, there may be exposed chalk bedrock, or chalk bedrock close to the surface below surficial sediments.

6.1.1.3 The exact proportions of these deposits that will form the basis of the drill arisings deposited on the seabed will vary according to the drilling locations and the depth to which drilling occurs.

*Dredged material*

6.1.1.4 The dominant sediment types identified in the array area that will be dredged are mainly fine sands, with some areas described as fine sand with some gravels in the south-easterly area, and fine, medium to coarse sand in the north western segment. Particle size information classifies the main sediment fraction as medium sands with a generally low (< 5%) contribution of fine sediments (muds and silts), with a few exceptions and with a similar low gravel content (typically less than 10%). **Figure 2** shows the sediment distribution across the array area.

6.1.1.5 Although the actual process of disposal may result in a slight change to the existing particle size composition of seabed sediments, the material disposed *in situ* via seabed preparation and cable trenching would be similar to the existing material as the spoil disposal will occur close to the site of production.

### 6.1.2 Offshore ECC

*Drilled material*

6.1.2.1 As with the array area, sub-surface geology in the HVAC booster station search area beneath the veneer of surficial sediments (sands), consists of a firm to stiff clay till (the Bolders Bank formation) and below that, chalk bedrock. In some areas, there may be exposed chalk bedrock, or chalk bedrock close to the surface below surficial sediments.

6.1.2.2 As with the array, the exact proportions of these deposits that will form the basis of the drill arisings deposited on the seabed will vary according to the location of drilling and the depth to which drilling occurs.

*Dredged material*

6.1.2.3 The nearshore section (landfall to Smithic Bank) comprises sands with patches of gravelly sands, becoming sands across the shallower Smithic Bank (< 10 m below LAT). As the bank shelves into slightly deeper water (>10 m below LAT) the seabed coarsens to sand gravel, an area which extends across the location of the proposed crossing of the Dogger Bank A and B export cables and to around 30 m below LAT. Further to the east, and out to the HVAC Booster Station Search Area, the seabed becomes gravelly sand to slightly gravelly sand. As the sand content further increases, there is evidence of megaripples from the HVAC Booster Station Search Area for around 32 km to the east. After this area, and up to the fan area connecting with the offshore array area, the seabed is relatively featureless with grab samples typically indicating muddy sand. For the fan area adjoining the offshore array, the seabed returns to being sandy with areas of megaripples and occasional sandwaves occurring mainly in the most southerly part. **Figure 3** shows the sediment distribution across the offshore ECC.

