Hornsea Project Four: Environmental Statement (ES)

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Volume A6, Annex 5.4: Geoarchaeological Desk-Based Assessment

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Glossary

Term	Definition
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 ES). Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are acceptable.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Energy balancing infrastructure (EBI)	The onshore substation includes energy balancing Infrastructure. These provide valuable services to the electrical grid, such as storing energy to meet periods of peak demand and improving overall reliability.
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Project Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
High Voltage Direct Current (HVDC)	High voltage direct current is the bulk transmission of electricity by direct current (DC), whereby the flow of electric charge is in one direction.
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
Landfall	The generic term applied to the entire landfall area between Mean Low Water Spring (MLWS) tide and the Transition Joint Bay (TJB) inclusive of all construction works, including the offshore and onshore ECC, intertidal working area and landfall compound. Where the offshore cables come ashore east of Fraisthorpe.
National Grid Electricity Transmission (NGET) substation	The grid connection location for Hornsea Four at Creyke Beck.
Onshore substation (OnSS)	Comprises a compound containing the electrical components for transforming the power supplied from Hornsea Project Four to 400 kV and to adjust the power quality and power factor, as required to meet the UK Grid Code for supply to the National Grid. If a HVDC system is used the OnSS will also house equipment to convert the power from HVDC to HVAC.
Order Limits	The limits within which Hornsea Project Four (the 'authorised project') may be constructed, operated and decommissioned.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).

Term	Definition
Planning Inspectorate (PINS)	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).

Acronyms

Acronym	Definition
AOD	Above Ordnance Datum
BC	Before Christ (used to indicate that a date is before the Christian era).
BGL	Below Ground Level
BGS	British Geological Survey
BP	Before Present
DCO	Development Consent Order
DMV	Deserted Medieval Village
DTM	Digital Terrain Model
EBI	Energy Balancing Infrastructure
ECC	Export Cable Corridor
ES	Environmental Statement
ESRI	Environmental Systems Research Institute
GI	Ground Investigation
GPS	Global Positioning System
HER	Historic Environment Record
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
KA	Thousand Years Ago
LGM	Last Glacial Maximum
MHWS	Mean High Water Spring
MYA	Million Years Ago
NGET	National Grid Electricity Transmission
NHLE	National Heritage List for England
NMP	National Mapping Programme
NGR	National Grid Reference
OD	Ordnance Datum
OnSS	Onshore substation
OS	Ordnance Survey
PEIR	Preliminary Environmental Information Report
SOBI	Single Onshore Boreholes Index
SSEAW	Soil Survey of England And Wales

Units

Unit	Definition
ka	Thousand years
km	Kilometre
kV	Kilovolt

1 Introduction

1.1 Project background

1.1.1.1 Orsted Hornsea Project Four Limited (the 'Applicant') is proposing to develop Hornsea Project Four Offshore Wind Farm (hereafter 'Hornsea Four'). Hornsea Four will be located approximately 69 km offshore the East Riding of Yorkshire in the Southern North Sea and will be the fourth project to be developed in 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 on to an onshore substation (OnSS) with energy balancing infrastructure (EBI), and connection to the electricity transmission network.

1.1.1.2 AOC Archaeology Group was commissioned to undertake a Geoarchaeological Desk-Based Assessment within and around the Hornsea Four Order Limits (i.e. the landfall, onshore ECC, OnSS including EBI, and 400 kV National Grid Electricity Transmission (NGET) connection area).

1.1.1.3 This technical annex has been produced to characterise the baseline environment to inform and support the Environmental Statement for **Volume A3, Chapter 5: Historic Environment**.

1.2 Site Description

1.2.1.1 The onshore works consist of a refined landfall location at Fraisthorpe Sands (south of Bridlington), an approximately 39 km long, 80 m wide onshore ECC easement with eight logistics compounds, heading south-westwards and crossing the River Hull before curving southwards to the west of Beverley and terminating at the OnSS, 4 km south of Beverley and 10 km north-west of Hull (**Figure 1**). The onshore ECC route passes through 15 parishes within East Riding (Barmston, Ulrome, Beeford, Foston, Hutton Cranswick, Watton, Beswick, Lockington, Leconfield, Cherry Burton, Molescroft, Bishop Burton, Walkington, Rowley and Skidby). The vast majority of current land-use around Hornsea Four is arable farmland and the landscape contains numerous small villages, with larger urban centres located to the north (Bridlington) and east (Beverley).

1.2.2 Aims

1.2.2.1 The aims of this study are to:

- further understand geological changes across the Hornsea Four Order Limits;
- better understand the varying depths of deposits likely to be present;
- establish a better understanding of the archaeological and geoarchaeological landscape; and
- highlight areas of potential geoarchaeological interest which will inform the assessment presented in **Volume A3, Chapter 5: Historic Environment**.

1.2.2.2 The aims of this report are to:

- review available existing/historic geotechnical and geoarchaeological sources of information to establish the geoarchaeological and palaeoenvironmental potential;
- prepare a fully illustrated report on the results of the geoarchaeological desk-based review that is compliant with all relevant policy, guidance and good practice and which is proportionate to the results, making recommendations for suitable (justified and proportionate) further work, if required; and
- provide a report of the geoarchaeological watching brief undertaken during the Hornsea Four geotechnical site investigations at the landfall (**Appendix A**).

2 Methodology

2.1 Study area

2.1.1.1 For ease of discussion and for the purposes of this background geoarchaeological and palaeoenvironmental review, the study area has been divided into five sections (**Figure 1**), comprising:

- **Section 1**: Landfall and the northern element of the onshore ECC (Fraisthorpe to North Pasture Farm, **Figure 2**);
- **Section 2**: Onshore ECC from North Pasture Farm to Rotsea (**Figure 3**);
- **Section 3**: Onshore ECC from Rotsea to Scorborough (**Figure 4**);
- **Section 4**: Onshore ECC from Scorborough to Killingwoldgraves (**Figure 5**); and
- **Section 5**: Onshore ECC from Killingwoldgraves to Cottingham, OnSS, EBI and 400 kV NGET connection area (shown in **Figure 6**).

2.1.1.2 The following data sources were consulted during preparation of this desk-based assessment:

- British Geological Survey (BGS) Single Onshore Boreholes Index (SOBI); for records of boreholes, shafts and wells from all forms of drilling and site investigation work within the 200 m study area;
- Ordnance Survey (OS); for OS Terrain® 50 Mapping for contour and spot height data for the study area;
- Environment Agency; for LIDAR Composite Digital Terrain Model (DTM) at 2 m spatial resolution;
- Soil Survey of England and Wales; for soil mapping of the study area;
- Environmental Systems Research Institute (ESRI) Digital Globe, GeoEye, Earthstar Geographics; for satellite imagery showing the study area;
- Britain from Above; for online aerial photographs showing the study area;
- The Humber Wetlands Project; for records relating to investigations within the study area; and
- Publications and grey literature reports concerning previous archaeological and palaeoenvironmental investigations within the 10 km study area as listed in the References in **Section 5**.

2.1.1.3 An initial review of SOBI records within a 100 m buffer of the Hornsea Four Order Limits (within which it is considered deposits would reflect those likely to be found within the landfall, onshore ECC, OnSS, EBI and 400 kV NGET connection area) revealed insufficient records to characterise deposits and as such a wider 200 m study area around the Hornsea Four Order Limits was selected. Many of the borehole records used in this study have only a very brief description of the lithologies. For example, a unit described as "Clay" could be alluvium, tidal flat deposits, head, till or glaciolacustrine. In interpreting this, judgement has been used based on the likely stratigraphy at that location and depth.

2.1.1.4 Palaeoenvironment records and literature have been reviewed for relevant sites surrounding each section within a 10 km study area either side of the Hornsea Four Order Limits. Paleoenvironmental studies frequently focus on palynological data which includes pollen from a wide 'pollen catchment' frequently extending several kilometres from the site of study and contributing to regional pollen diagrams. Therefore, it was considered relevant to include known palaeoenvironmental studies within 10 km and occasionally, such as in the case of Star Carr and Roos Bog, to consider sites beyond this where useful regional pollen diagrams have been established.

2.2 Baseline Data Limitations

2.2.1.1 A process of site and route refinement has been undertaken throughout the development of Hornsea Four, as detailed in **Volume A1, Chapter 3: Site Selection and Consideration of Alternatives**. The changes made to the Hornsea Four Order Limits, since the Preliminary Environmental Impact Report (Orsted 2019), have been considered and the 200 m study area has been revised accordingly.

2.2.1.2 A full review of the data sources outlined in **Section 2.1** has been undertaken with reference to the Hornsea Four Order Limits and revised 200 m study area. All information presented within the assessment set out in this report takes account of changes to the Hornsea Four Order Limits and associated 200 m study area.

3 Desktop Review

3.1 Geology

3.1.1.1 The 200 m study area is located within the Hull Valley and Holderness on low lying terrain at elevations of less than 20 m above Ordnance Datum (AOD) along its length. The 200 m study area is underlain by solid geological deposits of chalk belonging to the White Chalk Subgroup. The BGS geology maps show the bedrock within the Hornsea Four Order Limits to comprise the following formations (from oldest to youngest bedrock age):

- Burnham Chalk Formation (Section 1 and Section 2);
- Flamborough Chalk Formation (Sections 3-5); and
- Rowe Chalk Formation (Sections 2-5).

3.1.2 Geological Overview of the Study Area

3.1.2.1 The BGS geology maps show that various superficial deposits underlie the 200 m study area. These deposits include (from oldest to youngest deposit age):

- Basement Till (diamicton);
- Skipsea Till (diamicton);
- Glacifluvial Sand and Gravel Deposits;
- River Terrace Sand and Gravel Deposits; and
- Alluvial Clay Silt and Sand Deposits.

3.1.2.2 The oldest glacial deposit underlying the 200 m study area is the Basement Till, which is dated to the Wolstonian (Catt 2007). This is overlain by the Skipsea till which is of Devensian age. Radiocarbon dates of 18,500 ± 400 14 calendar years (C yrs.) Before Present (BP) and 18,240 ± 250 14C yrs. BP obtained by Penny et al. (1969) on plant remains between the Basement and Skipsea Tills provide a maximum age for the onset of the Dimlington Stadial in the region (Rose 1985). An additional date for the onset of the Stadial of 17,500 ± 1,600C yrs. BP was obtained by thermoluminescence techniques from beneath the Skipsea Till on the Wolds dip slope (Wintle and Catt 1985).

3.1.2.3 The western limit of the Basement till lies within Section 3 of the 200 m study area along the OS 510000 m line, although some outcrops extend towards the OS 505000 m line around Leconfield and Cottingham in Sections 4 and 5 respectively. The overlying Skipsea till largely mirrors this distribution and demarcates the former limit of the Dimlington Stadial (22,000 to 13,000 year ago) North Sea glacier lobe (Bateman et al. 2015).

3.1.2.4 An extensive buried cliff in the chalk bedrock runs roughly from north to south in Sections 3 and 4 of the 200 m study area. The onshore ECC crosses the cliff north of Leconfield in the vicinity of Scorborough. This palaeocliff formed during the Ipswichian (128,000 to 117,000 years ago), an interglacial period prior to the Devensian glaciation, and provides evidence that the pre-Devensian landscape was a marine erosion surface or 'wave-cut platform' in the chalk, which represents the shoreline during a period when the inferred relative sea level was approximately 2 m Above (present) Ordnance Datum (AOD) (Catt 2007).

3.1.2.5 The diamicton glacial till is the main deposit from the last (Devensian) cold stage and underlies the majority of 200 m study area. Till is deposited by glacial ice, either at the glacier base or derived from material within and on the ice. It comprises gravelly sandy silty clay with boulders and contains numerous lenses of sand and gravel. The till is also likely to contain interdigitating units of glaciolacustrine clay, plus sand and gravel formed during ice advance and retreat (Burke et al. 2015, 30).

3.1.2.6 The 200 m study area features upper deposits of clays, silts and peat that formed a fining-upwards tidal-flat sequence following the deglaciation and sea-level rise during the Holocene. As the sea rose to its present level, alluvium and the lower-level peat initially filled the channels. Later, the deposits were spread thinly over the adjacent low ground, with expanses of peat followed by the silts and clays. Some of the fine-grained sediments include 'warp', an artificially deposited silt and clay sequence formed in the last two or three centuries by controlled flooding to raise the land level and improve the quality of agricultural land. Consequently, there is potential along the onshore ECC, particularly within Section 2 of the 200 m study area in the vicinity of Corpslanding and Rotsea, to encounter deposits that represent both Quaternary and Holocene environments of the River Hull valley and are of interest for understanding the evolution and exploitation of the landscape throughout prehistory.

3.1.2.7 These superficial deposits contain, or are entirely composed of, sand and gravel which can provide good results from aerial survey, dependent on the time of year and ground conditions. Clay and silt, also present in many of these superficial deposits, is similarly capable of providing good results. However, the gravel-based deposits can result in 'noisy' geophysical survey data, and deep deposits of alluvium (i.e. depths beyond 1 m) are not always conducive to geophysical survey as smaller, discrete archaeological features can be masked from detection.

3.1.2.8 The bedrock deposits are well drained and very well suited to the recording of crop and soil marks over buried features from the air, and the recording of archaeological anomalies from geophysical survey.

3.1.3 Geology of Section 1 - Fraisthorpe to North Pasture Farm

3.1.3.1 Section 1 of the 200 m study area from Fraisthorpe to North Pasture Farm is underlain by a bedrock of Rowe Chalk Formation formed approximately 66 to 84 million years ago (mya) in the Cretaceous Period, under a shallow warm sea environment. Superficial geological deposits in Section 1 of the 200 m study area are variable. Storm beach deposits are mapped by the BGS on the coastline. Further inland, alluvial deposits associated with Earls' Dyke and the Barmston Main Drain may be encountered.

3.1.3.2 LIDAR data held by the Environment Agency shows that the onshore ECC crosses a possible palaeochannel tributary at National Grid Reference (NGR) 514516 458858. A wider probable palaeochannel is visible in the vicinity of tributaries to the Barmston Main Drain. The possible channel runs north to south and is crossed by the onshore ECC for a distance of approximately 420 m from NGR 514686 459009 to 514563 458688 (**Figure 2**). A further probable palaeochannel is visible north of Beeford Grange near Lissett Bridge from NGR 513284 456893 to 512270 456550 for a distance of 1.08 km (**Figure 2**).

3.1.3.3 The remainder of Section 1 of the 200 m study area is likely underlain by a range of till/diamicton deposits of the last glacial maximum (LGM) which in places are overlain by glacial outwash deposits. The BGS map glacial outwash deposits of sand and gravel where the onshore ECC crosses Gransmoor Road at Lissett.

3.1.4 Geology of Section 2 - North pasture Farm to Rotsea

3.1.4.1 The chalk bedrock in Section 2 of the 200 m study area rises from +30 m below ground level (bgl) at Fraisthorpe to c. 20 m bgl where the onshore ECC crosses the Barmston Main Drain just east of North Pasture Farm and where the underlying bedrock changes to Flamborough Chalk. The Flamborough Chalk formed 72 to 86 mya in the Cretaceous Period in a local environment previously dominated by warm chalk seas. Mapped superficial deposits within Section 2 of the 200 m study area are largely dominated by till relating to the LGM with areas of mapped alluvial deposits north-west of Brigham where the onshore ECC crosses the Driffield Canal and the River Hull/Nafferton Drain east of Corpslanding. A deposit model prepared by the BGS (Burke et al. 2015) shows an extensive area of glaciofluvial sand and gravel in the vicinity of Gembling and Foston on the Wolds. These deposits are associated with the till but generally have a lower clay content and correspondingly greater proportions of sand and gravel.

3.1.4.2 Review of LIDAR data indicates the probable alluvial floodplain from NGR 508709 455348 south of Carr House Farm for a distance of c. 700 m to the junction with B1249 at NGR 508102 454915 with further low lying land notable from NGR 507711 454407 to 507234 454132 for 735 m (**Figure 3**) where the onshore ECC crosses the Driffield Canal and Nafferton Drain in an area where preserved paleoenvironmental deposits within former palaeochannels are known (Lillie and Geary 2000, 40-41). Any such fluvial deposits have the potential to record finer grained clays, silts and sands of the Late Quaternary/Holocene as well as preserved land surfaces.

