Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Environmental Statement

Volume 3

Appendix 14.3 - Stage 1 Geoarchaeological Assessment of Geotechnical Data

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Summary

Wessex Archaeology (WA) have been commissioned by Royal HaskoningDHV to undertake a Stage 1 geoarchaeological assessment of geotechnical data acquired during a 2021 survey undertaken by GEO within the Sheringham Shoal and Dudgeon offshore wind farm extension project areas, which comprise interlink cables and associated offshore export cable corridors (ECC), including the nearshore ECC, connecting the Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and the Dudgeon Offshore Wind Farm Extension Project (DEP) areas to the landfall site at Weybourne on the North Norfolk coast.

A total of 51 geotechnical vibrocore logs were reviewed to identify deposits with geoarchaeological potential, assigning high, medium and low status accordingly.

The stratigraphy of the SEP and DEP areas comprise chalk bedrock, overlain by a sequence of Pleistocene and Holocene deposits. Pleistocene sediments are predominantly glacial diamict laid down during the Elsterian (Swarte Bank Formation) and Weichselian (Bolders Bank Formation) periods and therefore have low geoarchaeological potential. Holocene age deposits assigned low geoarchaeological potential include seabed sediments and shallow marine sands.

Pleistocene sediments are overlain by probably Holocene aged deposits and include terrestrial peats, organic clay (or 'gyttja') and associated minerogenic deposits, laid down at a time when the southern North Sea was subaerially exposed prior to sea-level transgression. Collectively, these deposits correspond to channel infill of the Botney Cut Formation, however they may potentially be equivalent to the Elbow Formation mapped further offshore.

Clayey sand and sand and gravel with organic material was recovered in seven vibrocores and interpreted as minerogenic alluvium deposited by fluvial processes. In many instances, these deposits are overlain by laminated sand, silt and clay with shell fragments interpreted as tidally influenced alluvial sediments deposited in a low energy shallow water environment. Given their potential to preserve inorganic microfossils, these deposits are considered to have medium priority status.

Organic clay units are recorded within a single vibrocore (VC59), interbedded within tidally influenced alluvium. Similar deposits were previously recorded from the existing Dudgeon Offshore Wind Farm and following a palaeoenvironmental assessment, were interpreted to document the gradual infilling of a proglacial freshwater lake system between 12,700 and 9260 cal. BP. However, it is likely that the organic clay preserved in VC59 reflects localised ponding of water within an environment becoming increasingly dominated by tidal processes, possibly at a later date. Palaeoenvironmental assessment would be required to determine if these sediments were deposited in either freshwater or brackish conditions.

Peat deposits occasionally preserving wood fragments have been recovered from five vibrocores from the SEP and DEP areas (VC53, VC57, VC59, VC73 and VC80). The sequence preserved in VC59 is of particular interest as it shows a transition from peat to organic clay and then peat again, all within a sequence of alluvium that shows varying influence of marine and terrestrial sources.

Organic clay and peat deposits have the highest potential for preserving material for radiocarbon dating, along with a range of palaeoenvironmental remains suitable for reconstructing past landscapes and environmental change in relation to human activity during the Upper Palaeolithic and Early Mesolithic.

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Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Projects

Stage 1 geoarchaeological assessment of 2021 geotechnical data

1 INTRODUCTION

1.1 Project background

1.1.1 Wessex Archaeology (WA) have been commissioned by Royal HaskoningDHV on behalf of Equinor New Energy Limited (the Applicant), to undertake a Stage 1 geoarchaeological assessment of 2021 geotechnical data acquired by GEO from the offshore export cable corridors (ECCs) associated with the Sheringham Shoal and Dudgeon Offshore Wind Farm Extension Project areas (**Figure 1**) including the nearshore ECC between mean high-water spring (MHWS) tide and 10 m below lowest astronomical tide (LAT) (**Figure 1**).

1.1.2 The proposed project includes the Sheringham Shoal Offshore Wind Farm Extension Project (SEP) and the Dudgeon Offshore Wind Farm Extension Project (DEP). Both SEP and DEP are located in the southern North Sea (**Figure 1**) and lie approximately 16 km (Sheringham Shoal) and 27 km (Dudgeon) from the coast at their closest point. An ECC connects the SEP and DEP wind farm sites to the landfall site at Weybourne on the North Norfolk coastline.