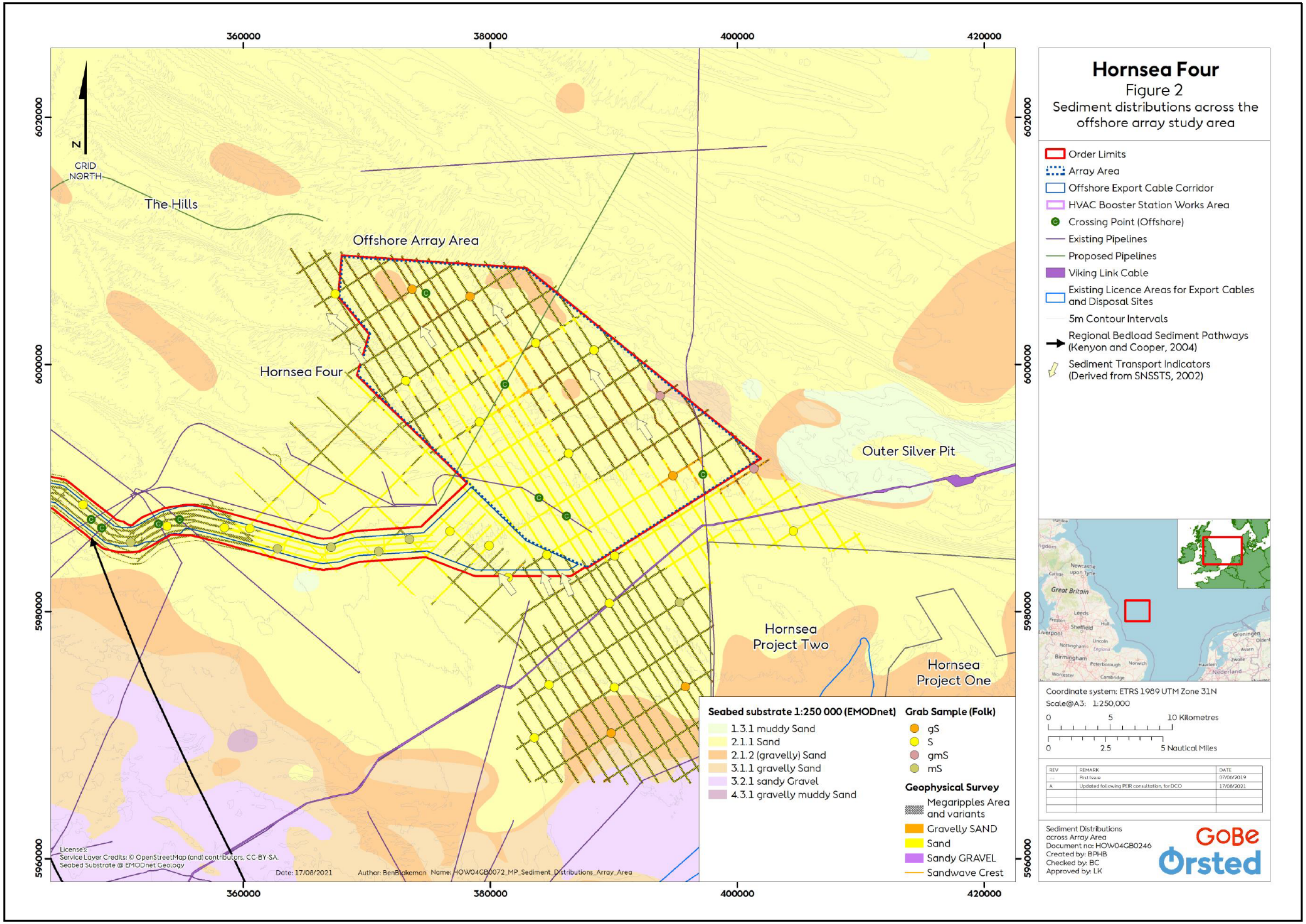


**Figure 2: Sediment distributions across the array area based on descriptive classifications by Folk (1954).**

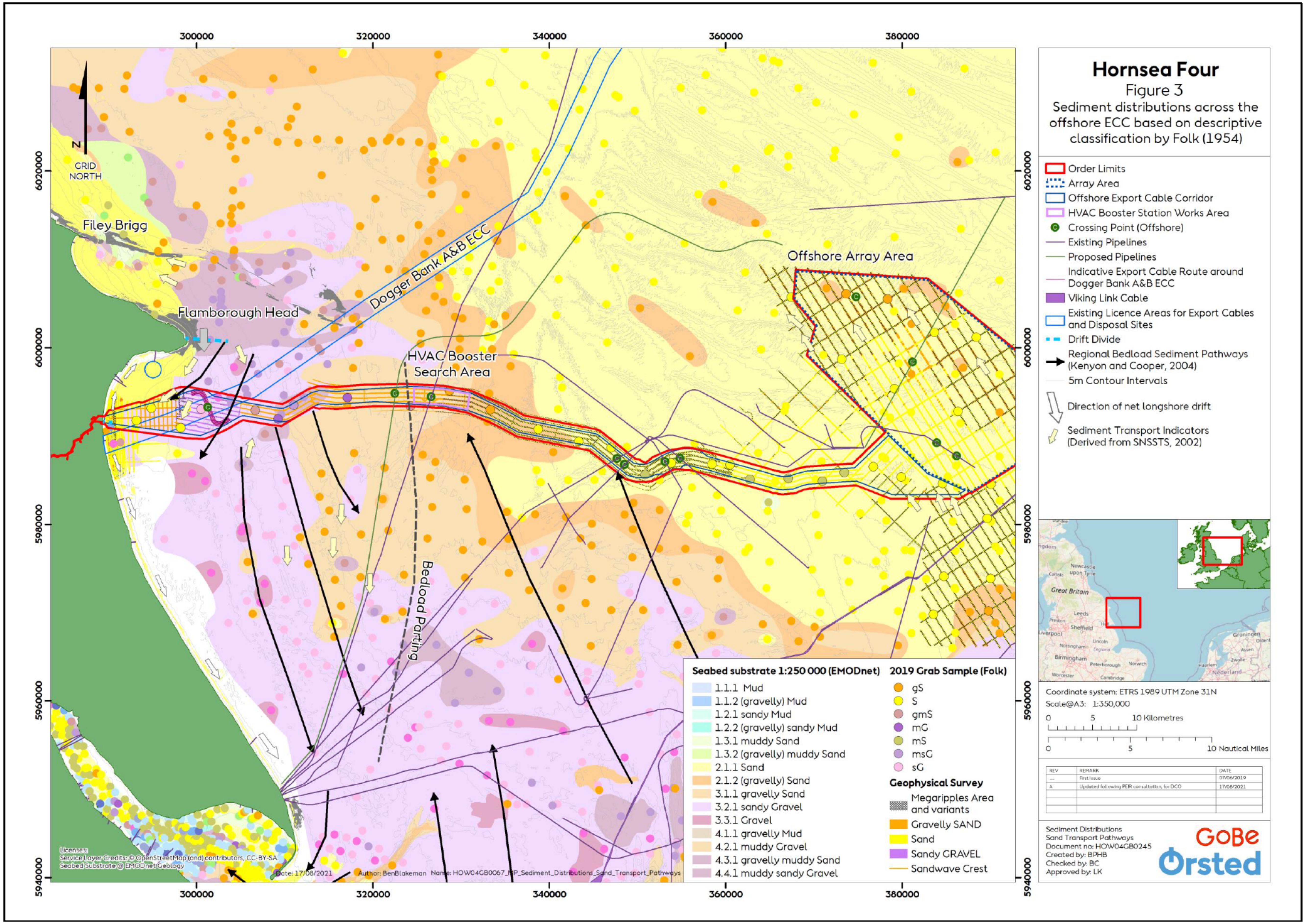


**Figure 3: Sediment distributions across the offshore ECC based on descriptive classifications by Folk (1954).**

6.1.2.4 As with the array, although the actual process of disposal may result in a slight change to the existing particle size composition of seabed sediments, the material disposed in situ via seabed preparation and cable trenching would be similar to the existing material as the spoil disposal will occur close to the site of production.

## 6.2 Chemical characteristics

6.2.1.1 This section summarises the chemical characteristics of sediments in the Hornsea Four array area and offshore ECC. Further detail can be found in **Volume A2, Chapter 2: Benthic and Intertidal Ecology**, **Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** and **G1.44: Clarification Note on Marine Sediment Contaminants (REP4-032)**.

### 6.2.2 Array area disposal site

6.2.2.1 The results of the sediment contamination analyses revealed that the total hydrocarbon concentrations recorded from the sediments within the Hornsea Four array occurred at expected background concentrations (and within threshold values), with some elevation in concentrations present in areas of historic oil and gas exploration. In relation to polycyclic aromatic hydrocarbons, all samples within the array were below Cefas Action Level 1 (CAL1) and the Canadian Marine Sediment Quality Guidelines Threshold Effect Levels (TELs). Gas Chromatography traces across the array area were generally indicative of background levels of hydrocarbons in areas of historic oil and gas exploration and suggested a mixture of petrogenic and pyrogenic sources.