3.1.5 Geology of Section 3 - Rotsea to Scorborough

3.1.5.1 Section 3 of the 200 m study area is underlain by a solid geology of Flamborough Chalk until a point just west of Acres Farm where the solid geology changes to the older Burnham Chalk Formation which formed approximately 84 to 94 million years ago in the Cretaceous Period. The majority of the section is underlain by superficial diamicton Till deposits with small patches of glacial sand and gravel mapped by the BGS where the onshore ECC passes Throstle Nest Farm, Kilnwick Arm Drain and Bryan Mills Farm. An area of alluvium is mapped between the sands and gravels at Kilnwick Arm Drain and Beswick New Cut and also where the onshore ECC crosses Bryan Mills Beck.

3.1.6 Geology of Section 4 - Scorborough to Killingwoldgraves

3.1.6.1 Section 4 of the 200 m study area is underlain by solid deposits of Burnham Chalk until it reaches a point parallel with the settlement of Cherry Burton where the onshore ECC is underlain again by Flamborough Chalk. Superficial deposits are dominated by Diamicton Till although patches of glacial sand and gravels are mapped by the BGS where the onshore ECC passes west of Leconfield. The onshore ECC also crosses channel deposits of glacial sand and gravels and glacial head deposits south-west of Leconfield where the onshore ECC crosses two offshoots of the Catchwater Drain.

3.1.7 Geology of Section 5 - Killingwoldgraves to Cottingham

3.1.7.1 Section 5 of the 200 m study area is underlain by Flamborough Chalk until west of Bentley where deposits of Burnham Chalk are mapped before returning again to Flamborough Chalk at the southern end of the onshore ECC and at the OnSS. Alluvial and head deposits north-west of Bentley mark a former palaeochannel. The majority of superficial deposits mapped by the BGS are Diamicton Till.

3.2 Soils

3.2.1.1 A review of soil survey data held by the Soil Survey of England and Wales (SSEAW) and readily available online satellite imagery and aerial photography has been undertaken to inform a review of soils and land use. The soils in the 200 m study area are mainly influenced by the geology and superficial till deposits, where glacial clays are inter-bedded with sands and gravels.

3.2.1.2 The flanks of the chalk Wolds at the south-western extremity of the onshore ECC, including the OnSS, have well drained loamy soils. In contrast the flat, poorly drained valley areas in the north-east of the onshore ECC are mainly characterised by gley soils, with some areas of freely drained brown earths. The varied depositional history means that the character of the overlying deposits changes across the 200 m study area. The LIDAR data shows changes in topography hinting at subtle depressions in landscape which appear to mark the route of various palaeochannels.

3.2.1.3 Soils in the vicinity of Barmston which underlie the Logistics Compounds and Landfall Connection Works as well as the onshore ECC as far as Lissett are mapped by the SSEAW (1984) as part of the Wick 1 Association which comprise deep, well drained coarse loamy brown earth soils usually overlying glaciofluvial and terrace drift. The remainder of the onshore ECC in Section 1 of the 200 m study area is underlain by fine loamy and moderately permeable coarse loamy soils of the Holderness series underlain by glacial clay till. Stones are common in these soils and reflect the glacial origin of the underlying till with igneous erratics from Scotland and Scandinavia present alongside Carboniferous stones from the north of England.

3.2.1.4 Soils underlying Section 2 of the 200 m study area are part of the Holderness series with the exception of where the onshore ECC crosses the Driffield Canal and River Hull where soils are mapped as part of the Frome association. The Frome association includes alluvial soils of streams draining the chalk Wolds and comprises grey and mottled silty clay loams affected by groundwater with calcareous chalky and flinty gravel at relatively shallow depth. Evidence of periodic or prolonged waterlogging is present in the form of grey and ocherous mottling. The distribution of Frome soils largely correlates with the distribution of superficial alluvial deposits mapped by the BGS and discussed in **Section 3.1.4**.

3.2.1.5 Soils underlying Section 3 of the 200 m study area are largely part of the Downholland 3 association. These are stoneless marine clays with peaty or humose upper horizons which give rise to humic alluvial gley soils. The soils are severely waterlogged in their natural state but are permeable and thus very responsive to drainage measures (Jarvis et al. 1984).

3.2.1.6 The northern part of Section 4 of the 200 m study area from Scorborough to Leconfield is underlain by the aforementioned fine loamy soils of the Holderness Series. Soils south of Leconfield including those in Section 5 of the 200 m study area are mapped (SSEAW) as part of the Burlingham 2 association. This association is dominated by stagnogleyic fine loamy soils with a slowly permeable subsoil, formed in chalky till. Stones of Scandinavian origin are common within these soils alongside locally derived chalk which increases with depth (Jarvis et al. 1984).

3.2.1.7 Soils in the 200 m study area are thus frequently mapped as semi-waterlogged. However, continued drainage within the Hull valley from the medieval period onwards has reduced the once extensive salt marsh and wetland carr areas (Sheppard 1976). These drainage measures combined with rich soils of glacial till and alluvium have meant the modern landscape is dominated by intensive agriculture, primarily arable cultivation. Post-medieval narrow ridge and furrow was largely located in the lower lying areas adjacent to the River Hull, benefiting from the fertile alluvial deposits found on the floodplain. The resulting field patterns are of note with irregular field boundaries visible on areas that were subject to pre-parliamentary enclosure largely located on the higher ground. The field systems lying in the former carrs were some of the last areas of the Hull valley to be enclosed and as such are notably more regular in plan (Chapman 2000).

3.2.1.8 Grassland pasture is evident on the poorly drained areas or on poorer clay soils. Field boundaries on the lower-lying areas are usually ditched for increased drainage, while on the higher ground hedged boundaries are more common. Woodland is very sparse across the 200 m study area and is present only in small copses or beside water courses. The modern settlement pattern was broadly established by the medieval period and reflects limited availability of dry areas prior to the effective drainage schemes of the 18th and 19th centuries.

3.2.1.9 Shrinkage of former peat land along with smaller scale 20th century drainage measures to facilitate agriculture have resulted in the canalised River Hull and Barmston Main Drain having water levels several metres higher than the surrounding land (Van de Noort and Ette 2000). Water transport was once of vital importance to the lowland areas and the River Hull played a central part in the transport network. Many of the earliest 'drains' crossed by the onshore ECC were intended primarily for water transport (Middleton 2000).

3.2.1.10 The soils are frequently mapped as semi-waterlogged, however the continued drainage within the Hull Valley from the medieval period onwards combined with the rich soils of glacial till and alluvium have proved favourable to the visibility of archaeological features as cropmarks and geophysical anomalies.

3.2.1.11 Less well drained soils located within the Hull Valley, (between Foston on the Wolds and Rotsea, and those to the west and south of Beverley) provide less suitable conditions for crop and soil marks. These less well drained soil types in combination with low-lying areas of alluvium, such as those within the Hull Valley, tend to be less conducive to geophysical survey as these overlying waterlogged deposits can mask smaller or less magnetically susceptible archaeological features from detection. However, the ability to detect geomorphological features, such as palaeochannels, in these ground conditions can indirectly inform the presence of archaeological activity.

3.2.1.12 Topographically, evidence for settlement and land division within the study area can be seen ranging from elevations of up to 40 m AOD on the Wold edge at Risby down to approximately 2 m AOD in the Hull Valley itself, although most sites are above 3 m AOD. Known archaeological settlement sites are commonly located on slightly higher ground which presumably would have ensured that they remained relatively dry, a trend that continued for settlements into the medieval period and beyond. However, the systematic draining of the land from the medieval period to form fertile agricultural land may have had a detrimental effect on any archaeological remains present either through desiccation or damage from ploughing regimes.

3.3 Review of Borehole Records

3.3.1 Introduction

3.3.1.1 Boreholes falling within a 200 m corridor either side of the Hornsea Four Order Limits and held within the BGS Single Onshore Boreholes Index have been reviewed. The locations of these boreholes are shown on **Figure 2** to **Figure 6**. Where relevant, boreholes sunk as part of the Humber Wetlands Survey (Van de Noort and Ellis 1995; 2000) have also been reviewed.

3.3.2 Section 1: Fraisthorpe to North Pasture Farm

3.3.2.1 The BGS record shows only a single borehole (TA16SE29) within the 200 m study area for Section 1 of the onshore ECC south-west of Landfall (**Figure 2**). This borehole recorded glacial drift deposits (with no further description) to a depth of 23.8 m bgl overlying chalk bedrock.

3.3.2.2 The Landfall Logistics Compounds are located in an area which crosses the Earl's Dike and associated narrow valley floor. The Earl's Dike valley was investigated as part of the Humber Wetlands Project. The survey found the valley to be less than 30 m across and infilled with approximately 2 m of inorganic alluvium which was likely deposited since c. 1260 cal BC, when water courses in the areas would have been aggrading in response to sea level reaching OD and/or following forest clearance. The peaty topsoil encountered in this valley indicated that prior to modern land drainage the valley bottom was waterlogged and thus may retain paleoenvironmental potential. A fieldwalking survey of the flat sandy ground adjacent to the valley in the vicinity of the proposed Landfall Compound revealed concentrations of worked flint material (Head *et al*. 1995 229-239).

3.3.2.3 Coring undertaken at Barmston Low Ground as part of the Humber Wetlands Project revealed a complex stratigraphic sequence which documented periods of lacustrine alluvial deposition following the formation of Barmston Mere followed by wind-blow sand deposition. Drainage and ploughing have probably destroyed many of the Holocene organic sediments which would have accumulated at the shallower margins of the mere (Dinnin and Lillie 1995). A coring transect was undertaken by Humber Archaeology in 2013 through Barmston Mere south of the proposed Landfall Connection Works. A plan of the mere drawn from ground survey during an earlier phase of works was also amended using LIDAR and aerial photographic images and showed it to extend further north than previously thought (Brigham and Jobling 2015). The coring allowed for the creation of a new profile of Barmston Mere, revealing a sequence of post-glacial lacustrine deposition. The boreholes passed through a sequence of lacustrine alluvial silts at least 7 m bgl (–2.74 m AOD). A perched water table was encountered close to the ground level. Several boreholes closest to both edges of the mere (BH1–2 and BH6–10) reached an indurated gravel surface which in several instances was impenetrable. The sequence above this included sand and gravel which in some instances formed discrete layers, in others it formed bands within the lower alluvium. Previous excavations at Barmston by Varley (1968) and Humber Wetlands Project (Fletcher & Van de Noort 2007) had revealed peat deposits and traces of Bronze Age settlement, but these were not encountered within the 2013 boreholes (Brigham and Jobling 2015).

3.3.2.4 Deposits in the north-east of Section 1 within the 200 m study area and in the vicinity of Barmston have the potential to preserve complex geoarchaeological deposits and paleoenvironmental remains associated with Earls' Dike valley and the former Barmston Mere. As far as is possible from the limited records available, it appears that deposits in the remainder of Section 1 of the 200 m study area largely comprise glacial till overlying chalk bedrock as indicated by BGS mapping.

3.3.3 Section 2: North pasture Farm to Rotsea

3.3.3.1 The BGS record three borehole records (TA05NE25, TA05SE40) and TA05SE33) within the 200 m study area for Section 2 (**Figure 3**). In addition, a borehole transect (Brigham Transect 2: Corpslanding) undertaken as part of the Hull Valley archaeological survey (Van de Noort and Ellis 2000) also falls within this section of the study area.

3.3.3.2 The northernmost borehole at Foston Beck (TA05NE25) recorded deposits of clay to a depth of 6.4 m bgl overlying a thin lens of sand 0.6 m thick which in turn overlay clay deposits to a depth of 16.2 m before chalk bedrock was encountered. The Brigham borehole (TA05SE40) similarly recorded clay to a depth of 2.9 m overlying a deposit of sand 2 m thick which in turn overlay clay to 11 m before encountering chalk bedrock.

3.3.3.3 The borehole sunk at Rotsea (TA05SE33) noted soil/made ground to a depth of 2.4 m overlying a deposit of sand to 5 m depth which in tun overlay boulder clay to a depth of 9.3 m. Gravels were encountered to a depth of 12.9 m bgl at which point the chalk bedrock had been reached. Review of this borehole alongside deposit modelling by BGS (Burke et al. 2015) indicates the existence of intra-till glacio-lacustrine deposits in the form of laminated clay between till units. Glaciolacustrine deposits such as those encountered at Rotsea represent temporary glacial lakes that form in topographic lows on the till surface. The laminated clay became incorporated into the till deposits when they were overridden during a later ice advance (Burke et al 2015, 37).

3.3.3.4 The Brigham Transect 2: Corpslanding comprised eight boreholes excavated in a north-south direction across the Nafferton Drain and the onshore ECC (**Figure 3**). The boreholes reached a maximum depth of 3 m bgl. Boreholes on the southern side of the floodplain encountered plough soil to 0.35 m depth on to glaciofluvial sands and clays to 0.88 m depth overlying a weathered chalk horizon to 0.95 m depth. The weathered chalk overlay a second horizon of glaciofluvial material comprising silt and fine sands with angular chalk gravels to 1.5 m where a compact till was encountered. Similar deposits, with the appearance of having been reworked were encountered 50 m to the north with the sequence being bottomed on to solid gravels at 2.4 m depth. The fluvial deposits were noted to be more sand dominated as the transect moved northwards. A borehole taken immediately south of the River Hull encountered a sequence with an upper partially oxidised clay-silt and fine sand alluvial unit comprising silts with occasional clays and molluscs to 1.72 m depth overlying a natural silt peat horizon with frequent fibrous material, rhizomes and molluscs to 1.97 m depth overlying fluvial coarse sands and gravels. On the northern side of the Nafferton Drain the uppermost sediments were found to comprise warp-like silts and fine sands to 1.3 m depth over oxidised silt-clay alluvium to 1.36 m depth onto a lower organic alluvial unit. This comprised peaty silts with fine sands and frequent wood (alder and birch) twigs and fibrous material through to 2.37 m depth on to chalk. A borehole 40 m further north encountered silt and fine sand to 0.7 m over intercalated alluvium and clayey floodplain with peats between 0.7 and 1.63 m. The alluvial horizons comprise silt-clays with fine sands and the clayey peats have poorly preserved plant macrofossil remains in the form of wood and fibrous material. At 1.63 m depth glaciofluvial deposits in the form of coarse sands and flint, chalks and quartzite gravels were found to underlie the floodplain deposits. The depositional sequence encountered in the northernmost boreholes exhibited evidence for colluviation from the adjacent hillslope which resulted in an overburden of 0.7 m depth on to alluvium 1.26 m in depth. The lower deposits in this sequence comprise glaciofluvial sands and gravels to 2.10 m bgl.

3.3.3.5 The Brigham Transect 2: Corpslanding indicates the existence of a palaeochannel feature south of the Nafferton Drain whereas on the north side of the drain the depositional sequence reflected low energy sedimentation comprising a silty biogenic rich deposit overlain with fine grained alluvium and warp like deposits (Lillie and Geary 2000, 41-43)

3.3.4 Section 3: Rotsea to Scorborough

3.3.4.1 Section 3 of the 200 m study area has four boreholes of note (**Figure 4**). Boreholes TA05SE7 and TA05SE34 are located adjacent to Throstle Nest Farm and were sunk to 24.69 m bgl and 26.5 m bgl, respectively. The sequence encountered in both boreholes revealed a sandy soil to a depth of over 1 m overlying clay deposits to just over 10 m where chalk was encountered. Borehole TA05SE7 encountered a more complex sequence noting the presence of laminated clays between 8.74 m and 10.36 m which may be indicative of former lakeland environments such as those at Gembling (Thomson and Evans 2001) and hypothesised at Rotsea (Burke et al. 2015).

3.3.4.2 Boreholes TA04NW24 and TA04NW6 were sunk north of Bryan Mills Farm. Both boreholes encountered soil to a depth of 0.3 m overlying gravels to 3.9 and 4.3 m, respectively. Clay overlying chalk at a depth of 11.3 m bgl was encountered within TA04NW24 whereas a second gravel deposit underlying the clay was encountered at 8 m before the chalk was encountered at 12.9 m bgl.