1.1.3 The extension of the existing Dudgeon Offshore Wind Farm encompasses areas to the north (DEP North) and southeast (DEP South), and the extension of the existing Sheringham Shoal Offshore Wind Farm includes areas to the north (SEP North) and east (SEP East) of the current Sheringham Shoal Offshore Wind Farm.

1.2 Summary of previous works

1.2.1 Marine archaeological works in support of the existing Sheringham Shoal and Dudgeon offshore wind farms have been ongoing since 2006 and include assessments of marine geotechnical and geophysical site-specific surveys (**Table 1** and **Table 2**). Although not directly within the SEP and DEP area, these previous works are relevant to this geoarchaeological assessment as they provide a baseline understanding of the geoarchaeological and palaeolandscape potential of this region of the North Sea.

1.2.2 Based on interpretation of sub-bottom profiler (SBP) data obtained from the existing Sheringham Shoal and Dudgeon offshore wind farms, and SEP and DEP, an extensive channel network has been evidenced through the identification of buried palaeolandscape features. These mapped palaeochannels were shown to frequently contain numerous high amplitude reflectors, interpreted as organic deposits and/or peats. The vast number and geographical extent of palaeochannels mapped through SBP data is demonstrated in **Figures 2a-b**.

1.2.3 Previous geoarchaeological works in the existing Dudgeon offshore wind farm include Stages 1 to 3 core assessments identifying deposits of archaeological significance, alongside a further Stage 4 palaeoenvironmental assessment of a single borehole (BH06). Multiple phases of peat development were recorded within BH06 (Wessex Archaeology 2014a). Radiocarbon dates from the base and top of the peats constrained the sequence from 12,463–12,438 cal BP to 8996–8760 cal BP (Brown *et al*. 2018), suggesting that peat

development is associated with a shift from warmer Bølling-Allerød interstadial to colder Younger Dryas stadial conditions (Brown *et al*. 2018). The date from the upper peat suggests the deposit continued accumulating throughout the early Holocene. Given the large number of channels previously mapped, combined with the recovery of organic deposits, there is high potential for peats with significant archaeological and geoarchaeological potential to be preserved within SEP and DEP.

Table 1 Summary of marine archaeological works undertaken in support of the Sheringham Shoal development

Document	Date	Reference	Wessex Archaeology report ref.
Sheringham Shoal Offshore Windfarm Archaeological Desk-Based Assessment. Technical Report	2006	Wessex Archaeology 2006a	61031.02
Sheringham Shoal OWF Stage 2 Archaeological Recording and Sampling of Vibrocores	2006	Wessex Archaeology 2006b	61032.02
Sheringham Shoal Offshore Wind Farm Desk Based Assessment	2006	Wessex Archaeology 2006c	61033
Sheringham Shoal Offshore Wind Farm Written Scheme of Investigation	2009	Wessex Archaeology 2009c	61035.03
Sheringham Shoal Offshore Wind Farm Archaeological Assessment of Post-Construction Data	2014	Wessex Archaeology 2014e	101841.03
Sheringham Shoal Offshore Wind Farm Archaeological Assessment of Post-Construction Data 2017	2017	Wessex Archaeology 2017	101841.01

Table 2 Summary of marine archaeological works undertaken for the Dudgeon development

Document	Date	Reference	Wessex Archaeology report ref.
Dudgeon Offshore Wind Farm: Archaeological Desk Based and Geophysical Assessment	2009	Wessex Archaeology 2009a	69680.08
Dudgeon Offshore Wind Farm : Archaeological Assessment of Marine Geophysical Data	2009	Wessex Archaeology 2009b	69680.04
Dudgeon Offshore Wind Farm: Stages 1 to 3 Geoarchaeological and Palaeoenvironmental Assessment	2014	Wessex Archaeology 2014a	69681.03
Dudgeon Offshore Wind Farm Geophysical Assessment of 2013 Data	2014	Wessex Archaeology 2014b	69682.04
Dudgeon Offshore Wind Farm Archaeological Monitoring and Mitigation: Written Scheme of Investigation	2014	Wessex Archaeology 2014c	69683.04
Dudgeon Offshore Wind Farm Review of Archaeological Material During Unexploded Ordnance Survey (Turbine Locations and Cable Route) Method Statement	2014	Wessex Archaeology 2014d	69683.06