6.2.2.2 Generally, metals were generally present at low concentrations. Metal concentrations varied across the array area with all concentrations below CAL1, apart from three stations (ENV2, ENV16 and ENV17) which exceeded CAL1 for arsenic. However, these three stations were below Cefas Action Level 2 (CAL2) for arsenic. The results of the metal analysis h indicated that toxicological impacts on the biota were unlikely across the array area. The TEL was exceeded for arsenic at 10 stations[3], these levels were not exceeded for other metals however (cadmium, chromium, copper, lead, nickel and zinc). The levels of contaminants for the array are all comparable to the wider regional background and not considered to be of a low quality that may result in a significant effect receptor pathway if made bioavailable.

### 6.2.3 Cable corridor disposal site

6.2.3.1 Sites ECC_20 and ECC_21 exceeded the CAL1 for PAHs. Three sites (ECC_19 to ECC_21) along the ECC where numerous PAHs are recorded between TEL and Probable Effect Level (PEL). There are no exceedance of PEL for any individual PAHs. A Gorham-Test approach was undertaken (see **G1.44: Clarification Note on Marine Sediment Contaminants (REP4-032)** for further details) to determine the toxicity of the recorded PAHs in the ECC. This concluded that probable adverse effects are not anticipated at stations ECC_19 to ECC_21 or elsewhere along the ECC.