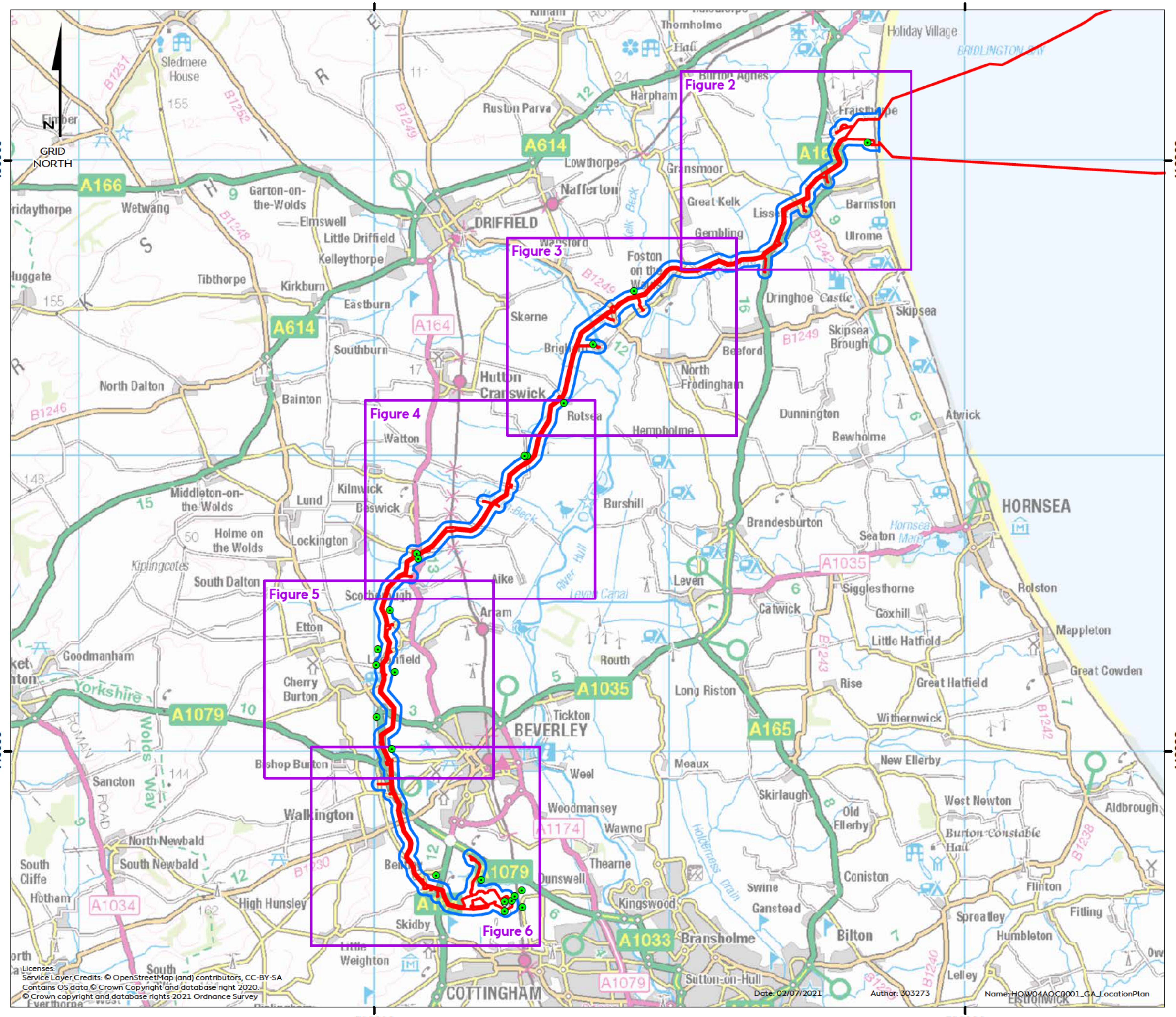
3.3.5 Section 4: Scorborough to Killingwold graves

3.3.5.1 Section 4 of the 200 m study area records two previous borehole records within the study area (**Figure 5**). However, neither borehole (TA04SW48B and TA04SW59) record stratigraphy in sufficient detail to characterise deposits with both being described as 'Drift on Burnham Chalk'.

3.3.5.2 A review of boreholes adjacent to the study area revealed a depth of soils/made ground to depths of between 0.4 m -1.5 m bgl overlying boulder clay or till to 5 m (TA04SW198 and TA04SW199) and 'Drift on Flamborough Chalk (TA04SW47 and TA04SW145). Deposit Modelling undertaken by the BGS indicates an area of glaciofluvial sands and gravels at Leconfield. Glaciofluvial sands and gravels are generally indicative of high energy depositional events possibly associated with cooler conditions during the last ice age. Information about deposits in Section 4 is relatively scarce and as such little is known about the potential for this part of the onshore ECC to contribute to the paleoenvironmental record and wider understanding of the Quaternary Holocene transition in the Hull Valley.

3.3.6 Section 5: Killingwoldgraves to Cottingham

3.3.6.1 Recorded boreholes within the 200 m study area in Section 5 are focused in the south of this section (**Figure 6**). TA03NW420 recorded south of Bentley noted deposits of made ground to 0.2 m overlying silty sand to 7.4 m below which chalk bedrock was encountered. TA03NW3 at Poplar Farm recorded topsoil overlying 'yellow clay' to a depth of 4.71 m below which boulder clay was recorded to 10.47 m bgl. A more complex sequence was revealed within TA03SW20 and TA03NE118 which recorded sandy and silty clays overlying sands and gravels to a depth of 4.42 m which in turn overlie silty clay deposits with chalk encountered at 5.14 m and may indicate intra-till glacio-lacustrine deposits. Limited detail of depths of deposits is provided for TA03SW97 which is one of several boreholes sunk at the Cottingham Water Works. These boreholes recorded a general sequence of made ground overlying gravel which in turn overlay clay and further gravel deposits onto Burnham Chalk. The sequences recorded within the south of Section 5 thus indicate the presence of glaciofluvial deposits indicative of the LGM outwash with some boulder clays and possible glacio-lacustrine clays. Information about deposits in the north of Section 5 as with Section 4 is relatively scarce and as such little is known about the potential for this part of Hornsea Four to contribute to the paleoenvironmental record and wider understanding of the Quaternary Holocene transition in the Hull Valley.



Hornsea Four

Figure 1

Location Plan

Order Limits

200m Study Area

BGS Boreholes

Coordinate system: British National Grid

Scale@A3: 1:125,000

0 1.25 2.5 5 Kilometres

0 0.75 1.5 3 Miles

REV	REMARK	DATE
	First Issue For PEIR	20/06/2019
A	Updated following PEIR consultations, for DCO	02/07/2021

Title: Location Plan
Document no: HOW04AOC0001
Created by: LOC
Checked by: LR
Approved by: RHDHV

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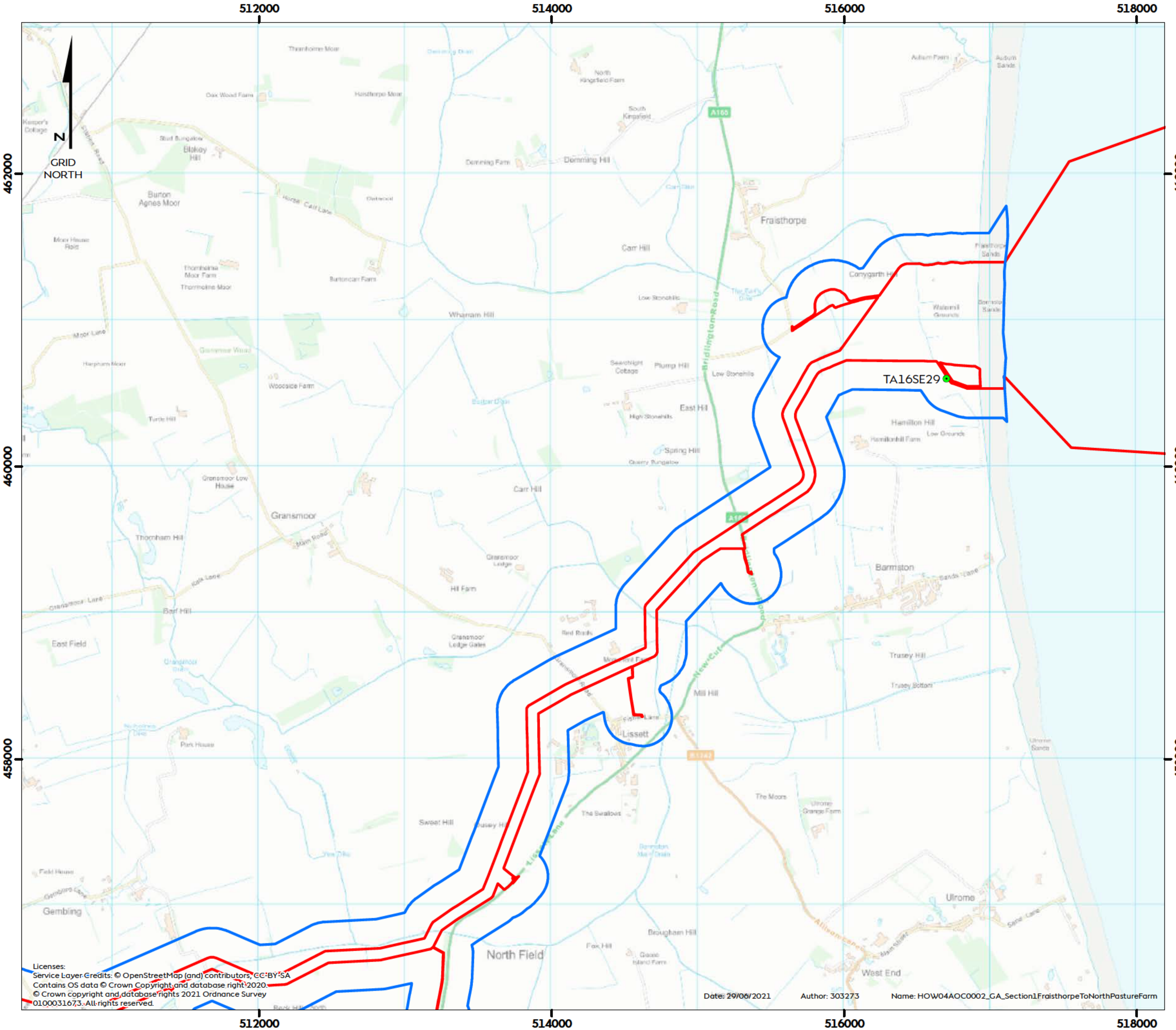

Hornsea Four

Figure 2

Section 1: Fraisthorpe to North Pasture Farm

Order Limits

200m Study Area

BGS Boreholes

Coordinate system: British National Grid

Scale@A3: 1:25,000

0 0.25 0.5 1 Kilometres

0 250 500 1,000 Yards

REV	REMARK	DATE
	First Issue For PEIR	20/06/2019
A	Updated following PEIR consultations, for DCO	29/06/2021

Title: Section 1- Fraisthorpe to North Pasture Farm

Document no: HOW04AOC0002

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Approved by: RHDHV

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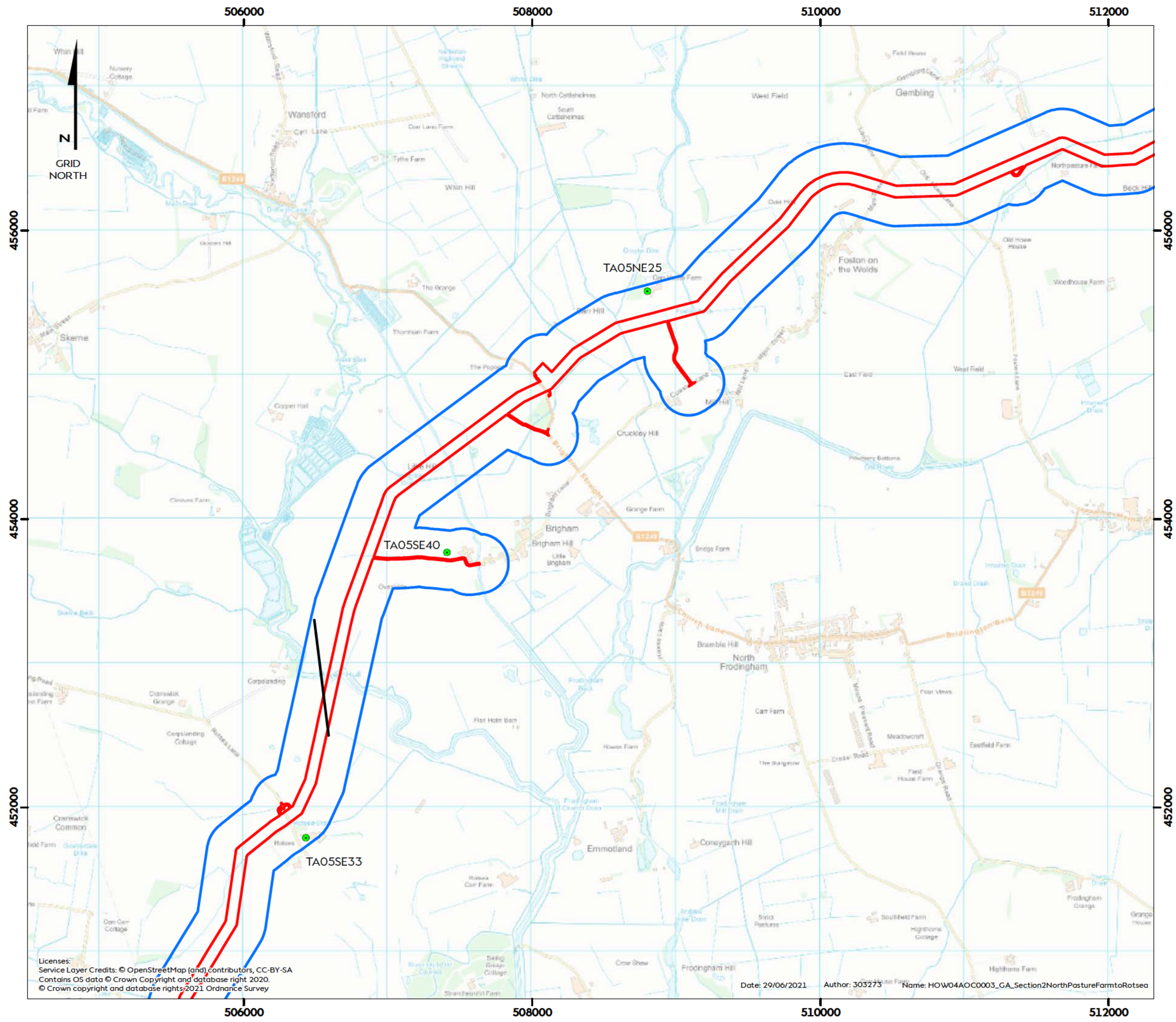

Date: 29/06/2021 Author: 303273 Name: HOW04AOC0003_GA_Section2NorthPastureFarmtoRotsea

Hornsea Four

Figure 3

Section 2: North Pasture Farm to Rotsea

- Order Limits
- 200m Study Area
- Brigham 2: Corpslanding Transect
- BGS Boreholes

Coordinate system: British National Grid
Scale@A3: 1:25,000
0 0.25 0.5 1 Kilometres
0 250 500 1,000 Yards

REV	REMARK	DATE
	First Issue For PEIR	20/06/2019
A	Updated following PEIR consultations, for DCO	29/06/2021