Document	Date	Reference	Wessex Archaeology report ref.
Dudgeon Offshore Wind Farm Archaeological Assessment of UXO Survey Results	2015	Wessex Archaeology 2015a	69684.01
Dudgeon Offshore Wind Farm Archaeological Assessment of UXO Survey Results April–May 2015	2015	Wessex Archaeology 2015b	69684.02
Dudgeon Offshore Wind Farm Stage 4 Palaeoenvironmental Analysis, Borehole BH06.	2016	Wessex Archaeology 2016	69685.01
Dudgeon Offshore Wind Farm Post-construction archaeological monitoring assessment of 2018 geophysical data	2019	Wessex Archaeology 2019a	69686.01
Dudgeon and Sheringham Offshore Wind Farms Extensions; Archaeological assessment of geophysical data	2020	Wessex Archaeology 2020	233450.01
Dudgeon and Sheringham Offshore Wind Farm Extensions; Archaeological assessment of geophysical data – addendum	2021	Wessex Archaeology 2021	223450.02

1.3 Scope of work

1.3.1 To help frame geoarchaeological investigations of this nature, WA has developed a five stage approach, encompassing different levels of investigation appropriate to the result obtained, accompanied by formal reporting of the results. The stages are summarised below (**Table 3**).

1.3.2 This report presents the results of a Stage 1 review of geotechnical logs acquired during a survey undertaken in 2021. Previous geoarchaeological assessments highlighted the potential for deposits of archaeological interest to be present within the SEP and DEP offshore areas (**Table 1**; **Table 2**). To further understand the spatial distribution of these deposits, and to assess if any other deposits of archaeological interest were present within the offshore or nearshore areas, a Stage 1 review was undertaken, as detailed in **Table 3**, with recommendations made for further geoarchaeological work if deemed necessary.

Table 3 Staged approach to geoarchaeological investigations

Stage	Description
Stage 1: Geoarchaeological review	Desk-based review of geotechnical and geological data. Establish likely presence/ absence/ distribution of archaeologically relevant deposits. Identify deposits or samples for Stage 2 works.
Stage 2: Geoarchaeological recording/monitoring	Target deposits or samples identified in Stage 1. Describe the sequences recovered and undertake deposit modelling (if suitable). Interpret depositional environment (if possible). Identify if suitable deposits are present for Stage 3 works.
Stage 3: Palaeoenvironmental assessment	Sub-sample deposits of archaeological interest for paleoenvironmental assessment (e.g. pollen, plant macrofossils, foraminifera, ostracod and diatoms) and associated scientific dating. Provide an outline interpretation of the archaeological and palaeoenvironmental context. Any recommendations for Stage 4 works will depend on the potential for further analysis and the project research objectives.

Stage	Description
Stage 4: Palaeoenvironmental analysis	Full analysis of samples and additional scientific dating as specified in Stage 3, together with a detailed synthesis of the results, in their local, regional or wider archaeological and palaeoenvironmental context. Publication would usually follow from a Stage 4 report.
Stage 5: Publication	Publication of the results of Stage 1-4 works for submission in a peer reviewed journal, book or monograph, depending on the archaeological significance of the work. The scope and location of the final publication will be agreed in consultation with the client and regulatory bodies where appropriate.

2 GEOARCHAEOLOGICAL BACKGROUND

2.1 Introduction

2.1.1 Geoarchaeological assessments are typically undertaken with reference to geological periods (e.g. Quaternary), epochs (e.g. Pleistocene) and sub-epochs (e.g. Weichselian) that reflect major climate sea-level and/or environmental changes. Here we adopt standard European nomenclature correlated to the Marine Isotope Stage (MIS) record to distinguish between different climatic periods, with dates given in ka (thousands of years before present). Marine Isotope Stages are deduced from marine palaeoclimatic records and reflect alternating warm (interglacial and interstadial) and cold (glacial and stadial) periods throughout the Quaternary.

2.2 Geological baseline

2.2.1 The SEP and DEP ECC stretches from the North Norfolk coastline to the outskirts of the Wash (**Figure 1**). Chalk bedrock from the Upper Cretaceous are present across this area as well as throughout much of the North Sea and southern England. Bedrock geology across the SEP and DEP areas is unconformably overlain by considerable thickness of Pleistocene and Holocene sediment (Cameron *et al.* 1992), dominated by glacial diamict and marine sands, overlain by Holocene age fluvial, semi-terrestrial and lacustrine sediments, and post-transgression marine sands.