6.2.3.2 Concentrations measured in a subset of the stations closer to shore (ECC_18 to ECC_21) is evident in the Gas Chromatography traces in the form of an elevated baseline of Unresolved Complex Mixtures. The presence of a consistent hydrocarbon signature from stations ECC_18 to ECC_21 is consistent with diffuse input of hydrocarbons from runoff and shipping activity, as opposed to point source input of hydrocarbons from oil and gas exploration. All

[3] ENV2, ENV5, ENV6, ENV16, ENV17, ENV18, ENV21, ENV22, ENV24 and ENV25.

hydrocarbons were below the threshold levels considered likely to exert an effect on the faunal community.

6.2.3.3 Across the offshore ECC, metal concentrations were generally low. Arsenic, was recorded between CAL1 and CAL2 at seven stations[4]. In addition, nickel was recorded between CAL1 and CAL2 at ECC_21. No metals were recorded above CAL2 in the offshore ECC. The TEL (but not CAL1) was exceeded for lead at ECC_17 and ECC_19. Arsenic was recorded above TEL at 15 sites and recorded above PEL at ECC_14. Due to the high natural occurrence of this metal, it is often difficult to precisely discern between natural and anthropogenic sources of this metal (OSPAR, 2005). The arsenic concentrations were within the range reported for the southern North Sea: < 0.5 mg $kg^{-1}$ to 135 mg $kg^{-1}$ of dry weight arsenic (Whalley et al., 1999). When considered within this context, the recorded data are considered typical for the region and not of particular note in terms of contamination.

### 6.3 Biological characteristics

6.3.1.1 Biological characteristics were similar in both the array and the offshore ECC. Further detail can be found above in **Section 5.2** and in the sources described in **Table 4** below.

**Table 4: Locations of more detailed information for specific data categories.**

| Data | Relevant ES Document |
|---|---|
| Contaminant analysis | **Volume A2, Chapter 2: Benthic and Intertidal Ecology**<br>**Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** |
| Seabed geology | **Volume A2, Chapter 1: Marine Geology, Oceanography and Physical Processes**<br>**Volume A5, Annex 1.1: Marine Processes Technical Report** |
| Biotopes and benthic fauna | **Volume A2, Chapter 2: Benthic and Intertidal Ecology**<br>**Volume A5, Annex 2.1: Benthic and Intertidal Ecology Technical Report** |
| Fish and shellfish spawning and nursery areas | **Volume A2, Chapter 3: Fish and Shellfish Ecology**<br>**Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report** |

## 7 Assessment of the potential adverse effects of *in situ* spoil disposal

### 7.1 Physical environment

7.1.1.1 Marine processes are not themselves receptors in the majority of cases. However, changes to these processes may have an impact on other sensitive receptors. This section summarises the findings of the impact assessment of these physical changes on sensitive biological and human receptors.

#### 7.1.2 Drilled material

7.1.2.1 The impact of drilling operations mainly relates to the release of drilling spoil at or above the water surface which will release material into suspension and the subsequent re-deposition of that material to the seabed. The nature of this disturbance will be determined by the rate and total volume of material to be drilled, the seabed and sub-bottom material type, and the drilling method which affects the texture and grain-size distribution of the drill spoil. The typical conservative assumption is to treat 100% of material as fines, although existing evidence of drill cutting piles suggests this is unlikely, and in some cases semi-

[4] ECC_14. ECC_16, ECC_17, ECC_18, ECC_19, ECC_20 and ECC-23.

permanent cuttings piles have formed of relatively large clasts, for example at North Hoyle (Department of Energy & Climate Change (DECC), 2008).

7.1.2.2 Monopile foundations and pin-piled jacket foundations would be installed using standard drilling techniques. In some locations, the particular geology may present some obstacle to piling, in which case some or all of the seabed material might be drilled within the pile footprint to assist pile installation. It is assumed that drilling of the full pile depth may be required at up to 10% of pile locations. However, it should be noted that drilling (though consented) was not required at Hornsea Project One, which represents broadly similarly regional seabed characteristics to those at Hornsea Four.