Title: Section 2-North Pasture Farm to Rotsea
Document no: HOW04AOC0003
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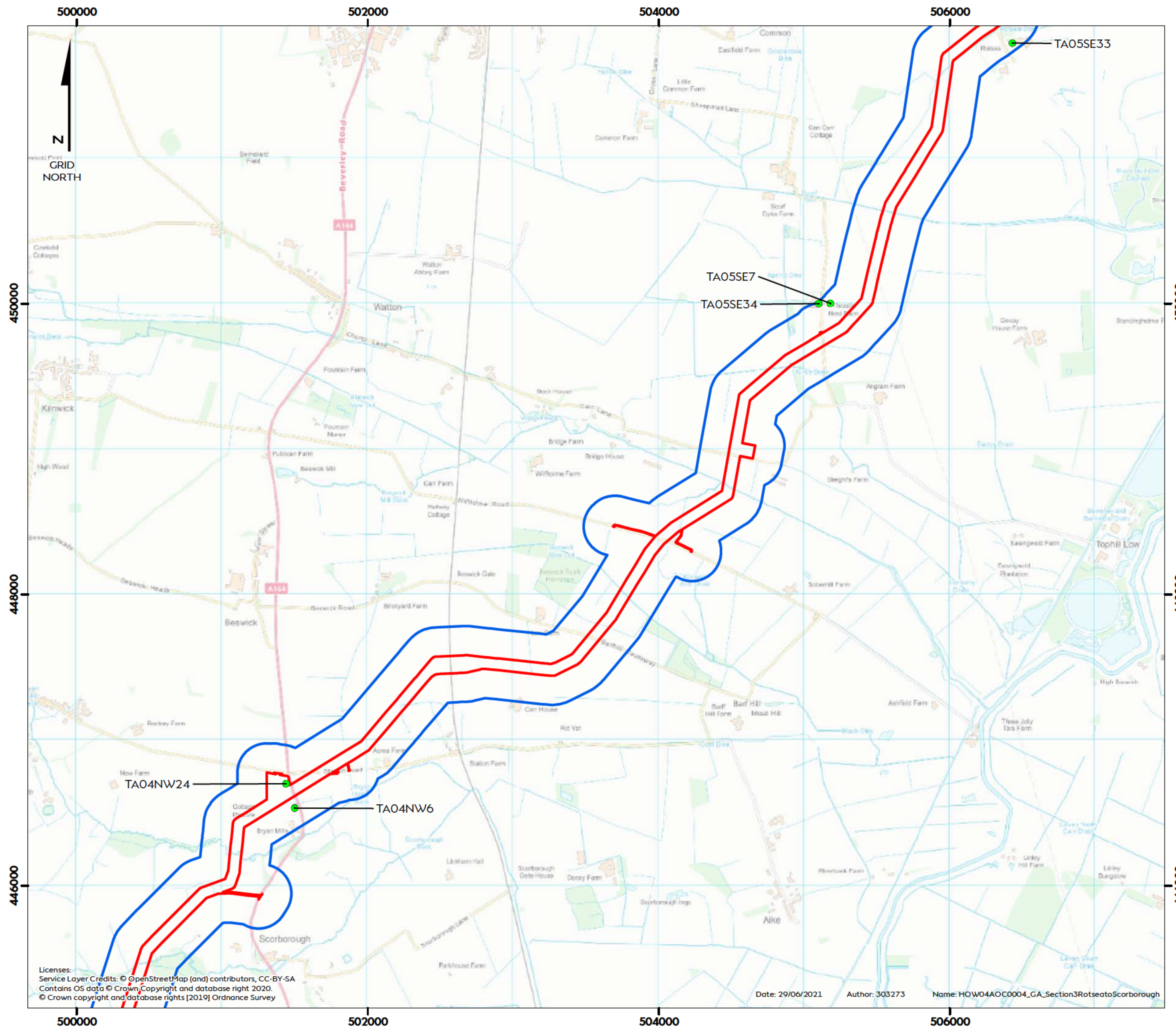
Hornsea Four

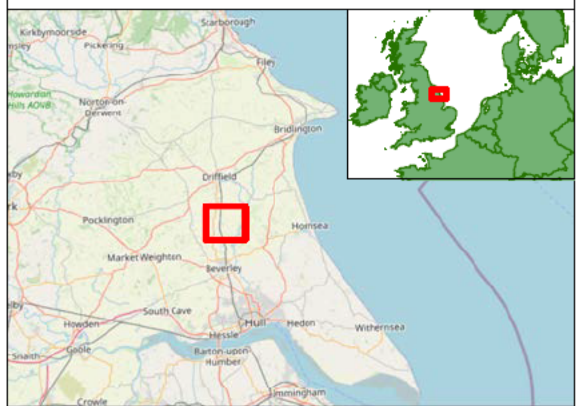
Figure 4

Section 3: Rotsea to Scorborough



Date: 29/06/2021 Author: 303273 Name: HOW04AOC0004_GA_Section3RotseatoScorborough

- Order Limits
- 200m Study Area
- BGS Boreholes



Coordinate system: British National Grid
Scale@A3: 1:25,000

0 0.25 0.5 1 Kilometres

0 250 500 1,000 Yards

REV	REMARK	DATE
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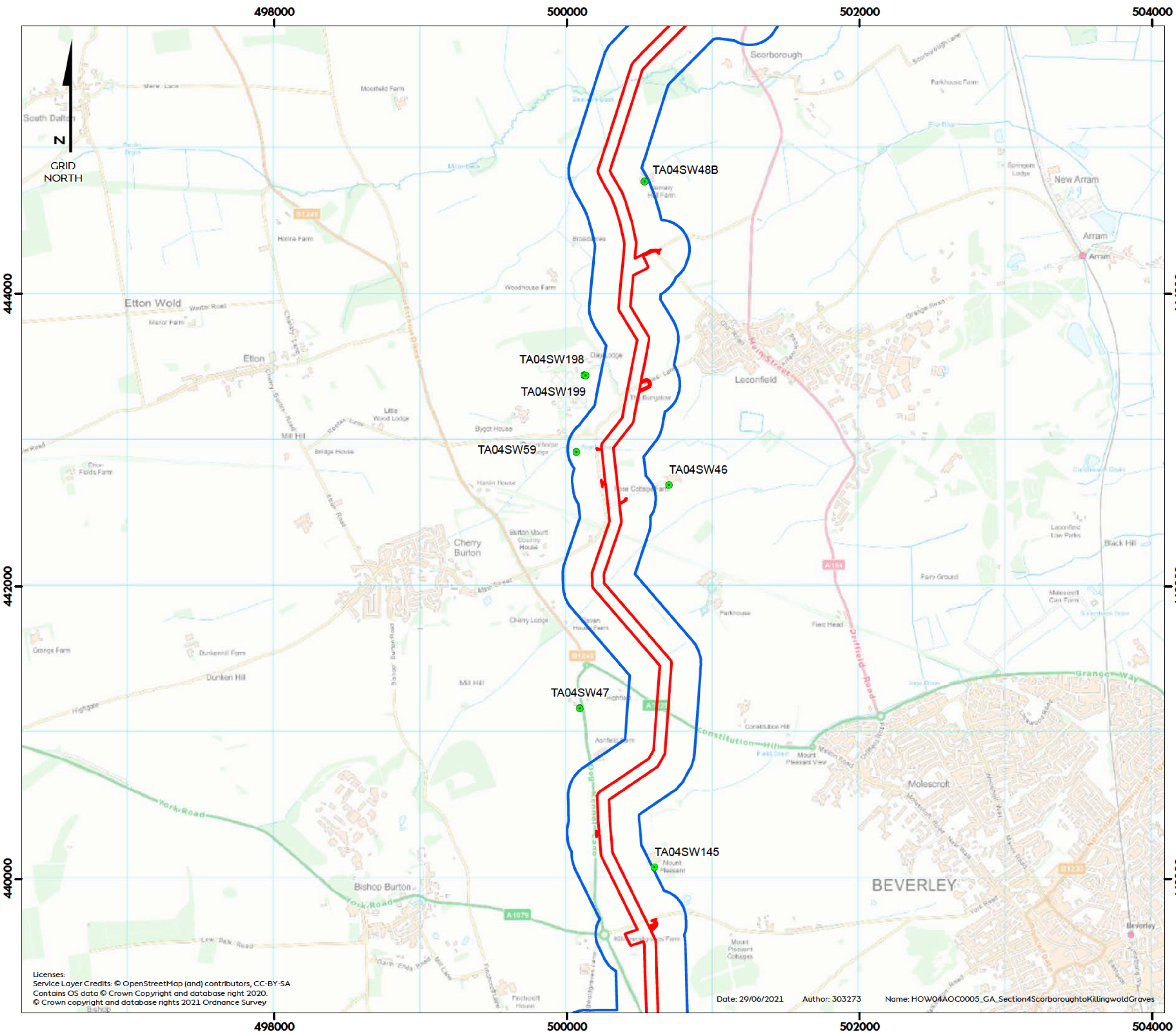
Hornsea Four

Figure 5

Section 4: Scorborough to Killingwoldgraves



Date: 29/06/2021 Author: 303273 Name: HOW04AOC0005_GA_Section4ScorboroughtoKillingwoldGraves

Order Limits

200m Study Area

BGS Boreholes

Coordinate system: British National Grid

Scale@A3: 1:25,000

0 0.25 0.5 1 Kilometres

0 250 500 1,000 Yards

REV	REMARK	DATE
	First Issue For PEIR	20/06/2019
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Title: Section 4 Scorborough to Killingwoldgraves
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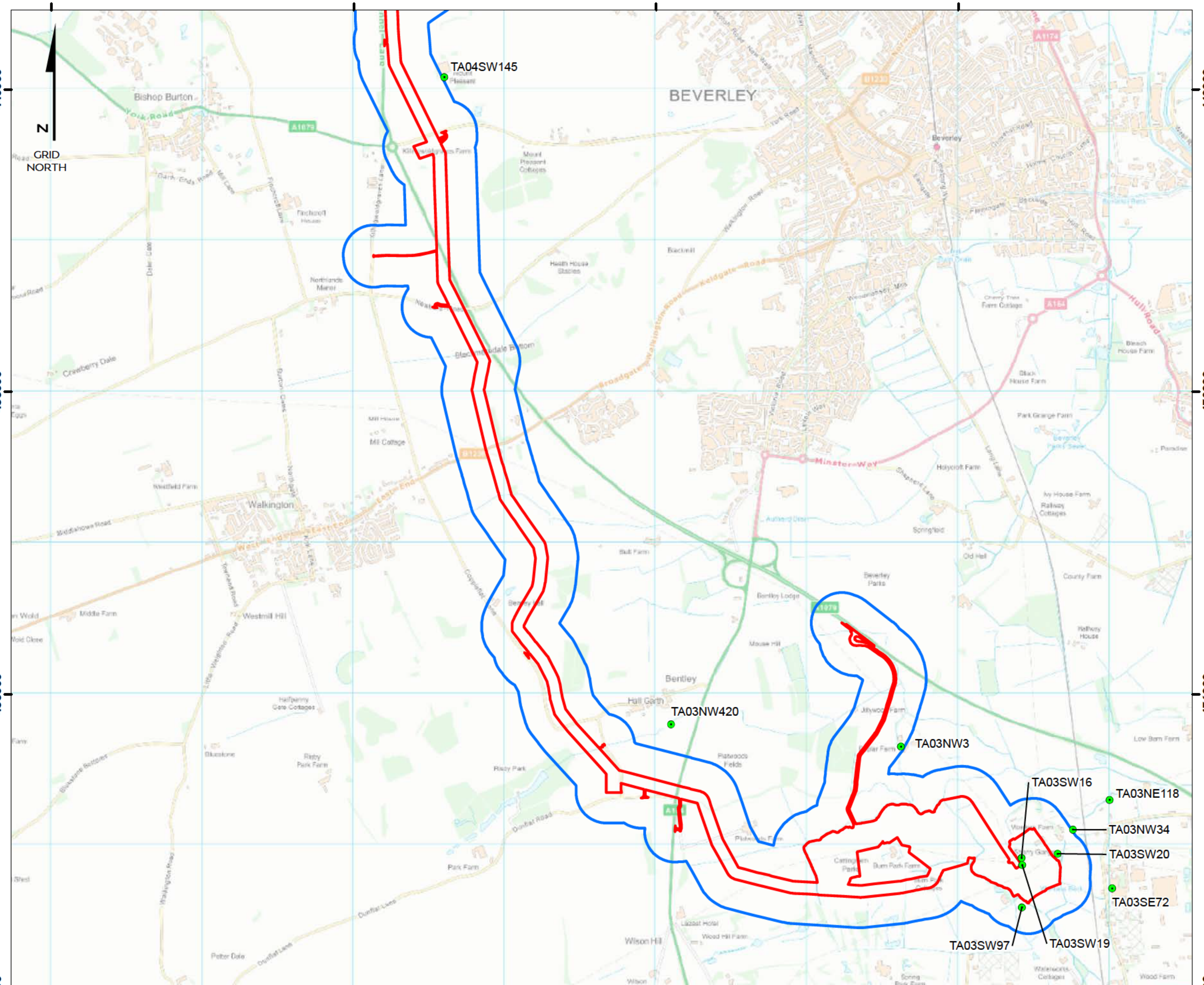

Date: 29/06/2021 Author: 303273 Name: HOW04AOC0006_GA_Section5KillingwoldgravestoCottingham

Hornsea Four

Figure 6

Section 5: Killingwoldgraves to Cottingham

- Order Limits
- 200m Study Area
- BGS Boreholes

Coordinate system: British National Grid
Scale@A3: 1:25,000

0 0.25 0.5 1 Kilometres

0 250 500 1,000 Yards

REV	REMARK	DATE
	First Issue For PEIR	20/06/2019
A	Updated following PEIR consultations, for DCO	29/06/2021

Title: Section 5 Killingwoldgraves to Cottingham
Document no: HOW04AOC0006
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Checked by: LR
Approved by: RHDHV

3.4 Palaeoenvironmental overview

3.4.1.1 During the latter stages of the last (Devensian) Ice Age, the Hull Valley and Holderness were covered by an ice lobe (North Sea Lobe) extending down the eastern margins of the North Sea Basin as far as North Norfolk, depositing extensive till and glaciofluvial sands and gravels across the region. During the colder Pleistocene periods, global sea levels were substantially lower than today and the study area occupied part of an important location on the western margins of 'Doggerland' now submerged beneath the southern North Sea, but which formerly linked the Humber to Denmark (Gaffney et al. 2007). Following the final retreat of the ice sheet (<13 ka BC), there was a rapid incision of the river valleys down to contemporary sea-level, creating steep sided valleys up to 9 m deep (Van de Noort 2000) now largely infilled with Holocene sediment. Large numbers of lakes formed in depressions left in the till (kettle-holes and pingos), where a significant number contain Late Glacial deposits of palaeoenvironmental importance. Palaeoenvironmental records within the 10 km study area are discussed below followed by a review of the implications of these records for an understanding of past environment of Hornsea Four.

3.4.1.2 Skipsea Withow Gap within the 10 km study area, located approximately 2 km south of the Landfall Connection Works has been the subject of several paleoenvironmental investigations (Gilbertson 1984a, Flenley 1987). Deposits from within the former mere have been dated to 10,710±70 BP to c. 4,500 ± BP at the top of the peat sequence. The peat sequence is overlain by clay silts and sandy silts thought to be of colluvial origin. Thermophilious plants and molluscs characterised the early part of the pollen record being replaced by a sedge-grass tundra with strands of birch. By 7,000 BP the landscape was dominated by alder, elm, oak and lime with the mere becoming increasingly infilled with sediment enabling fen and fen carr to encroach on the peat surface by 5,000 BP. The paleoenvironmental record at Gransmoor (**Figure 2**) to the west of the onshore ECC in Section 1 provides a record spanning the LGM and Holocene and is comparable to the record at Skipsea Withow Gap. A juniper phase existed c. 12,400-12,500 BP followed by the arrival of birch as temperatures warmed (Walker et al. 1993). The Gransmoor sequence expresses a greater importance of lime-dominated wildland in the mid-Holocene in contrast to other sites (Beckett 1975) reflecting both localised variations in conditions as well as wider regional trends such as the elm decline which was dated to 4,030-3,783 cal BC and thus comparable to other sites in northern Britain.

3.4.1.3 Peat deposits at Barmston within the 10 km study area south of the onshore ECC in Section 1 (**Figure 2**) have been preserved beneath c. 1 m of colluvium. The deposits developed in a small basin and have been dated to 2,960±150 BP and 2,890±150 BP. The pollen diagram at Barmston is sparser than at other nearby sites but suggests a local fen carr landscape with human exploitation and deforestation in the Middle Bronze Age and Iron Age (Fletcher and Van de Noort 2007). Further work undertaken at Barmston by Humber Archaeology (Brigham and Jobling 2015) has revealed birch pollen in cores extracted below 3.1 m bgl; although the sequence as a whole could not be dated.