2.2.2 The Pleistocene geological history of the North Sea basin is dominated by repeated glacial/interglacial cycles, resulting in rising and falling sea levels (**Figure 3**) and the deposition of terrestrial, marine, and glacial sediments. Across the SEP and DEP areas there is evidence of at least two phases of glaciation, which occurred during the Elsterian (478,000–424,000 years BP; MIS 12) and Weichselian (110,000–13,000 years BP; MIS 2) when ice extended into the southern North Sea.

2.2.3 The southern extent of the Elsterian glaciation is debatable, however bathymetric data suggests a southernmost extent of Felixstowe (Emu 2009). Alternatively, Dix and Sturt (2011) argue for an Elsterian glacial origin for over-steepened valleys (tunnel valleys) identified within the Outer Thames estuary. The maximum extent of the Weichselian glaciation has been mapped along the North Norfolk coast and is suggested to extend offshore based on stratigraphic correlation to the Bolders Bank Formation (Roberts *et al*. 2018). The Weichselian ice sheet is suggested to have reached its maximum extent by around 27,000 years ago in North Norfolk (Clark *et al*. 2012; Roberts *et al*. 2018).

2.2.4 The Saalian glaciation of 352,000–130,000 years BP is not believed to have extended to within the SEP and DEP areas (Eaton *et al*. 2020). Despite this, indirect affects resulting from changing sea levels and cold periglacial conditions will have influenced the region.

2.2.5 The oldest deposits likely to be encountered in SEP and DEP are associated with the Swarte Bank Formation, which records the first invasion of ice into the southern North Sea Basin (Cameron *et al*. 1992). The Swarte Bank is characterised by gravels, sands and stiff grey diamictons, overlain by glaciomarine and glaciolacustrine sands and muds. The formation is associated with the infill of a subglacial valley system originally cut by subglacial meltwater during MIS 12 and subsequently infilled during the early part of MIS 10-9 (ca. 350–280 ka) (Mellett *et al*. 2020).

2.2.6 The Egmond Ground Formation overlies the Swarte Bank Formation, dating to MIS 11 (423–326 ka). This deposit is lithologically variable with gravelly shelly sands interbedded with silt and clay (Brown *et al*. 2018) and represent shallow marine deposits that likely formed in a lagoonal environment, suggesting there were periods during the Holsteinian when the southern North Sea was spatially more restricted and habitable. Holsteinian shallow marine faunas and spores (e.g. the freshwater fern *Azolla filiculoides*) are also occasionally recorded within associated deposits. However, very little research has been undertaken to establish a chronology for this interglacial, or to understand the palaeoenvironment in relation to archaeological potential.

2.2.7 Extensive till deposits comprising reddish brown gravelly sandy clays are observed overlying marine sands of the Egmond Ground Formation in the southern North Sea, referred to as the Bolders Bank Formation and dating to MIS 2 (ca. 18 ka). Diagnostic features of the Bolders Bank Formation include the entrained chalk gravel and reddish brown colouration of clay which differs considerably from the predominantly flint rich and grey diamicton of the older Swarte Bank Formation (Cameron *et al*. 1992).

2.2.8 Superficial deposits of potential geoarchaeological significance likely to be encountered within the SEP and DEP areas include the Botney Cut Formation (**Table 4**), tentatively dating from the late Weichselian deglaciation to early Holocene interglacial.

2.2.9 The spatial distribution of the Botney Cut Formation appears discontinuous across the southern North Sea with isolated channels identified within SEP and DEP (Wessex Archaeology 2019; 2020). To the north of SEP and DEP at Dogger Bank, deposits interpreted as the Botney Cut Formation predominantly comprise glaciolacustrine sediments. Despite this, in the SEP and DEP areas these channels appear to be infilled with terrestrial-shallow marine sediment as opposed to glacial and proglacial (Wessex Archaeology 2009b) as typically mapped elsewhere in the southern North Sea (Cameron *et al*. 1992). This demonstrates that there is much more complexity in the Botney Cut Formation, with deposits varying at a local scale.

2.2.10 A previous palaeoenvironmental assessment of deposits from the existing Dudgeon Offshore Wind Farm show the gradual infilling of a proglacial freshwater lake between 12,700 and 9260 cal. BP (Brown *et al*. 2018). However, based on known ice sheet history, during this time the Devensian ice sheet had retreated forming an icecap in the Scottish Highlands hundreds of kilometres to the north of the site (Hubbard *et al*. 2009). The lake deposits therefore more likely reflect localised ponding of water within a formerly glaciated landscape, with climate being the key driver of landscape change and arguably having greater archaeological significance when compared with proglacial lake deposits.