7.1.2.3 The MDS foundation option related to drill arisings in the HVAC booster station search area is the Piled Jacket (Small OSS) with 16 pin piles with a 3.5 m diameter an embedment depth of up to 100 m. Provisions for drilling these piles assumes up to 4,617 $m^3$ of drill arisings for all pin-piles and foundations. This potential volume of sediment release is comparable to seabed levelling and the potential release of fines from the same location in overspill. The conservative assumption is drilling would produce similar (but lesser) sediment plumes in comparison to the seabed levelling activity in this area.

7.1.2.4 The requirement to drill into chalk depends on the hardness of the substrate which is presently unknown. Notably, Sheringham Shoal, 90 km to the south of Hornsea Four, encountered Cretaceous Chalk but was still able to drive all piles into the seabed without the need of drilling (Carotenuto et al. 2018).

7.1.2.5 Any sediment plumes, and associated deposition are considered to be pathways for effects which are considered for impacts in related chapters. Consequently, no impact assessment is offered here for marine processes.

7.1.2.6 It is noted that, whilst the absolute width, length, shape and thickness of local sediment deposition as a result of drilling is estimated, it cannot be predicted with certainty and is likely to vary due to the nature of the drill spoil, the local water depth, and the ambient environmental conditions during the drilling activity. If the total volume of drill arisings were distributed equally across the relevant disposal site (array or offshore ECC), the increase in bed elevation would be almost immeasurable. However, in reality, the change will consist of a series of smaller, discrete, overlapping and non-overlapping deposits distributed throughout parts of the array area and offshore ECC where foundations are located. Monitoring of drill arising mounds on the Lynn and Inner Dowsing Offshore Wind Farm found that after four months, mounds had been reduced from 3 m to 1.2 m, however this figure is only presented as a guide as sediment and oceanographic conditions may be slightly different at Hornsea Four.

### 7.1.3 Dredged material

7.1.3.1 No significant adverse effects are predicted on marine geology, oceanography and physical processes from the disposal of dredged material from seabed preparation, sandwave clearance and cable trenching within the array or the offshore ECC. The MDS involves seabed preparation by suction hopper dredger with release of dredged material at the sea surface, as well as sandwave clearance and cable installation by CFE.

7.1.3.2 Dredging of coarse sediment would not create persistent plumes as the coarse material would quickly settle to the seabed. However, the disturbance of finer sediment has the potential to give rise to more persistent plumes that settle out over a wider area. It should be noted that sediments within the Hornsea Four array are predominantly sands containing a low portion of fines.

7.1.3.3 In the case of dredging, when dredged material is released, approximately 90% will fall directly to the seabed (termed the dynamic plume phase). The remaining 10% will become more dispersed and stay in suspension (termed the passive plume phase). Sand-sized material could remain in suspension for a short time and be transported downstream (depending on the flood/ebb tides at the time of release). Finer sediment could remain suspended for longer, in the order of hours to days. Localised increases in SSC of up to several hundred mg/l in the immediate vicinity of the release location will be considerably higher than background levels, although highly localised and lasting for a very short period (in the order of hours). Modelling of spoil disposal (Appendix C of **Volume A5, Annex 1.1: Marine Processes Technical Report**) demonstrated that the scale of tidal advection where the silt fraction determines the material held in suspension to form a plume would be approximately 4-7 km within the array area on neap tides and 8-10 km on spring tides, and approximately 5-7 km within the HVAC booster station search area on neap tides and 9-12 km on spring tides. Away from the point of release, concentrations are predicted to be around 10 mg/l, but are expected to dissipate in the order of hours to days from the point of release.

7.1.3.4 For sandwave clearance and cable trenching using CFE, the height of release is at or near the seabed, and there is far less potential for persistent plumes or significant deposition away from the location of the activity.

7.1.3.5 In terms of bed-level changes associated with dredging for installation of all non-piled foundations, if the total volume of dredged material were deposited evenly across the relevant disposal site (array or offshore ECC), the increase in bed elevation would me almost immeasurable. In reality, as with drill arisings, the change will comprise a series of smaller, discrete, overlapping and non-overlapping deposits, potentially from multiple dredging cycles around each dredged area, distributed throughout the parts of the array area of offshore ECC where foundations, sandwaves and cables are located. Immediately within the vicinity of release, coarse materials can be expected to be deposited in mounds, reaching a local thickness of 10 – 20 cm. Away from the point of release, silts are not expected to settle to a discernible thickness.