3.4.1.4 Research in the River Hull floodplain has identified basal peats within a palaeochannel sequence at Copper Hall, Skerne (**Figure 3**) within the 10 km study area approximately 1 km west of the onshore ECC in Section 2. Analysis of two samples from the base of these deposits revealed a pollen taxa characteristic of the late glacial and indicative of Holocene biogenic sedimentation in the channel between 12,000-9,000 BP. South of Copper Hall, within the Nafferton drainage sequences at Corpslanding (**Figure 3**), the pollen taxa is indicative of a later date of the onset of sedimentation between 9,000 and 7,000 BP (Lillie and Geary 2000).

3.4.1.5 Palynological investigations at Brandesburton within the east of the 10 km study area in Section 3 were undertaken following finds of a Maglemosian harpoon (Van de Noort and Ellis 1995). The pollen diagram from this site is low resolution and focuses on organic material within the sequence. It is interpreted as representative of the Late Glacial, Post Glacial, Atlantic, Sub-boreal and modern periods. During the Late Glacial, birch is the dominant tree taxa accompanied by abundant herbaceous plants such as grasses and sedges. The Post Glacial begins with a dominance of birch, giving way to an expansion of pine and hazel in low frequencies. The Atlantic period is characterised by a sharp rise in alder. Higher up the sequence is a mixed oak forest taxa followed by pollen types associated with deforestation and animal husbandry with modern taxa represented in the final 20 cm of the record (Clark and Godwin 1957). Although the palynological sequence remains undated, this study indicates the potential for recovery of palynological sequences within the 10 km study area and thus indicates the potential for waterlogged deposits within Section 3 to preserve palaeoenvironmental deposits of interest.

3.4.1.6 Routh Quarry falls within the 10 km study area to the east of the onshore ECC in Section 4. Extensive gravel and sand deposits underlying the organic sequence at Routh indicate glacio-fluvial activity at the end of the Devensian glaciation (Geary 2008). The site at Routh is therefore thought to represent a kettle hole similar to the site at Gransmoor (**Figure 2**). The pollen record indicates vegetation typical of late glacial Interstadial sequences from this area, with an initial phase of birch-willow scrub with open grassland including herbs typical of disturbed soils (e.g. Beckett 1981; Day 1996). A radiocarbon date of 12,595±80 BP from 2.58 m depth indicates that initial organic sedimentation occurred around the time of the thermal maximum. Birch percentage at Routh are lower than those recorded at Gransmoor (Walker et al. 1993) and further north at Star Carr (Day 1996) but are considered sufficient to reflect a local presence of birch. This was followed by a subsequent rise and decline in Juniper followed by an increase in birch characteristic of the late glacial. The transition to the Holocene is not clearly resolved in the pollen record from Routh but appears to be defined by an increase in birch and pine. The vegetational sequence continues throughout the Holocene with a notable elm decline at 3,465±50 BP (Griffiths and Geary, 2017).

3.4.1.7 Palaeoecological studies carried out at Skipsea Withow Mere, (Gilbertson et al. 1984), Barmston Mere (Dinnin and Lillie 1995; Brigham and Jobling 2015) and Brandesburton (Van de Noort and Ellis. 1995) in Holderness and at Routh Quarry (Geary 2008) and Gransmoor Quarry (Walker et al. 1993) in the Hull valley have provided key information about late glacial environments across the 10 km study area. Studies from Roos Bog Holderness (Beckett 1981), Starr Carr in the Vale of Pickering (Day 1996; Dark 1998; Taylor et al. 2018; Taylor and Allison 2018); Cove Farm Quarry in the Humberhead levels (Bateman et al. 2001) lie beyond the 10 km study area but do provide important data for the understanding of past environments of Hornsea Four and in particular in providing dated continuous sequences which are largely absent from the Hull valley palynological record (Van de Noort et al. 2000). These pollen records have allowed the development of the post-glacial environment in the area to be reconstructed as a series of 'Regional Pollen Assemblage Zones' (Beckett 1981) and tentatively dated (Flenley 1991; Lillie and Geary 2000).

3.4.1.8 The earliest late glacial pollen records date from c. 13,000-12,400 BP and indicate an open landscape with few trees of birch, willow and juniper. Between 12,000 and 11,000 BP an expansion of birch woodland is evident although discrepancies between the records from Gransmoor (Walker et al. 1993) and Roos Bog (Beckett 1981) indicate local climatic variations. Between 11,000 and 10,200 BP the pollen records form Roos Bog, Gransmoor and Star Carr all indicate deterioration in climate evidenced by a decrease in tree species and an increase in open ground conditions with herbs suggestive of unleached and calcium-rich soils (e.g. Helianthemum), and woody taxa limited to isolated patches of birch or hazel scrub (Lillie and Geary 2000).

3.4.1.9 Birch and Scots Pine dominated the area as the tundra-like conditions of the Loch Lomond Interstadial gave way to the early Holocene, with probably smaller areas of juniper and willow between 10,200-9,500 BP. As the climate ameliorated further, hazel and elm began to dominate around 9,500-9,000 BP, with alder also increasing, and ash, lime and oak also appearing, beginning to shade out hazel and some of the other 'pioneer' species (Lillie and Geary 2000).

3.4.1.10 Large-scale clearance of woodlands on the dry ground did not happen until the later Bronze Age and Iron Age by which time much of the Hull valley was dominated by eutrophic wetlands with transgression and encroachment of intertidal events. Alder dominated the marginal wetlands forming carr woodland, while pine and lime were more prevalent on free-draining soils. Following the elm decline (c. 3,800 cal BC), oak, hazel and lime dominated within woodlands until large-scale clearance from 1,000 cal BC (Van de Noort and Ellis. 1995). Although the earliest evidence for woodland clearance dates to c. 4,000 cal BC, these are typically small-scale and impermanent and are reflected in the archaeological record by evidence of temporary seasonal activity in the form of Mesolithic and Neolithic flint scatters. Investigations at Routh Quarry have shown that Mesolithic groups were exploiting the rich riparian environments of the region in a landscape that exhibited a mixed range of vegetation types (Lillie and Geary 2000).

3.4.1.11 Records of late Holocene environmental change within the palynological record are constrained due to the effects of post-medieval drainage, arable exploitation and urban and industrial development. Sea-level rise continued until c. 500 BC, followed by drier conditions and a phase of marine regression during the late Iron Age and Romano-British period. Palynological data are sparse for the Iron Age and Romano-British periods.

3.4.1.12 The landscape of the Hornsea Four Order Limits went through a transformation over the course of the post-medieval period, largely as a result of extensive drainage schemes (Shephard 1976) gradually reducing the impact and frequency of flooding in the lower lying carrs. Where previously these carrs had been underwater for much of the year, by the mid-19th century they were largely dry (Shephard 1976). The move to enclosure also effected a substantial change in the Hull Valley. It signified a shift away from the communal, open field methods of the medieval period and reflects an intensification of agriculture during this period.

4 Discussion and Conclusion

4.1.1.1 Review of geological and palaeoenvironmental data have revealed that the Hornsea Four Order Limits are located within an area rich in evidence for landscape evolution from the Quaternary and Holocene periods.

4.1.1.2 Abundant wetlands and lakes existed in the 200 m study area from post-Devensian to medieval times and were likely formed in the original depressions in the till (Gilbertson et al. 1984). Subsequent sediment accretion in the late glacial and Holocene has likely masked many earlier archaeological sites. Drainage of the wetlands in the 18th and 19th centuries has resulted in desiccation and deterioration of many shallower former peat deposits although deeper sequences in former paleochannels and deeper kettle holes have been shown to retain higher palaeoenvironmental potential. Sediment accretion caused by warping (controlled flooding of land to increase fertility) may also have preserved earlier deposits along some areas of the onshore ECC as demonstrated by fine grained warp deposits identified at Corpslanding. It is possible that further such deposits exist and mask earlier sequences in other sections of the onshore ECC and OnSS. **Table 1** summarises the geoarchaeological and paleoenvironmental potential of Hornsea Four based on this desktop review.

Table 1: Summary of geoarchaeological and palaeoenvironmental potential.

Section	Summary of Geoarchaeological and Palaeoenvironmental Potential	Potential
1	The north-east of the onshore ECC is located within an area known to contain preserved alluvial deposits associated with the Earl's Dike and also lies close to the northern margin of the infilled Barmston Mere. Possible palaeochannel at Lissett Bridge.	High
2	Sand and gravel deposits in the vicinity of Foston-on-the Wolds are indicative of better drained areas within Watton Carrs which may have been attractive for past settlement. Intra till glaciofluvial deposits identified at Rotsea. Alluvial deposits, palaeochannels and warp deposits known at Nafferton Drain and in the valley of River Hull near Skerne.	High
3	Laminated clays identified in a borehole at Throstle Nest potentially represent lake deposits. Possible alluvial deposits associated with Bryan Mills Beck.	Moderate
4	Superficial deposits in boreholes of dominantly clay and glaciofluvial and gravels overlying bedrock. No known	Moderate

Section	Summary of Geoarchaeological and Palaeoenvironmental Potential	Potential
	palaeoenvironmental data. Glaciofluvial sands from possible river terrace deposits associated with River Hull and fluvial deposition.	
5	Superficial deposits in boreholes of dominantly clay and glaciofluvial and gravels overlying bedrock. No known palaeoenvironmental data. Glaciofluvial sands from possible river terrace deposits associated with River Hull and fluvial deposition	Moderate

4.1.1.3 The quality and preservation of the waterlogged and paleoenvironmental resource along the Hornsea Four Order Limits reflect recent changes in landscape with only pockets of well-preserved sediments where once extensive carr land would have preserved prehistoric landscapes.

4.1.1.4 Analysis of cropmarks with reference to soils and geology is beyond the scope of this assessment and is reviewed by Chapman (2000, 180), and specifically for Hornsea Four (see **Annex 5.2: Aerial Photographic and Lidar Assessment Technical Report**). However, there is unsurprisingly often a correlation between cropmarks and areas of better drained sands and gravels. This leads inevitably to bias in the archaeological record with areas of deeper alluvium being less well represented in the archaeological record as they are less conducive to the formation of crop marks. Similarly, a review of links between material culture and changing landscapes is beyond the scope of this study but a recent review undertaken by Halkon and Innes (2017) highlights the importance of understanding changing landscapes when interpreting the archaeological record. These points are considered within **Volume A3, Chapter 5: Historic Environment**.

4.1.1.5 Monitoring or review of geotechnical test pit records for Hornsea Four will provide further details regarding the nature of deposits and allow for targeted mitigation proposals. This work is anticipated to be undertaken alongside an engineering-led programme of Ground Investigation (GI) works which are to be undertaken post-consent. Palaeoenvironmental sampling and investigation where preservation of deposits allows will provide a more detailed account of the context in which any archaeological material was deposited and within which human activity took place along Hornsea Four Order Limits. Of particular relevance to the palaeoenvironmental record is establishing a more secure Holocene sequence.

4.1.1.6 It is clear from the evidence reviewed that the environments forming along Hornsea Four changed throughout the time that people inhabited this landscape. An integration of the geoarchaeological and paleoenvironmental data is key to understanding the pattern of archaeological survival and informing the likely significant effects of Hornsea Four (see **Volume A3, Chapter 5: Historic Environment**).

4.1.1.7 The results of this Geoarchaeological DBA have been utilised to inform and support the Environmental Statement (**Volume A3, Chapter 5: Historic Environment**). A post-consent approach to geoarchaeology and the palaeoenvironment will be formulated in the post-consent/pre-construction phases for approval by ERYC, in consultation with HAP (and HE, as required), and subsequently implemented (**Volume 2, Chapter 10: Outline Written Scheme of Investigation for Onshore Archaeology**).

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Appendix A: Landfall Site Investigations Watching Brief Report

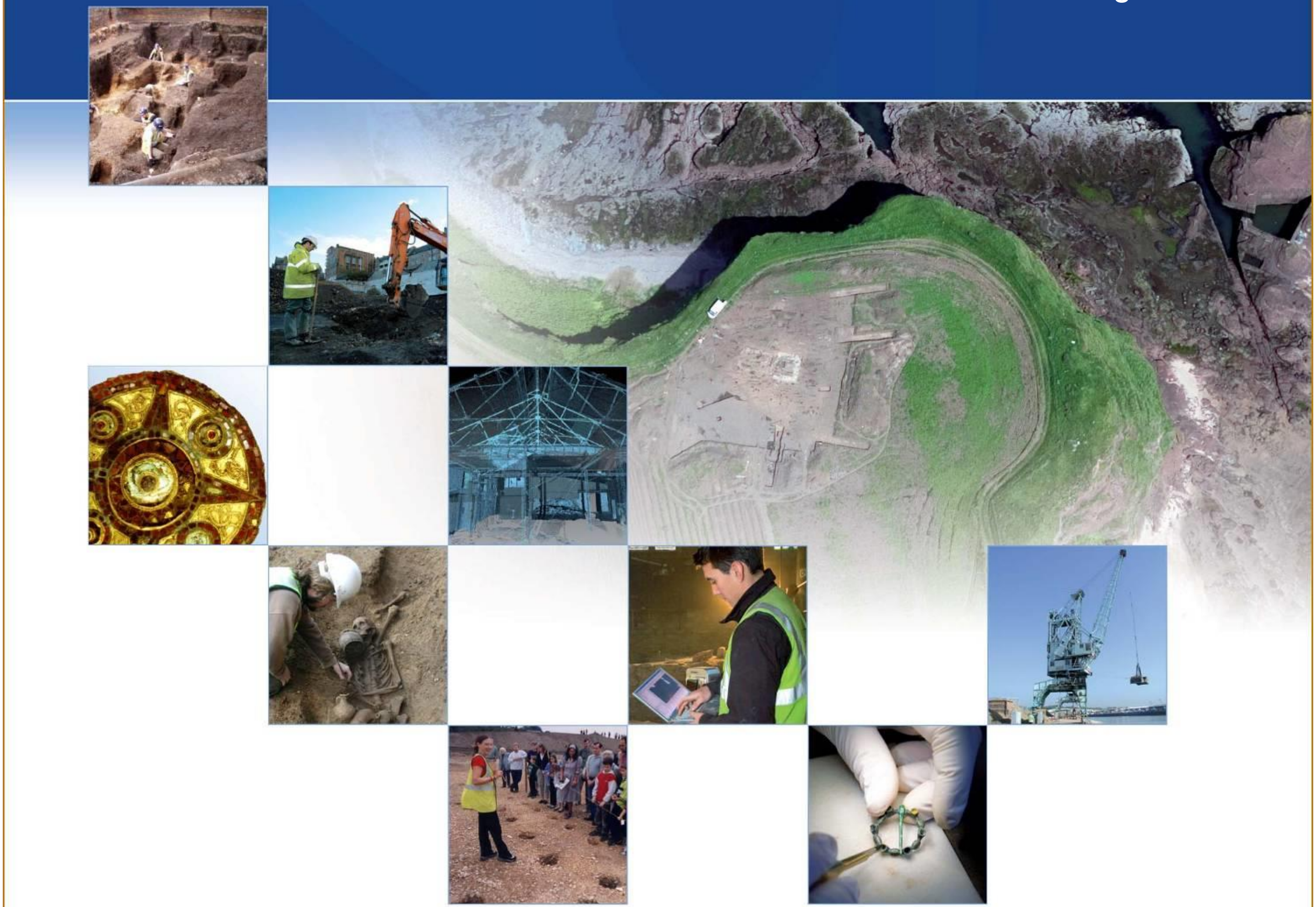
Hornsea Four
Offshore Wind Farm

Geoarchaeological Watching Brief Report

National Grid Reference: TA 1676 6108 (centre)

AOC Project No: 53010

August 2021



AOC Archaeology Group

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Hornsea Four Offshore Wind Farm

Geoarchaeological Watching Brief Report

Surveyed and Prepared for:	**Royal HaskoningDHV** **2 Abbey Gardens** **Great College Street** **Westminster** **London** **SW1P 3NL**
National Grid Reference (NGR):	**TA 1676 6108 (centre)**
AOC Project No:	**53010**
Fieldwork:	**Kim Hosking And Lynne Roy**
Prepared by:	**Lynne Roy**
Illustrations by:	**Lynne Roy**
Date:	**August 2021**

This document has been prepared in accordance with AOC standard operating procedures.