2.2.11 In some areas across the southern North Sea, a sequence of early to mid-Holocene deposits are mapped overlying Pleistocene sediments. These sequences have been recorded as infilling palaeochannels and isolated depressions within other offshore wind farms (Wessex Archaeology 2021) including the existing Sheringham Shoal and Dudgeon offshore areas (Brown *et al*. 2018). The Holocene sediments include organic-rich peats

along with minerogenic fluvial and alluvial sediments and record a transition from semi-terrestrial to shallow marine and brackish conditions. This sequence correlates to the Botney Cut Formation and is potentially equivalent to the Elbow Formation (Stoker *et al*. 2011). The peats are of high geoarchaeological potential, preserving a range of palaeoenvironmental remains and material suitable for radiocarbon dating.

2.2.12 Pleistocene and early Holocene sediments are capped by post-transgression marine sands (**Table 4**). The progressive inundation of the North Sea occurred over an extended time scale, with particularly rapid sea-level rise during the early Holocene (11.5-7 ka), and with fully marine conditions occurring by around 6 ka (Sturt *et al*. 2013). However, limitations in the availability of reliable sea-level index-points (Hazell 2008) combined with uncertainty around the glacio-isostatic response of the southern North Sea, make it difficult to accurately reconstruct sea-level history and the timing of inundation across the SEP and DEP areas.

Table 4 Stratigraphy of SEP and DEP based on site specific geophysical and geoarchaeological assessments (Wessex Archaeology 2009c; 2014a; 2016; 2020; 2021)

WA Unit	Unit Name (Age)	Geophysical Characteristics	Sediment Type	Archaeological Potential
Unit 8	Holocene seabed sediments (post-transgression, MIS 1)	Generally observed as a veneer or thickening into large sand waves and bank features. Boundary between superficial sediments and underlying units not always discernible.	Gravelly sand with frequent shell fragments, sand waves and ripples (marine)	Considered of low potential in itself, but possibly contains reworked artefacts and can cover wreck sites and other cultural heritage.
Unit 7	Holocene sediments (pre-transgression, MIS 2-1)	Small shallow infilled channels with either seismically transparent fill, or fill characterised by subparallel internal reflectors. May also comprise a basal, high amplitude reflector, possibly representing a peat layer	Sand with organics (fluvial), laminated sand, silt and clay (estuarine) and peat (semi-terrestrial)	Potential to contain *in situ* and derived archaeological material, and palaeoenvironmental material. Peat is considered to have high potential as it may be radiocarbon dated and record vegetation change.
Unit 6b	Botney Cut (Weichselian to possibly Early Holocene, MIS 2-1)	Channel features with distinct basal reflectors and fill characterised by sub-parallel internal reflectors. Acoustic blanking occasionally seen at base and within.	Clays and sands (estuarine and terrestrial peats relating to the Holocene)	
Unit 6a	Botney Cut (Weichselian to possibly Early Holocene, MIS 2-1)	Acoustically chaotic unit with faint basal reflector, possibly infilling broad, faint channel features. Some sub-horizontal internal reflectors.	Stiff red brown gravelly, sandy clays (Glacial till) and laminated sands and clays (glaciolacustrine and glaciomarine)	Considered low but has potential to bury deposits of interest or to contain reworked material
Unit 5	Bolders Bank (Late Weichselian, MIS 2)	Acoustically chaotic blanket deposit often with internal reflectors and some occasional internal channelling	Stiff red brown gravelly, sandy clays containing	