7.1.3.6 In relation to the intertidal area, the MDS sediment volume for the HDD cofferdam excavation is up to 2,500 $m^3$ for each exit pits (eight in total – 20,000 $m^3$). The excavation operation for each exit pit is likely to be sequential, with up to three pits open at any one time and for up to three months, limiting the chance for any spill events acting in combination. The MDS option is that the excavated material will be side-cast and left on the seabed.

7.1.3.7 Depending on the final method of excavation and the type of material being removed (consolidated till or unconsolidated sands), the chances remain for some of the excavated sediment to be spilt into the sea. Any fine sediments would be rapidly dispersed away to become part of the nearshore sediment plume. Coarser sediments would quickly drop back to the seabed.

7.1.3.8 The material that is cast aside of the excavated pit to form a temporary spoil mound would be subject to wave and tidal action with any eroded unconsolidated fine sediments and sands from the surface of the mound becoming assimilated into the local sediment transport process. The amount of sediment loss from a side-cast mound would depend on the sediment composition and local water depths, wave, and tidal processes as well as the period until back-filling. Any gravels or consolidated clays would most likely experience the lowest amount of loss.

7.1.3.9 Further detail on the impact assessment can be found in **Volume A2, Chapter 1: Marine Geology, Oceanography and Physical Processes**.

**Table 5: Summary of potential impacts from disposal of material from seabed preparation, sandwave clearance, pile drilling and cable trenching within the Hornsea Four Order Limits on marine geology, oceanography and physical processes receptors.**

| Potential Impact | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
|---|---|---|---|
| Seabed preparation activities in landfall area | **Negligible** | Bridlington Harbour, Long Sea Outfall (LSO), disposal site HU015: **Low** | **Not significant** |
| Seabed preparation activities - sandwave clearance | **Negligible** | Nearshore - Bridlington Harbour, LSO, disposal site HU015: **Low** | **Not significant** |
| | N/A | Pathway for other receptors | N/A |
| Seabed preparation activities: Seabed levelling – HVAC Booster Station Search Area | N/A | Pathway for other receptors | N/A |
| Seabed preparation activities: Seabed levelling – offshore array area | N/A | Pathway for other receptors | N/A |
| Seabed installation activities: Cable trenching – offshore ECC (nearshore section) | **Negligible** | Bridlington Harbour, LSO: **Medium** | **Slight (not significant)** |
| Seabed installation activities: Cable trenching – offshore array area | N/A | Pathway for other receptors | N/A |
| Seabed installation activities: Foundation installation: drilling at HVAC Booster Search Area | N/A | Pathway for other receptors | N/A |
| Seabed installation activities: Foundation installation: drilling at offshore array area | N/A | Pathway for other receptors | N/A |

## 7.2 Biological and Human Environment

7.2.1.1 The ES for Hornsea Four provides a detailed impact assessment relating to disposal activities on a number of sensitive biological and human environment receptors, including (amongst others) benthic habitats, fish and shellfish spawning and nursery habitats, marine mammals, birds, and commercial fisheries. It is important to note that construction impacts in relation to marine archaeology of relevance to disposal activities (e.g. disturbance of sediments containing potential archaeological receptors) have been scoped out based on the implementation of relevant Hornsea Four commitments (see **Volume A4, Annex 5.1: Impacts and Effects Register** for further details).

7.2.1.2 For all of these assessments, the effects defined within **Volume A2, Chapter 1: Marine Geology, Oceanography and Physical Processes** have been interpreted with regard to their subsequent impact on various receptors. The sensitivity of various receptors to these effects (increased suspended sediment concentrations, sediment deposition and potential loss of seabed habitats) has been determined based on relevant literature and an assessment of the significance of any impacts undertaken.

7.2.1.3 **Table 6** provides a summary of the key impacts relating to the activities described in this document on biological and human receptors assessed within the ES. The relevant chapters/documents of the ES are also referenced where further detail of those impact assessments can be found. It is important to note that only impacts related to the disposal of sediment (increased suspended sediment concentrations, sediment deposition and potential loss of seabed habitats) and considered in **Table 6**.