Author: Lynne Roy	**Date: 6 July 2021**
Revised in accordance with the client's comments	**Date: 3 August 2021**
Approved by: Stephen Potten	**Date: 3 August 2021**
Report Stage: Final Draft	**Date: 3 August 2021**

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Non-Technical Summary

AOC Archaeology Group was commissioned by Royal HaskoningDHV on behalf of Orsted Hornsea Project Four Limited Ltd to undertake a programme of geoarchaeological works within the Landfall Connection during the implementation of Geotechnical Investigation Works. These works form part of a broader programme of archaeological works within the Landfall Connection and follow a geophysical survey of the Site (**Volume A6, Annex 5.3: Priority Archaeological Geophysical Survey**) and a geoarchaeological desk-based assessment (**Volume A6, Annex 5.4: Geoarchaeological Desk Based Assessment**). The works were monitored and recorded by a team of geoarchaeologists and aimed to establish the presence / absence, character, and extent of any archaeological or palaeoecological deposits.

The Landfall is centred at NGR: TA 1676 6108 and located within the local authority area of East Riding of Yorkshire Council. The Site is located south of Earl's Dike at Barmston Sands and Watermill Grounds approximately 1.5 km north-east of Barmston and approximately 1.2 km south-east of Fraisthorpe. The west of the Site is currently in use as arable land, the east of the Site comprises a sandy beach with low cliffs of boulder clay.

The results of the borehole monitoring alongside reviews of other nearby geotechnical works have been used to create a series of Projected Profiles across the Site and to the south of the Site showing the main deposits encountered. These have been used to further discuss and understand the geoarchaeological and palaeoenvironmental potential of the Site.

The north of the site contains thin alluvial deposits of likely Holocene date and relating to the Earl's Dike. No evidence for organic horizons was located within these deposits. The Site is underlain by glaciofluvial sand and gravel deposits of Pleistocene date. The glaciofluvial sands and gravels are underlain by diamicton glacial till of Pleistocene date which also contain occasional lenses of sand and gravel. The Tertiary Rowe Chalk formation was encountered in all four boreholes at depths of between 19.25 m and 24.5 m below the ground surface.

Direct evidence for buried wetland deposits and associated palaeoenvironmental evidence appears to be absent from the Site. However, prior to drainage of the landscape in the 19h century the sands and gravels identified within the Site would have formed important relatively free draining area of land in an otherwise wetland landscape. This is reflected in evidence for later prehistoric activity within the Site and it is likely that these drier sand and gravel rich areas in the Site would have proved an attractive base for occupation and for exploiting surrounding wetland areas from the start of the Holocene.

1 Introduction

1.1 AOC Archaeology Group undertook a programme of geoarchaeological works and have prepared this report for Royal HaskoningDHV on behalf of Orsted Hornsea Project Four Limited Ltd (hereafter the 'Applicant'). It details the results of a geoarchaeological watching brief at the Landfall Connection undertaken during Geotechnical Investigation works. These works form part of a broader programme of archaeological works within the Landfall Connection (hereafter 'the Landfall Search Area') and follow a geophysical survey of the Landfall Search Area (as detailed in **Volume A6, Annex 5.3: Priority Archaeological Geophysical Survey**) and a geoarchaeological desk-based assessment (as detailed in **Volume A6, Annex 5.4: Geoarchaeological Desk Based Assessment**). The works were monitored and recorded by a team of geoarchaeologists in order to establish the presence / absence, character, and extent of any archaeological or palaeoecological deposits within the Landfall Search Area, supplementing the information gained through desk-based review (**Volume A6, Annex 5.4: Geoarchaeological Desk Based Assessment**).

1.2 The geoarchaeological monitoring and reporting of the Ground Investigation (GI) works were undertaken in accordance with a Written Scheme of Investigation (WSI) produced by AOC Archaeology (as detailed in Appendix A of **Volume A6, Annex 5.4: Geoarchaeological Desk Based Assessment**). The geoarchaeological works were managed to the standards laid down in the Historic England guideline publication *Management of Research Projects in the Historic Environment (MoRPHE): Project Managers Guide* (Historic England, 2015, hereafter HE). It also met the requirements of the National Planning Policy Framework (NPPF, 2019; Chapter 16: 'Conserving and enhancing the historic environment').

1.3 This report is Appendix B of **Volume A6, Annex 5.4: Geoarchaeological Desk Based Assessment**.

2 Site Location and Description

2.1 The Landfall is centred at NGR: TA 1676 6108 and located within the East Riding of Yorkshire (Figure 1). The Landfall Search Area is located south of Earl's Dike at Barmston Sands and Watermill Grounds, approximately 1.5 km north-east of Barmston and approximately 1.2 km south-east of Fraisthorpe. The west of the Landfall Search Area is currently in use as arable land, while the east comprises a sandy beach with low cliffs of boulder clay.

2.2 The Landfall Search Area is gently sloping lying at 8 m above Ordnance Datum (AOD) in the north of the Landfall Search Area, reducing via a gentle gradient through to 5 m AOD in the south. The Landfall Search Area also slopes eastwards towards Barmston Sands which lie at an elevation of 3 m AOD. A north-south aligned drainage dike runs through the centre of the Landfall Search Area and converges with Earl's Dike approximately 250 m north-west of the location of Borehole 1 (Figures 2-3). There is a slight depression in the land surface either side of this dike as shown on the topographic map presented in Figure 4.

2.3 The British Geological Survey (BGS) indicates that the Landfall Search Area has an underlying bedrock composed of the Rowe Chalk Formation. The Rowe Chalk is described in the BGS Lexicon as "white, flint-bearing chalk with sporadic marl bands" and formed approximately 66 to 84 million years ago (mya) in the Cretaceous Period, under a shallow warm sea environment (BGS 2021). This is overlain by a diamicton glacial till from the Devensian or the Last Glacial Maximum (LGM) (Usai 2005). Till is deposited by glacial ice, either at the glacier base or derived from material within and on the ice. It comprises gravelly sandy silty clay with boulders and contains numerous lenses of sand and gravel. The till is also likely to contain interdigitating units of glaciolacustrine clay, plus sand and gravel formed during ice advance and retreat (Burke et al., 2015, 30). Superficial deposits comprising fluvio glacial sand and gravels of Devensian date are mapped by BGS in the centre of the Landfall Search Area (Figure 4). Extensive gravel and sand deposits underlying the organic sequence at Routh Quarry south-west of the Landfall Search Area indicate glaciofluvial activity occurred in the region at the end of the Devensian glaciation (Geary, 2008). Deposits of Alluvium are mapped in the north and west of the Landfall Search Area in the vicinity of Earl's Dike and are likely of post-glacial Holocene date. Head et al (1995, 229) note that the BGS (1985) records a large spread of alluvium south of Earl's Dike centred around Sand Road. However, coring undertaken within the Landfall Search Area as part of the Humber Wetland Project identified a sandy and gravel parent material suggesting that this area has been erroneously mapped and that a map of 1885 which shows it as sands and gravel is more accurate. As shown on Figure 4, with the exception of Borehole 4 the geotechnical works within the Landfall Search Area were all located within areas mapped as glaciofluvial deposits. In the east of the Landfall Search Area along Barmston Sand Marine Beach Deposits are recorded (BGS 2021).

2.4 The Landfall Search Area is located on the wider Holderness coastal plain which experiences high cliff erosion and retreat rates, largely due to the geological composition of the cliff material (glacial tills overlain with sands), which is readily eroded by direct wave action.

2.5 The Earl's Dike is a canalised drain running along the north boundary of the Landfall Search Area and discharging into the sea (Plate 1). The line of the modern Earl's Dike although canalised roughly follows the line of a natural drainage channel and associated natural valley.

Plate 1: Mouth of Earl's Dike from east

2.6 Soils in the Landfall Search Area are mapped by the Soil Survey of England And Wales (SSEAW 1984) as part of the Wick 1 Association which comprise deep, well drained coarse loamy brown earth soils overlying glaciofluvial and terrace drift. The soils are relatively free draining due to the high sand and gravel content of the underlying material and thus consequently they have a limited potential for wetland preservation (Head et al 1995).

3 Geoarchaeological Background

3.1 The character and distribution of past human activity can be better understood through the consideration of the past landscape or environmental context. The topography and nature of the ancient land surface during the early Holocene, the current geological epoch and equivalent to the early Mesolithic (c. 11,500 BP or 10,000 BC), is dictated by and inferred from the surface of the

Pleistocene superficial deposits (the previous epoch) and older solid geology (e.g. gravel or chalk). Overlying the Pleistocene - or older - deposits, Holocene deposits may preserve palaeoenvironmental evidence (e.g. pollen, diatoms, ostracods) of landscape development, from local channel migration and vegetation change to regional effects of climate and relative sea level change. In combination, preservation of palaeoenvironmental remains and deposit data (e.g. depth and character) provide a comparative framework to assess archaeological potential. Peat represents vegetated and waterlogged landscapes (e.g. marshland) which developed within local or regional fluctuations of hydrology. The anaerobic and acidic conditions of the deposit are particularly conducive to organic preservation. Palaeoenvironmental remains from floodplain deposits, especially peat, provide information on the nature and timing of environmental change and the interplay with past human activity (HE 2015a, 2015b).

3.2 During the latter stages of the last (Devensian) Ice Age, Holderness was covered by an ice lobe (North Sea Lobe) extending down the eastern margins of the North Sea Basin as far as North Norfolk, depositing extensive till and glaciofluvial sands and gravels across the region. During the colder Pleistocene periods, global sea levels were substantially lower than today and the Study Area occupied part of an important location on the western margins of 'Doggerland' now submerged beneath the southern North Sea but which formerly linked the Humber to Denmark (Gaffney *et al*., 2007). Following the final retreat of the ice sheet (<13 ka BC), there was a rapid incision of the river valleys down to contemporary sea-level, creating steep sided valleys up to 9 m deep (Van de Noort, 2000) now largely infilled with Holocene sediment. Large numbers of lakes formed in depressions left in the till (kettle holes and pingos), and a significant number survive and contain Late Glacial deposits of palaeoenvironmental importance.

3.3 The Earl's Dike valley was investigated as part of the Humber Wetlands Project. The survey found the valley to be less than 30 m across and infilled with approximately 2 m of inorganic alluvium which was likely deposited since c. 1260 cal BC when water courses in the areas would have been aggrading in response to sea level reaching OD and/or following forest clearance. The peaty topsoil encountered in this valley indicated that prior to modern land drainage the valley bottom was waterlogged and thus may retain paleoenvironmental potential (Head et al 1995, 229). A survey of the mouth of Earl's Dike undertaken as part of the Rapid Coastal Zone Assessment (RCZA) Survey by Brigham and Jobling (2013, 14) recorded no traces of a potential former mere or settlement remains within this area.

3.4 Coring undertaken at Barmston Low Ground south of the Landfall Search Area as part of the Humber Wetlands Project revealed a complex stratigraphic sequence which documented periods of lacustrine alluvial deposition following the formation of Barmston Mere after the LGM followed by wind-blow sand deposition. Drainage and ploughing have probably destroyed many of the Holocene organic sediments which would have accumulated at the shallower margins of the mere (Dinnin and Lillie, 1995). An additional coring transect was undertaken by Humber Archaeology in 2013 through Barmston Mere south of the Landfall Search Area. A plan of the mere drawn from ground survey during an earlier phase of works was also amended using LIDAR and aerial photographic images and showed it to extend further north than previously thought (Brigham and Jobling, 2015). The coring allowed for the creation of a new profile of Barmston Mere, revealing a sequence of post-glacial lacustrine deposition. The boreholes passed through a sequence of lacustrine alluvial silts at least 7 m bgl (–2.74 m AOD). A perched water table was encountered close to the ground level. Several boreholes closest to both edges of the mere (BH1–2 and BH6–10) reached an indurated gravel surface which in several instances was impenetrable. The sequence above this included sand and gravel which in some instances formed discrete layers, in others it formed bands within the lower alluvium. Previous excavations at Barmston by Varley (1968) and Humber Wetlands Project (Fletcher & Van de Noort,

2007) had revealed peat deposits and traces of Bronze Age settlement, but these were not encountered within the 2013 boreholes (Brigham and Jobling, 2015).

3.5 Palaeoecological studies carried out at Skipsea Withow Mere, (Gilbertson *et al*., 1984), Barmston Mere (Dinnin and Lillie, 1995; Brigham and Jobling, 2015) and Brandesburton (Van de Noort and Ellis., 1995) in Holderness and at Routh Quarry (Geary, 2008) and Gransmoor Quarry (Walker *et al*., 1993) in the Hull Valley have provided key information about late glacial environments. Studies from Roos Bog Holderness (Beckett, 1981), Star Carr in the Vale of Pickering (Day, 1996; Dark, 1998; Taylor *et al*., 2018; Taylor and Allison, 2018) provide important data for the understanding of past environments in the wider area and in particular provide dated continuous sequences which are largely absent from the Hull Valley palynological record (Van de Noort *et al*., 2000). These pollen records have allowed the development of the post-glacial environment in the area to be reconstructed as a series of 'Regional Pollen Assemblage Zones' (Beckett, 1981) and tentatively dated (Flenley, 1991; Lillie and Geary, 2000).

3.6 Evidence of occupation from as early as the Mesolithic has been recovered from the area of Holderness including Brandesburton, Hornsea, Gransmoor and Skipsea in the form of barbed points of bone and antler and a Mesolithic blade core found during fieldwalking at Ulrome (Brigham *et.al.* 2008, 62). Elk antler is reported as having been found on the beach in 1837 and a harpoon was found at the mouth of Earl's Dyke (Van de Noort et al 1995, 359). It is possible that occupation of the lower areas of the Humber Wetlands was intermittent prior to the post-medieval period due to the nature of the wetland environment and the rise and fall in sea level, and therefore settlements of medieval or earlier date would often be situated on slightly higher ground. However, periods of low sea level allowed regular cultivation and exploitation of this resource-rich environment which can be seen from previous finds of tools and pottery. Palaeoenvironmental survey undertaken as part of the Humber Wetlands Project indicated that some of the wetlands dried out during the Mesolithic period (Van de Noort et. al., 1995: 359) allowing for a wider range of land use, and woodland clearance during the Bronze Age indicates a shift towards agriculture (ibid).

3.7 The Humber Wetlands Project divided land into field/parcel numbers which are shown on accompanying maps within the Humber Wetland Survey report (ibid, Figures 10.29 and 10.30). Parcel numbers are prefixed by the name of the survey area to which they relate, for example Barmston 16-25 and Skipsea 63, as referenced in the text below. Fieldwalking within and around the Landfall Search Area as part of the Humber Wetland Project revealed numerous concentrations of flint artefacts. The artefacts totalled 27 individual worked flints flakes or scrapers (Barmston 16-25), most were plough damaged and of uncertain date. One blade-like flint collected from 20m south of Earl's Dike near to the top of the cliff was hypothesised as Neolithic. A large settlement and square ditch barrows recorded from aerial photography are located within Watermill Grounds. In addition, finds of waterlogged wooden artefacts and objects such as quernstones, along with Middle Bronze Age settlement at Barmston (Skipsea 63) (Head et al 1995) and the Middle Bronze Age / Iron Age 'lake dwelling' at Round Hill near Ulrome suggest that occupation of the area was fairly continuous throughout the prehistoric period (Brigham *et.al.* 2008, 63).

3.8 Roman occupation of the area is known from various finds including varied finds from the cliff and beach at Ulrome (Brigham *et. al*., 2008: 63).