WA Unit	Unit Name (Age)	Geophysical Characteristics	Sediment Type	Archaeological Potential
			erratics including chalk (glacial till)	
Unit 4	Egmond Ground (Holsteinian/Saalian, MIS 11-8)	Fill characterised by numerous faint reflectors and a distinct basal reflector	Shelly sands and gravel with interbedded silt and clay (marine)	
Unit 3	Swarte Bank (Elsterian/Early Holsteinian, MIS 12/11)	Acoustically chaotic unit with faint basal reflector, possibly infilling broad, faint channel features. Some sub-horizontal internal reflectors.	Stiff grey gravelly sandy clays with lenses of coarse glaciofluvial sand (glacial till)	
Unit 2	pre-Devensian Weybourne Channel	Broad, distinct channel feature with an undulating basal reflector. Fill characterised by an upper unit characterised by numerous, faint subhorizontal reflectors, overlaying a more acoustically chaotic unit	Alluvial sequence found to comprise sand, clay and organic silt.	Exact age, and therefore archaeological potential, is uncertain however has the potential to contain *in situ* and derived archaeological material, and palaeoenvironmental material.
Unit 1	Upper Cretaceous Chalk	Fairly acoustically quiet with some, faint dipping reflectors	White and greyish white chalk with some nodular flint	Considered of low potential
(1) Based on geophysical data (Wessex Archaeology 2020; 2021) (2) Based on vibrocore and borehole data (Wessex Archaeology 2009c; 2014a; 2016) and Cameron *et al.,* (1992)				

2.3 Archaeological record

2.3.1 The southern North Sea and in particular East Anglia is a key region with internationally significant archaeology recovered from onshore (Pakefield; Parfitt *et al*. 2005 and Happisburgh; Parfitt *et al*. 2010; Ashton *et al*. 2008) and nearshore (Area 240; Tizzard *et al*. 2014) contexts. However, archaeological findspots located in the region of SEP and DEP, are limited.

2.3.2 Despite this, recent developments have been made in resolving the submerged Holocene landscape in the southern North Sea, for the purpose of targeted prospecting for archaeological material (Missiaen *et al*. 2021). North of the Cromer coastline, high-resolution seismic surveys undertaken identified an extensive channel which during the Holocene, crossed the subaerially exposed southern North Sea. At this location, the "Southern River" entered an ancient coastal system, with evidence of peat and wood preserved throughout the study area (Missiaen *et al*. 2021). An assemblage including a stone hammer was recovered following targeted dredging and represents the only prehistoric archaeological material recovered from the deeper areas of the southern North Sea (Gaffney *et al*. 2019). Equivalent organic deposits with high archaeological and

geoarchaeological potential may be preserved within SEP and DEP as supported by previously mapped palaeochannels (Wessex Archaeology *et al*. 2019; 2020; 2021).

3 AIMS AND OBJECTIVES

3.1.1 The principle aim of the Stage 1 geoarchaeological assessment is to assess the archaeological potential of deposits recovered in vibrocores collected within SEP and DEP.

3.1.2 This will be achieved by addressing the following objectives;

- Review geotechnical vibrocore logs to identify deposits of potential archaeological interest, assigning high, medium and low priority status, and;
- Make recommendations for Stage 2 geoarchaeological recording and deposit modelling, where necessary.

4 METHODOLOGY

4.1 Co-ordinate system

4.1.1 All location information and figures are presented as projected coordinates in ETRS 1989 UTM 31N Eastings and Northings.

4.1.2 The vertical reference level is given as metres below sea floor (mbsf) which assumes the top of the vibrocore is equal to the level of the sea floor. Water depths are given as metres below Lowest Astronomical Tide (LAT).

4.2 Geotechnical coring strategy

4.2.1 A total of 51 vibrocores were acquired during a geotechnical survey undertaken in 2021. The location of vibrocores recovered from SEP and DEP are presented in **Figure 4** and **Appendix 1**.

4.2.2 Vibrocores were acquired using a high-performance corer along the ECCs (**Figure 3**). Target depth of engineering vibrocores was 6.30 mbsf. Vibrocores were acquired in clear liners, split into 1 m sections offshore and transported to the laboratory of the Norwegian Geotechnical Institute (NGI) where they were split open lengthways, photographed, and described in detail. Geotechnical logs and core photographs were provided to Wessex Archaeology for review and geoarchaeological assessment.

4.3 Review of geotechnical logs

4.3.1 Geoarchaeological review of vibrocores was undertaken in two stages; the first stage included a review of preliminary vibrocore logs that were drafted on the vessel by describing the deposits through liner and inspecting the top and base of each 1 m cut section. These preliminary logs were sent to Wessex Archaeology direct from the vessel and were used to flag vibrocores with potential to contain high priority deposits (e.g. organic material and peat).