**Table 6: Summary of impacts from disposal of material from seabed preparation, sandwave clearance, pile drilling and cable trenching within the Hornsea Four Order Limits.**

| Potential Impact | Relevant Section of ES | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
|---|---|---|---|---|
| *Benthic and Intertidal Ecology* | | | | |
| Temporary increases in SSC and sediment deposition in the Hornsea Four array area and offshore ECC | **Volume A2, Chapter 2: Benthic and Intertidal Ecology** | **Minor** | <u>Sensitivity to heavy smothering (5 – 30 cm)</u><br>*A. islandica*, SS.SMu.CFiMu.SpnMeg: **Not sensitive**<br>SS.SSa.IFiSa.NcirBat, SS.SMx.CMx.MysThyMx, SS.SCS.ICS.MoeVen, SS.SMX.CMx.FluHyd: **Low**<br>SS.SSa.CMuSa.AalbNuc, SS.SSa.CFiSa.ApriBatPo, SS.SSa.CFiSa.EpusOborApri, SS.SMu.CSaMu.AfilMysAnit, SS.SCS.CCS.MedLumVen, SS.SSa.IMuSa.FfabMag, SS.SMx.OMx.PoVen: **Medium**<br><br><u>Sensitivity to light smothering (<5 cm)</u><br>Chalk reef habitat of Flamborough Head SAC: **Medium**<br>Submerged or partially submerged sea caves of Flamborough Head SAC: **Medium**<br>Broadscale habitat features of the Holderness Offshore and Inshore MCZ: **Medium** | **Slight (not significant)** |
| Temporary increases in SSC and sediment deposition in the intertidal area | | **Negligible** | The magnitude is negligible therefore receptor sensitivity is not considered further in the assessment as it will not lead to a significant effect based on the matrix | **Not significant** |
| Direct and indirect seabed disturbances leading to the release of sediment contaminants | | | | |

| Potential Impact | Relevant Section of ES | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
|---|---|---|---|---|
| | | | used for the assessment of significance and expert judgement. | |
| Temporary habitat disturbance in the Hornsea Four array area and offshore ECC from construction activities | | **Minor**<br><br>**Negligible**<br>(*A. islandica*) | SS.SSa.IFiSa.NcirBat,<br>SS.SSa.CMuSa.AalbNuc,<br>SS.SSa.CFiSa.ApriBatPo,<br>SS.SSa.CFiSa.EpusOborApri,<br>SS.SMx.CMx.MysThyMx,<br>SS.SCS.CCS.MedLumVen,<br>SS.SCS.ICS.MoeVen,<br>SS.SSa.IMuSa.FfabMag, SS.SMx.OMx.PoVen: **Low**<br>SS.SMu.CFiMu.SpnMeg,<br>SS.SMu.CSaMu.AfilMysAnit,<br>SS.SMX.CMx.FluHyd: **Medium**<br>*A. islandica*: **High** | **Slight (not significant)** |
| *Fish and Shellfish Ecology* | | | | |
| Temporary localised increases in SSC and smothering | | **Minor** | Herring: **High**<br>Brown crab, European lobster, scallop: **Medium**<br>Sandeel, *Nephrops*, common whelk and all other valued ecological receptors: **Low** | **Neutral to Slight (not significance** |
| Direct and indirect seabed disturbances leading to the release of sediment contaminants | **Volume A2, Chapter 3: Fish and Shellfish Ecology** | **Negligible** | The magnitude is negligible therefore receptor sensitivity is not considered further in the assessment as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement. | **Not significant** |
| Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities | | **Minor**<br>(herring, sandeel, brown crab, scallop, *Nephrops*, common whelk and European lobster) | Herring and sandeel: **High**<br>Brown crab, scallop, *Nephrops* and common whelk: **Medium**<br>European lobster: **Low** | **Slight (not significant)** |