3.9 Environmental evidence shows that occupation of the area during the early medieval period declined and the area was recolonised in the later medieval period with structures such as the motte and bailey castle at Skipsea and religious houses such as Meaux Abbey and Watton Priory being constructed (Van de Noort, 2004:129). Moated sites, mainly constructed between 1250 and 1350 are also quite common in the Holderness regions (*ibid*: 148). During the late medieval period, a worsening climate (known as the 'Little Ice Age') and poor rural economic stability, along with outbreaks of the Bubonic Plague, reduced the quantity and quality of grain production, leading to land being given over to pasture and encouraging peasant migration to urban centres. Deserted settlements are relatively common within the region, including those found at Hartburn (Fraisthorpe) and Winkton (Barmston).

3.10 Coastal erosion in the vicinity of the Landfall Search Area has been recorded for many years. The underlying Diamicton Devensian till typically consists of about 72% mud/silt, 27% sand and 1% boulders and large pebbles (Catt & Penny, 1966; Madgett & Catt, 1978). The till has very little resistance to erosion, especially when wet. Within and overlying the till are beds and pockets of sands and gravels as well as small and occasionally larger boulders, or ‘erratics’. This loosely consolidated material is easily eroded by the action of waves, falling into the sea in repeated landslip activity/cliff failure mechanisms. The loss of a house in the village of Auburn is recorded in 1570. In 1636 there were ten houses in the village of Auburn but by 1731 this had fallen to only three and by 1823 there was only the one farmhouse remaining. The original church at Auburn was known as St Nicholas and was built in the 12th century, however this was lost to the sea and was re-built inland sometime between 1590 and 1605.

3.11 Large-scale drainage of the area was undertaken during the post-medieval period and by the nineteenth century, with the construction of drains such as the Holderness Drain and the Beverley-Barmston Drain along with the floodwarping of fields, the area was successfully transformed from wetland into farmland (Van de Noort 2004, 160). Floodwarping involved enclosing the fields within embankments and allowing flooding of the field over several years in order to deposit silt and raise the level of the land to reduce the flood risk (Shephard, 1976). Drainage and ploughing within the Landfall Search Area in the post medieval and modern periods resulted in changing water regimes and likely desiccation of Holocene organic deposits.

3.12 A large number of World War II pillboxes, anti-tank defences, searchlight batteries, observation posts and other military installations and structures are common along the Holderness coast. This includes the Royal Observer Corps underground monitoring post at Skipsea and two pill boxes within the Landfall Search Area.

Previous works

3.13 Archaeological excavations undertaken in advance of the Fraisthorpe Wind Farm north of the Landfall Search Area recorded a dark brown silty clay topsoil with organic inclusions 0.20-0.35m in depth. Subsoil was recorded to vary in thickness across the Landfall Search Area with slightly thicker deposits recorded within three areas, in shallow bowl-shaped depressions. It was concluded that the increased depth was due to colluvium gradually filling up these basins over time. The natural substrate was described as consisting of a mixture of light-brown to yellow sandy clay with small stone inclusions, and yellow sandy gravel. (CFA 2016, 8-9). The programme of archaeological work undertaken at Fraisthorpe Wind Farm revealed a range of archaeological features surviving across the landscape. The majority of the features that contained dateable finds dated to the 3rd-5th centuries AD. No structural evidence was recorded at Fraisthorpe Wind Farm and it is likely that any surviving archaeology related to habitation lay beyond the extent of the development boundary (CFA 2016).

3.14 Ground investigation works undertaken by Structural Soils Limited in 2012 in association with proposed construction of the Humber CCS Pipeline included numerous geotechnical investigations south of the Landfall Search Area which have been included in the deposit model (see Section 7). Seven cable percussion boreholes (BH270 to BH279) south-east of the Landfall Search Area extended by rotary coring techniques to depths of between 22.70m and 35.50. All of the boreholes initially encountered topsoil, which varied in depth from 0.30 to 0.40m. Material thought likely to be glaciofluvial in origin was encountered in boreholes BH275 to BH279 to depths of between 1.10 m and 3.00 m. The glaciofluvial material generally became thicker towards the coast and varied from sandy clay (BH275) to sand (BH279) and sand over gravel (BH278). Gravelly clay considered to be glacial till was encountered underlying the topsoil in boreholes BH270 to BH274 and underlying the glaciofluvial deposits in boreholes BH275 to BH279. Beds of sand and or gravel were encountered within this horizon at various depths up to 3.20 m thick. A bed of granular material running through the Landfall Search Area with a top depth of between 7.80 m and 9.80 m was recorded. Weathered chalk was encountered at a depth of between 17.40 m and 20.7 0m underlying the till in boreholes BH270 to BH279.

4 Aims

4.1 The specific aims of the monitoring of geotechnical works within the Landfall Search Area were:

- to further understand geological changes across the Landfall Search Area;
- to better understand the varying depths of deposits present;
- to build a better understanding of the archaeological and geoarchaeological landscape;
- to prepare a fully illustrated report on the results of the geoarchaeological desk based review and the results of GI watching brief that is compliant with all relevant policy, guidance and good practice, and which is proportionate to the results, making recommendations for further assessment and analysis in a manner proportionate to the impact of the scheme; and
- to produce a site archive for deposition with an appropriate local museum service and to provide information for accession to the Humber Historic Environment Record (HHER).

5 Methodology

5.1 The geoarchaeological watching brief consisted of the monitoring of four boreholes. The locations of the boreholes (Figure 2) were designed to investigate the engineering and hydrological properties of sediments overlying the cretaceous bedrock.

5.2 Each borehole location was hand excavated to a depth of 1m prior to drilling. The hand excavation was monitored by the on-site geoarchaeologist. Geoarchaeological monitoring took place between 13th April 2021 and 30th April 2021. Monitoring of the borehole excavations ceased once it was judged by the geoarchaeologist that the base of the Holocene organic deposits had been reached and/or when the underlying glacial diamicton deposits were encountered.

5.3 An overview of the lithology and stratigraphic character of the Landfall Search Area was obtained from a review of upcast material and from the extracted the cores, and was used to identify formation processes and assess palaeoenvironmental / archaeological potential. Metadata for each borehole were entered on recording sheets including borehole number and date.

5.4 Descriptions followed standard geological criteria (Troels-Smith 1955; Tucker 2003) on pro-forma log sheets (Appendix 3).

5.5 A scale was placed beside each length of core and each core was then examined to identify the presence of any distinct layers or boundaries between deposits, so far as possible from the upcast and visible through the core casing. The depth of each deposit was recorded.

5.6 As a minimum all recording sheets contained:

- Borehole / ID Number
- Depth of each deposit and layer (m)

- Description of sediment/deposit characteristics.
- Sediment colour and boundary characteristics.

5.7 A digital photograph, containing an appropriate scale, was taken of each core, using a camera with a resolution of at least 10 megapixels. A digital photographic register was maintained.

5.8 Direct access to the boreholes and CPTs extracted for geotechnical investigations was not possible. The core samples were removed for testing by the geotechnical contractor and access was not possible for sub-sampling for archaeological / palaeoenvironmental purposes. Borehole logs were obtained from the contractor following completion of the survey and were reviewed and used to inform the deposit model.

5.9 The term 'deposit modelling' describes any method used to provide visual representations of the spatial and stratigraphic relationships between sediments; they provide an effective strategy for investigating the subsurface stratigraphy and the potential for the preservation of associated palaeoenvironmental and archaeological remains (see Carey et al 2018).

6 Results and Interpretation

Boreholes

6.1 Each borehole location was hand excavated to a depth of 1 m prior to drilling after which boreholes were excavated using a Hagglund Cable Percussion Rig (Plate 2).

Plate 2: Hagglund rig working shot from south

6.2 Borehole 1 was located in the north of the Landfall Search Area approximately 50 m south of Earl's Dike. Hand excavation of the pit (Plate 3) revealed a silty sand underlying the topsoil to a depth of 1.45 m below ground level (bgl) (4.55 m AOD). This deposit was interpreted as Holocene alluvium relating to the nearby Earl's Dike.The alluvium directly overlay a sand deposit containing frequent sub-angular to fine coarse mixed gravel interpreted as a glaciofluvial deposit. Diamicton till or boulder clay was encountered at a depth of 7.6 m bgl (-1.6m OD). Weathered chalk deposits were encountered at 19.25 m bgl (-13.25m AOD). The borehole was terminated at 24.8 m bgl (-18.8 m AOD).

Plate 3:Borehole 1 hand excavated pit from south

6.3 Borehole 4 (Plate 4) was located in the central eastern area of the Landfall Search Area known as Watermill Grounds. The borehole encountered topsoil overlying glaciofluvial sands and gravels to a depth of 9.95 m bgl (-1.95m AOD). Between 3.6 m and 5.10 m the sand was found to be very wet with voids in the casing frequently occurring. The sand was underlain by stiff clay 13.55 m thick which is interpreted as Devensian Till. Weathered Chalk was encountered at 23.5 m bgl (-15.5 m AOD) and the borehole was terminated at 25 m bgl (-17 m AOD).

Plate 4: Borehole 4 hand excavated pit from east

6.4 Borehole 8 (Plate 5) was located in the central area of the Landfall Search Area within the Watermill Grounds. It encountered silty sand deposits to a depth of 1.2 m overlying a coarse wet sand (Plate 6) interleaved with bands of minerogenic clay to a depth of 5.3 m bgl (1.3 m AOD). Given the proximity of Borehole 8 to mapped deposits of alluvium and the nearby associated drainage channel it is possible that the silty sand and associated minerogenic clays relate to Holocene alluvial deposition rather than fluvioglacial deposition. Below the sand was a dense clay deposit becoming firmer with increasingly large stones at depth. This directly overlay the weathered chalk which was encountered at a depth of 22.73 m bgl (-14.3 m AOD). The borehole was terminated at 25 m bgl (-17 m AOD).

Plate 5: Borehole 8 hand excavated pit from east

Plate 6: Borehole 8 wet sand extracted at 5.3m below ground level

6.5 Borehole 10 was located in the south of the Landfall Search Area (Plate 7). It encountered a very sandy topsoil (Plate 8) overlying glaciofluvial sands to a depth of 6.85 m (0.8 5m AOD), below which was a dense clay containing occasional bands of sand. Weathered Chalk was encountered at 22.38 m bgl (-16.38 m OD) and the borehole was terminated at 25.2 m bgl (-19.2 m AOD).

Plate 7: Borehole 10 in advance of excavation from north-east

Plate 8: Borehole 10 hand excavated pit from north-east

6.6 The geoarchaeological monitoring of ground investigation has thus confirmed that the sequence below the Landfall Search Area (in order of deposition) comprises:

- Rowe Chalk Formation - encountered at the base of all boreholes proven to a maximum of 25.2 m below ground level (bgl);
- Devensian Diamicton Till- comprising medium dense to dense brown to grey clay containing angular to sub rounded stone and gravel inclusions. Bands of coarse sand and pebbles are also common. Encountered in all boreholes at an average depth of 7.4 m bgl.
- Glaciofluvial Sands and Gravels – dominated by orange to yellowish brown coarse to fine sand deposits. It is possible that some of the upper sands are wind blown. Gravels tend to be sub-rounded and increase in frequency with depth indicating higher energy regimes influencing the earlier deposits. Encountered in all boreholes at an average depth of 1.6 m bgl
- Alluvium - comprising soft to firm grey minerogenic silty sands. Located to between 0.45 m and 1.45 m bgl in Borehole 4 and also possibly between 0.64 m and 1.2 m in Borehole 8. Not encountered in Boreholes 4 and 10

- Topsoil - comprising silty sand with frequent rooting, becoming lighter and more sandy with depth. Located between 0m and 0.64 bgl to an average depth of 0.51 m bgl. Encountered in all boreholes.

6.7 No significant archaeological deposits or artefactual material were encountered during the monitoring of the geotechnical works.

Cliff exposure

6.8 Given the limited number of monitoring locations, understanding of the geoarchaeological and palaeoenvironmental character of deposits within and around the Landfall Search Area was restricted and thus review of sediment stratigraphy exposed in the cliff face was also undertaken. The exposed cliff section reveals key information on buried deposits within the Landfall Search Area as well as their stratigraphic relationships.

6.9 The lowest deposit visible in the cliff section is the boulder or glacial Devensian till. It is exposed at the base of the cliff where its visible thickness is approximately 2 m (Plate 9). It is a dense brown to grey deposit consisting of heavily consolidated clays, sands and silts with frequent rounded stones and occasional large, rounded boulders. The till has a clear undulating horizontal boundary with the overlying sand and gravel deposits. In section these were observed to be dominated by orange to yellowish brown sand with occasional beds of rounded gravel (Plate 10). The deposit becomes more laminated upwards and distinct beds of gravel are visible towards the top of the cliff (Plate 11).

Plate 9: Basal cliff deposits (Devensian Till) within Landfall Search Area from east

Plate 10: Cliff section at coastal edge of Landfall Search Area

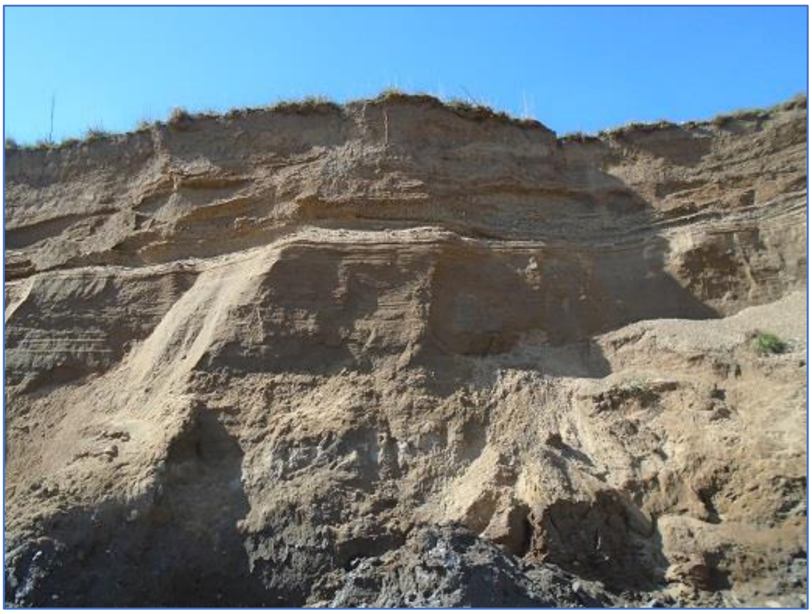

Plate 11: Bands of sand and gravel exposed in cliff section in centre of Landfall Search Area

6.10 A discontinuous thin layer of dark brown sediment was observed within the cliff section in the south of the Landfall Search Area (Plate 12). This layer appears to be located between two layers of fine yellow sand which may be a wind blown deposit. A slightly thicker dark brown deposit below the ground surface is also visible in this cliff section and may indicate an area of accumulation of more organic rich deposits.

Plate 12: Old ground surface exposed in cliff section in south of Landfall Search Area

7 Deposit Model

7.1 In order to create the deposit model, the geotechnical data was entered into a digital database (Rockworks 20). In the associated Figures the boreholes subject to geoarchaeological monitoring have been given the prefix 'BH' for boreholes. BGS logs (BGS 2020) added to the database were given a prefix relating to the two-letter grid square of the associated national grid reference e.g. SE. Geotechnical logs obtained from works undertaken by Structural Soils to inform a National grid project to the south of the Landfall Search Area are prefixed ‘NG’. A total of 46 sedimentary logs were included in the deposit model. The distribution of this data set is presented in Figure 3 and the data references for the sedimentary logs are presented in Appendix A.

7.2 Each lithology type (gravel, sand, silt, clay etc.) was given a unique colour (primary component) and pattern (secondary component) enabling correlation of the sediment components of deposits across the Landfall Search Area. By examining the relationship of the lithology types (both horizontally and vertical) in preliminary and iterative transects, correlations can inform the site-wide deposit groups. The grouping of these deposits is based on the lithological descriptions, which represent distinct depositional environments, coupled with a wider understanding of the local sedimentary sequences. Thus, a sequence of stratigraphic units ('facies'), representing certain depositional environments, and/or landforms can be reconstructed both laterally and through time.