4.3.2 To manage any potential conflict in sampling needs and to ensure delivery of both the archaeological and engineering objectives of the survey, vibrocores assigned high priority status were imaged using X-ray computed tomography and magnetic susceptibility and gamma density measurements were taken at the same time using a multi-sensor core logger (MSCL). The images and data were reviewed by a trained geoarchaeologist to identify deposits of interest and select depths for core retention and sampling. This was

undertaken without splitting the cores in half, therefore ensuring whole round core sections remained available for engineering testing, where necessary. The result of this process meant there was no conflict of interest between archaeological and engineering objectives.

4.3.3 All other medium and low priority cores were split open by the geotechnical contractor, after which a second stage of review was undertaken by a geoarchaeologist using the final vibrocore logs and core photographs. Vibrocores were assigned either a high, medium or low priority status based on their perceived geoarchaeological significance as itemised in **Appendix 2** and shown on **Figure 5**.

5 RESULTS

5.1.1 A total of 51 vibrocore logs from the 2021 geotechnical survey were reviewed as part of the Stage 1 works, with the aim of identifying deposits of potential geoarchaeological significance with recommendations made for further geoarchaeological work, if necessary. Outline descriptions based on geotechnical logs are presented in **Appendix 1**, accompanied by an initial interpretation of the deposits.

5.1.2 High strength olive grey clay with pockets of sand, traces of fine to coarse chalk and flint gravel, shell fragments and organic matter, was recorded in two vibrocores (VC36 and VC37) at depths between 0.70 mbsf and 6.30 mbsf. In VC37, this deposit is interbedded with a thin (0.25 m) layer of clayey sand. These deposits are interpreted to have been deposited in a glacial environment given their high strength and heterogeneous nature and have therefore been characterised as glacial till (diamict).

5.1.3 In 29 vibrocores, a medium to high strength slightly reddish brown silty sandy clay with frequent chalk gravel was recorded. These deposits range in thickness between 0.80 m (VC31) and 6.30 m (VC54) and are occasionally interbedded with sands. These sand deposits are recorded within 13 vibrocores and can reach up to 2.0 m (VC36). Shell fragments and organic material were frequently recorded from the clay deposits. The high strength and heterogeneous nature of this deposit also suggests deposition in a glacial environment. However, this brown deposit differs lithologically from the grey diamict interpreted from other vibrocores.

5.1.4 Dense clayey sand and sand and gravel with organic material was recovered in seven vibrocores (VC37, VC59, VC62, VC65, VC74, VC80, VC82) at depths between 0.66 mbsf and 6.30 mbsf in VC80 and VC59, respectively. These deposits are typically recorded beneath laminated sand, silt and clay. However, in VC62 this deposit appears to interbed soft laminated sediment. The coarse nature of these sediments, coupled with the absence of shell fragments, may suggest deposition within a floodplain or active fluvial channel.

5.1.5 Low to medium strength dark greyish brown laminated sand, silt and clay with shell fragments was recovered in 20 vibrocores. These deposits range in thickness from 0.50 m and 5.90 m in VC62 and VC48, respectively. The reintroduction of shell fragments, traces of organic matter and fine-grained laminated appearance, may represent a low energy shallow water environment influenced by marine processes.

5.1.6 Dark brown clayey gyttja was recorded in a single deposit (VC59) as two distinct layers between 5.45 mbsf and 4.80 mbsf, described as containing thin laminae of sand and traces of organic material captured between tidally influenced deposits, and between 2.05 mbsf and 2.75 mbsf. The latter organic layer includes shell fragments and interbeds peat. The high organic content of this deposit suggests formation within a semi-terrestrial

environment, possibly influenced by marine processes, and as such, is considered to have a high priority status.

5.1.7 In five vibrocores (VC53, VC57, VC59, VC73 and VC80), very dark brown occasionally clayey peat is recorded. Wood fragments and traces of shells are also occasionally recorded in these deposits. The peat layers are typically interbedded within tidally influenced alluvium, although in VC57 overly glacial diamict which may suggest deposition within a small hollow or local depression. Despite this, these organic-rich peats were deposited in a semi-terrestrial landscape, possibly a freshwater wetland predominantly situated within or at the margin of a palaeochannel.

5.1.8 Loose to very dense sand with few shell fragments and occasional organic matter was recorded in four vibrocores (VC34, VC49, VC50 and VC74). This deposit typically overlies chalk bedrock, however, in some instances, these sand deposits are represented throughout an entire vibrocore (e.g. VC49). Given the extensive thickness of deposits (<6.0m in VC49) and presence of shell fragments, this deposit is interpreted as shallow marine sands.