| Potential Impact | Relevant Section of ES | Magnitude of Impact | Sensitivity of Receptor | Significance of Effect |
| --- | --- | --- | --- | --- |
| | | **Negligible** (all other valuable ecological receptors) | The magnitude is negligible therefore receptor sensitivity is not considered further in the assessment as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement. | **Not significant** |
| *Marine Mammals* | | | | |
| Reduction in prey availability | **Volume A2, Chapter 4: Marine Mammals** | **Negligible** | The magnitude is negligible therefore receptor sensitivity is not considered further in the assessment as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement. | **Not significant** |
| Reduction in foraging ability | | | | |
| *Offshore and Intertidal Ornithology* | | | | |
| Indirect impacts through effects on habitats and prey | **Volume A2, Chapter 5: Offshore and Intertidal Ornithology** | **Negligible** | The magnitude is negligible therefore receptor sensitivity is not considered further in the assessment as it will not lead to a significant effect based on the matrix used for the assessment of significance and expert judgement. | **Not significant** |
| *Commercial Fisheries* | | | | |
| Hornsea Four array area and offshore ECC construction activities leading to displacement or disruption of commercially important fish and shellfish resources | **Volume A2, Chapter 6: Commercial Fisheries** | **Minor** (potting and dredge fisheries) | **Medium** | **Slight (not significant)** |
| | | **Minor** (pelagic, demersal trawl and seine fisheries) | **Low** | **Slight (not significant)** |
| | | **Minor** (pelagic, demersal trawl and seine fisheries, and dredge fisheries) | **Low** | **Slight (not significant)** |

# 8 Monitoring

8.1.1.1 Based on the findings of the impact assessments presented in the ES, and summarised within this document, long-term impacts of disposal of spoil and dredged material within the Hornsea Four array and offshore ECC are not anticipated. This is due to the limited increase in seabed level and the temporary nature of any sediment plumes generated.

8.1.1.2 The deposition of sediment from disposal activities is also predicted to only result in short-term, spatially discrete impacts, and the fact that the seabed material to be disposed of *in situ* is not heavily contaminated has shown that contamination will not occur.

8.1.1.3 The only potential longer-term impact of disposal that may arise will be the deposition of drill arisings on the seabed which may consist of large, granular materials that are too large to be moved by tidal currents and may remain *in situ* for long periods of time. The exact scope for this potential impact will rely on the nature of the materials drilled out during pile drilling.

8.1.1.4 A suite of monitoring proposals (including engineering studies) are outlined in **F2.7: Outline Marine Monitoring Plan**. Hornsea Four have proposed to undertake pre- and post-construction PSA monitoring along the cable route to provide data to enable a validation of the ES predictions in relation to sediment composition to be undertaken associated with herring and sandeel spawning habitats. Post-construction bathymetric monitoring is proposed for a number of reasons; however, no other monitoring specific to the disposal of dredged material is proposed.

# 9 Conclusions

9.1.1.1 This document represents the site characterisation for the Hornsea Four array area and offshore ECC. It forms the proposal for licensed disposal sites within the array area and the offshore ECC for drill arisings, and material from foundation seabed preparation, cable installation preparation, and in relation to the ECC, excavation of HDD exits pits. This is required by the MMO to allow them to consider the potential impacts of disposal within these sites.

9.1.1.2 Noting that all the information required for a site characterisation to support a disposal licence application is contained within the wider ES, this document takes the form of a 'framework' document that provides a summary of the key points of relevance to site characterisation and refers to more detailed information and data presented within the relevant sections of the ES at this stage.

9.1.1.3 The source of material proposed to be disposed of within the array and ECC will be sediment dredged from the upper layer of the existing seabed via suction hopper dredger as part of foundation seabed preparation works and cable installation preparation, and/or materials from the deeper soil profile and upper sediments derived from drilling activities for piled foundations.

9.1.1.4 Within the Hornsea Four Array Area Disposal Site, an upper estimate of 7,211,601 $m^3$ of material will be disposed of *in situ*. Within the Hornsea Four Cable Corridor Disposal Site, an upper estimate of 4,105,735 $m^3$ of material will be disposed of *in situ*.

9.1.1.5 Where drilling is required to facilitate the installation of piles to target depth, the drill arisings will be disposed of at sea, adjacent to the foundation location.

9.1.1.6 The impacts of disposal via the return of dredged material to the water column and/or the placement of drill arisings adjacent to foundations has been fully assessed. No moderate, large or very large (significant in EIA terms) adverse effects have been identified, with only neutral and slight (not significant in EIA terms) effects predicted on certain receptors.

9.1.1.7 As the assessment has not identified any significant adverse effects on receptors for this proposed disposal activity, it is concluded that, whilst potential alternative options for the use of this material may exist, disposal *in situ* remains the most viable option.

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