7.3 An inverse distance weighted (IDW, weighting =2, number of points =12) digital elevation model (DEM) plot was produced for the surface of the glacial till. This plot (Figure 8) gives an approximation of the topography of the Landfall Search Area as it existed at the end of the Devensian. The development of the overlying deposits is likely to have been influenced by the topography inherited from the Pleistocene/Late glacial period.

7.4 The overlying deposit sequence across the Landfall Search Area depicted by the stratigraphic units, as representative of specific depositional environments and/or landforms laterally and through time for the Landfall Search Area and immediate vicinity, is illustrated in profile or transect form (Figures 5-7). Such transects present a straight-line correlation between the data points, extrapolating the stratigraphic units identified within each borehole.

7.5 The reliability of the model is dependent upon the data upon which it is founded. The borehole logs used for the model within the Landfall Search Area have been interpreted by a geoarchaeologist but interpretations were limited by the fact that boreholes were extracted within plastic casings. Interpretation of deposits from boreholes beyond the Landfall Search Area boundary rely upon the accuracy of the original observations. Furthermore, while the borehole data are relatively well distributed over the Landfall Search Area and to the south where extensive geotechnical works have been focused, availability of datasets to the north and west of the Landfall Search Area was very limited and as such the reliability of the model decreases north and west of the Landfall Search Area. Modelling also extrapolates and smooths between the data sets and as such the modelled levels of stratigraphic contexts vary slightly from the levels recorded in each individual geotechnical log.

8 Discussion

8.1 Although the results and interpretation detailed in this report have been produced as accurately as possible, it should be noted that the conclusions offered are a subjective assessment of collected data sets.

8.2 As discussed by AOC in the 2019 Geoarchaeological Desk Based Assessment (**Volume A6, Annex 5.4**), the Holderness area is characterised by Cretaceous Chalk deposits overlain by thick deposits of glacial boulder clay dating to the Last Glacial Maximum (LGM) overlain by glaciofluvial sands and gravel (Bateman et al 2010). These were encountered in all four boreholes at variable depths. The boulder clay or till was deposited by glacial ice, either at the glacier base or derived from material within and on the ice. It comprises gravelly sandy silty clay with boulders and contains numerous lenses of sand and gravel. The till also contains interdigitating units of glaciolacustrine clay, plus sand and gravel formed during ice advance and retreat. The till is 10 - 15 m thick.

8.3 Deposits of glaciofluvial sand and gravel are closely associated with the till deposits. They generally have a lower clay content and correspondingly greater proportions of sand and gravel, compared with the till. They are quite variable in thickness and composition, even over very short distances (a few tens of metres). In some places, sand and gravel deposits may be associated with fluvial deposition and related to the Holocene Earl's Dike rather than glaciation, although this cannot be determined from the current model.

8.4 As the glacial waterflow abated and sedimentation changed in the Late Pleistocene and Early Holocene, rivers retracted to the lower parts of their valleys close to modern channel courses and soil formation occurred. The character of the surface topography of sands and gravels would have defined the landscape and environmental development for much of the Holocene. It also provides a broad indication of archaeological potential with higher well drained areas being the likely focus of human occupation and low-lying areas preserving remains of palaeoenvironmental potential.

8.5 A ubiquitous pattern of minerogenic sedimentation and soil formation continued throughout the Holocene. Buried soils associated with earlier land use may be preserved beneath the surface and potentially preserve palaeoenvironmental remains especially where they have formed in depressions in the landscape where drainage has been inhibited and waterlogging conditions have prevailed. Features may include natural depressions and anthropogenic drainage ditches, cut through earlier deposits and infilled with comparatively similar clays/silts.

8.6 Widespread agricultural improvements took place from the medieval period onwards. Medieval and post-medieval archaeology could survive within the upper deposits.

8.7 Review of evidence from the surrounding area has thus revealed the Landfall Search Area to be located within a wider area rich in evidence for Pleistocene and Holocene landscape evolution.

However, review of borehole evidence from within the Landfall Search Area indicates that deposits are of limited palaeoenvironmental potential. These deposits nevertheless provide evidence for dynamic landscape formation processes at the end of the Pleistocene which have shaped how the land was exploited by people throughout the Holocene.

9 Recommendations

9.1 In Holderness, paleoenvironmental evidence for post-glacial landscape is found largely at the sites of former meres, channels and wetlands. The coring programme revealed no evidence for peat or organic clay deposits which might preserve paleoenvironmental remains. However, it is noted that the borehole investigation locations were located largely beyond the mapped extent of alluvium associated with drainage channels and thus the possibility that organic alluvial deposits survive within the Landfall Search Area cannot be ruled out. Additionally, examination of the exposed cliff section revealed a thin band of dark organic sediment which may represent an old ground surface or area of waterlogged peat extending into the south of the Landfall Search Area. However this appeared to be thin and discontinuous and no evidence for this sediment was revealed at the monitored coring locations. Owing to the limited depth and extent of this deposit and its absence from the deposit model it is not possible to devise a sampling strategy that would specifically target its extent. However, should ground breaking works necessitate excavation to depths of over 1m (the approximate depth of the observed deposit) it is advised that archaeological monitoring should occur to monitor the deposit's potential to hold in situ (or otherwise) artefactual or ecofactual evidence of past human activity (e.g. fishing activity evidence associated with river / watercourse edges). If the deposit is exposed in section then Monolith and/or kubiena samples should be taken in order that its formation can be studied in detail by a geoarchaeologist and, if appropriate, relevant samples for dating and paleoenvironmental analysis should be taken to place archaeological remains in their wider environmental context. Any further information that can be obtained from sediments within the Landfall Search Area could aid further understanding of the existing sequence. In particular a greater understanding of the mid-late Holocene would contribute to knowledge on the development of the landscape following the LGM and prior to drainage for modern agriculture.

9.2 The waterlogged preservation of material culture in Holderness occurs where archaeological sites are buried by peat growth and alluvial sedimentation and where the exploitation of wetlands resulted in human activity. While direct evidence for buried wetland deposits and associated palaeoenvironmental evidence appears to be absent from the Landfall Search Area, the sands and gravels identified would have formed an important relatively free draining area in an otherwise wetland landscape. This is reflected in evidence for later prehistoric activity within the Landfall Search Area and it is likely that these drier sand and gravel rich areas in the Landfall Search Area would have proved an attractive base for occupation and for exploiting surrounding wetland areas from the start of the Holocene, and thus the archaeological potential of this Site remains high.

10 Archive

10.1 The archive will contain all the data collected during the archaeological monitoring, including all digital and paper records. It will be quantified, ordered, indexed and internally consistent.

10.2 The archive will be assembled in line with the recommendations provided in Historic England's *MoRPHE Project Planning Note 3: Archaeological Excavation* (PPN3) (2015). It will also be prepared in accordance with the *Guidelines for the preparation of Excavation Archives for long–term storage* (United Kingdom Institute for Conservation, 1990) and *Standards in the museum care of* *archaeological collections* (Museums and Galleries Commission 1994). Provision will be made for the stable storage of paper records and their long–term storage

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Appendix 1: Troels-Smith Sediment Classification

Physical Features	
Degree of darkness	Varies from 0 in the lightest occurring shades (e.g. clear (Nigror) quartz sand and lake marl), through 1 (e.g. calcareous clay), 2 (e.g. fresh swamp peat), 3 (e.g. partly humified peat) to 4 in the darkest sediments (e.g. completely disintegrated peat).
Degree of stratification	Visual or structural horizontal banding or layering. Varies (Stratification) from 0 where the deposit is completely homogeneous or breaks in all directions, to 4 which consists of clear thin layers or bands.
Degree of elasticity	The sediment's ability to regain its shape after being (Elasticitas) squeezed or bent. Varies from 0 in plastic clay, sand, disintegrated peat etc. to 4 in fresh peat.
Degree of dryness	Deposits fall between 0 (clear water) and 4 (air dry material). (Siccitas) 1 indicates very wet runny sediment such as surface lake muds, 2 represents saturated sediments, the normal condition below the water table, while sicc. 3 indicates moist, unsaturated sediments.
Colour	Best determined by reference to Munsell soil colour charts. Changes in colour with exposure to air should be noted.
Structure	The dominant structural feature (eg. fibrous, homogeneous)
Sharpness of boundary	The boundary can be diffuse (> 1 cm: lim. 0), very gradual (Limes superior) (<1 cm to > 2 mm: lim. 1), gradual (< 2 mm to >1 mm: lim. 2), sharp (<1 mm to > 0.5 mm) or very sharp (< 0.5 mm).
Humicity: The degree of humification or disintegration of organic (Humicitas) substances. It is measured by determination of the nature and amount of material passing through the fingers on squeezing; 0 (fresh peat yielding clear water), 1 (slightly decomposed peat yielding dark coloured, turbid water), 2 (decomposed peat yielding half its mass), 3 (very decomposed peat yielding three-quarters of its mass) and 4 (totally decomposed peat yielding almost all its mass).	
Components	
Mosses	Sphagnum is the most common peat-former.
Woody plants (Turfa lignosa)	Roots of trees and shrubs together with attached stumps and branches, frequently in growth position.
Herbs (Turfa herbacea)	Roots of herbaceous plants together with attached stems and leaves, frequently in growth position.
Woody detritus	Fragments of woody plants >2 mm.
Herb detritus	Fragments of herbaceous plants >2 mm.
Fine detritus	Fragments of woody or herbaceous plants <2 mm.
Charcoal	Carbonised fragments of predominantly woody plants.

Organic lake mud	Homogeneous organic lake sediment composed of remains (Limus detrituosus) of microplankton and humified remains of macrophytes.
Humus	Completely disintegrated organic substances and precipitated humic acids.
Organosilicates	Siliceous skeletons or skeleton fragments of diatoms, sponges etc.
Carbonates (Limus calcareus)	Calcium carbonate or marl. Similar in colour and texture to L. siliceous but soluble in hydrochloric acid.
Iron oxides	Iron oxides of various types and colours.
Clay (Argilla steatodes)	Mineral particles <0.002 mm
Silt (Argilla granosa)	Mineral particles 0.002 - 0.06 mm
Sand (Grana minora)	Mineral particles 0.06 – 2 mm.
Gravel (Grana majora)	Mineral particles >2 mm.

Appendix 2: Survey Metadata

Field	Description
Surveying Company	AOC Archaeology
Data collection staff	Kim Hosking, Lynne Roy
Client	Undertaken and prepared for Royal HaskoningDHV on behalf of Orsted Hornsea Project Four Limited Ltd
Site name	Hornsea 4
County	East Yorkshire
NGR	TA 1676 6108
Land use/ field condition	Arable and beach
Duration	13/04/21 - 30/04/21
Weather	Overcast, Sunny
Survey type	Test-pit monitoring
Processing software	RockWorks
Visualisation software	ArcGISPro
Geology	Bedrock: White Chalk Subgroup – Chalk. Superficial: Till-Diamicton, Glacial Sand and Gravel – Sand and Gravel; Alluvium - Clay, Silt And Sand; Sand And Gravel Of Uncertain Age And Origin - Sand And Gravel (BGS, 2021).
Soils	Freely draining slightly acid loamy soils and areas of clayey soils of coastal flats with naturally high groundwater; (Soilscapes, 2019).
Scheduled Ancient Monument	No
Known archaeology on site	Yes
Historical documentation/ mapping on site	Yes
Report title	Hornsea Four Offshore Wind Farm
Project number	53010
Report Author	Lynne Roy
Report approved by	Stephen Potten

Appendix 3: Geoarchaeological recording form

AOC Archaeology Geoarchaeological Log Sheet

Site / AOC Code		Sample / BH No.		Elevation		Coordinates	

				Description							
Drawn log	Top (m bgl)	Base (m bgl)	Sub Sample (eg P/D/O)	Lithology	Colour	Soil strength	Soil structure	Moisture	Boundary	Inclusions	Peat
				(secondary PRIMARY / peat, organic, clay, silt, sand, gravel)	(munsel or very light, light, mid, dark, very dark, primary / secondary)	(very soft, soft, firm, stiff, very stiff, hard / friable, elastic)	(homogenous, bedded, fissured, polished, slickensided, blocky, lensoidal)	(dry, moist, wet, saturated)	(diffuse, very gradual, gradual, sharp, very sharp / undulating)	(rootlets, rooting; angular to rounded flint)	(firm, spongy, plastic, fibrous, amorphous, decompostion)
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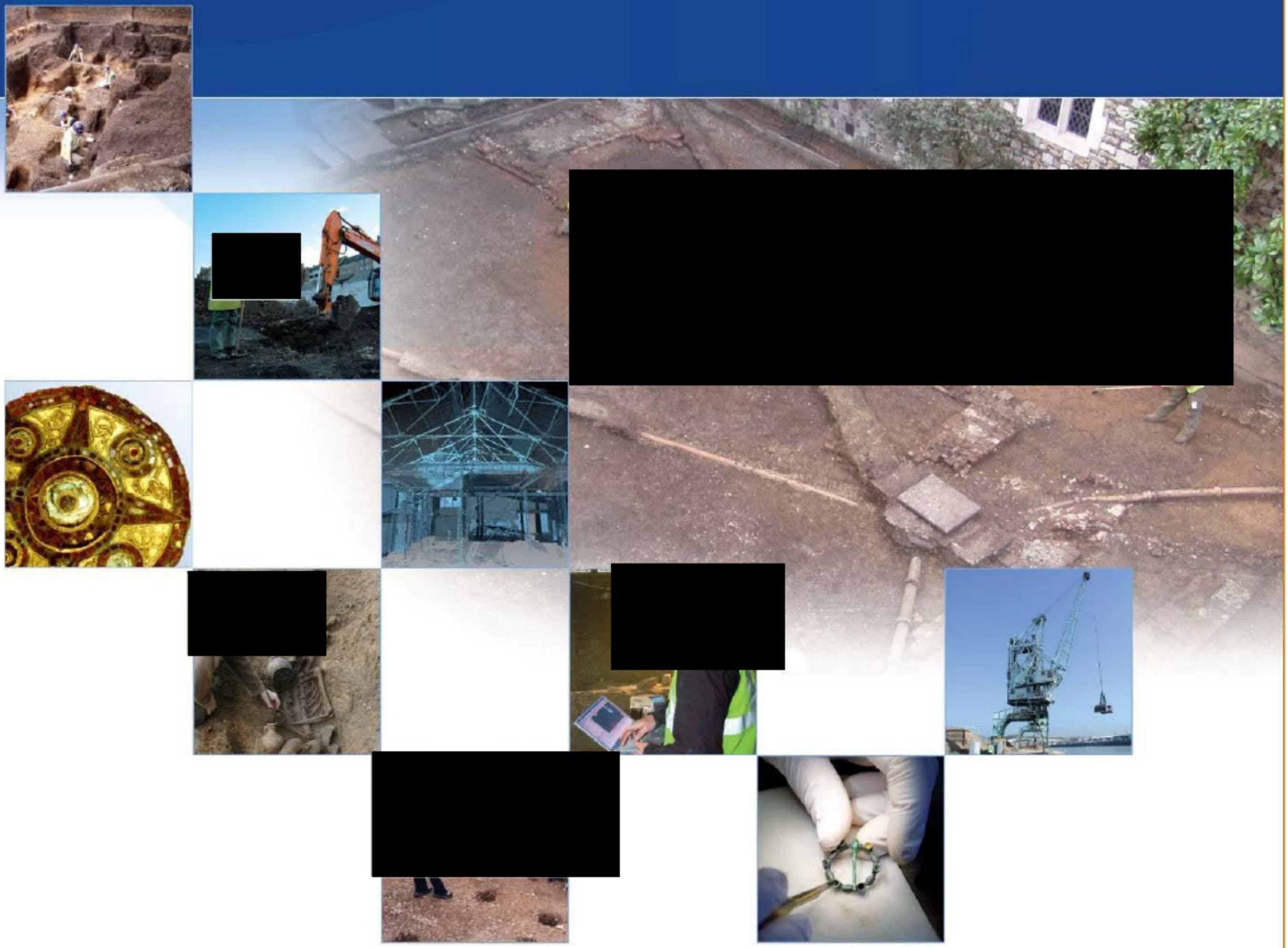
AOC Archaeology Geoarchaeological Log Sheet

Logged by		Date	

AOC Archaeology Geoarchaeological Log Sheet



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