5.1.9 In 31 vibrocores, loose gravelly sands with shell and shell fragments were recorded at seabed. This deposit is lithologically dissimilar to shallow marine sands, due to the increased gravel and shell content. In addition, these gravelly sand deposits are comparatively thinner (<2.8 m) than deposits interpreted as shallow marine sand. These deposits are therefore interpreted to represent modern seabed sediments.

6 DISSUSION

6.1.1 The results from the geotechnical vibrocores in SEP and DEP are broadly consistent with the expected stratigraphy (**Table 5**; **Appendix 2**). These deposits collectively comprise a sequence of Pleistocene sediments characteristic of the Swarte Bank Formation and Bolders Bank Formation, overlain by Holocene aged minerogenic, organic, peat deposits and shallow marine sands. The sequence is sealed by modern seabed sediments.

6.1.2 Based on this stage 1 review, marine sands representative of the Egmond Ground Formation were not identified.

6.1.3 The stratigraphy of deposits recovered in vibrocores in the SEP and DEP offshore areas has been summarised in **Table 5**. Holocene age deposits characterised in previous geophysical and geoarchaeological assessments (Wessex Archaeology 2009c; 2014a; 2016; 2020; 2021) as summarised in **Table 4** have been subdivided based on interpreted depositional environment.

Table 5 Shallow stratigraphy of deposits within SEP and DEP

WA Unit	Lithofacies	Description	Formation	Epoch
8	Seabed sediment	Loose gravelly sand with shell fragments	Seabed sediment	Modern/Late Holocene
	Shallow marine sand	Sand/ silty sand with shell fragments	Shallow marine	Mid/Late Holocene
Unit 6b and/or Unit 7	Alluvium and Peat	Low strength laminated sand, silt and clay with shell fragments (tidally influenced)	Botney Cut (potentially equivalent to Elbow Formation which has not previously been mapped in area).	Early to mid-Holocene
		Dark brown gyttja with occasional organic and		

WA Unit	Lithofacies	Description	Formation	Epoch
		shell fragments (organic clay)		
		Dark brown peat		
		Clayey sand/ sand and gravel (fluvial)		
Unit 6a and/or Unit 5	Diamict	Brown high strength silty sandy clay with frequent chalk gravel	Bolders Bank Formation	Late Weichselian
		Medium dense sand that is occasionally slightly gravelly	Bolders Bank Formation – sand unit	
Unit 4	Not identified in vibrocores	n/a	Egmond Ground	Hoxnian/Wolstonian
Unit 3	Diamict	Olive grey high strength clay with pockets of sand and flint and chalk gravel	Swarte Bank Formation	Elsterian
Unit 2	Not identified in vibrocores	n/a	Pre-Devensian Weybourne Channel	Unknown
Unit 1	Not identified in vibrocores	n/a	Chalk	Cretaceous

6.2 Diamict

Swarte Bank Formation

6.2.1 The oldest sediments recovered in vibrocores comprise high strength olive grey clay with pockets of sand, traces of chalk and flint gravel and shell fragments and occasionally interbedded with clayey sand. These heterogeneous sediments are interpreted as representing the infill of deep subglacial valley systems, originally formed during the Elsterian, and subsequently infilled during early part of the Saalian period (MIS 10-9; ca. 350 to 280 ka) (Lonergan *et al*. 2006).

6.2.2 Within the southern North Sea, the Swarte Bank Formation is stratigraphically located beneath marine sands associated with the Holsteinian aged Egmond Ground Formation (**Table 4**). However, the vibrocores recovered from SEP and DEP show a comparatively different structure, with grey glacial diamict preserved at shallow depths (from 0.7 mbsf in VC36) and overlying brown sandy diamict interpreted as a sand unit forming part of the Swarte Bank Formation. Evidence of large-scale glaciotectonic deformation has previously been documented in this area through high-resolution shallow sub-bottom seismic data, with multiple moraine ridges identified comprising folded and thrusted sediments associated with the Swarte Bank Formation (Mellett *et al*. 2020). The variability in the composition of Swarte Bank may reflect reworking and remobilisation through glacitectonism.

Bolders Bank Formation

6.2.3 In the majority of vibrocores recovered from SEP and DEP, lowermost sediments are described as high strength reddish brown silty sandy clay with frequent chalk gravel (Cameron, *et al*. 1992). These deposits are extensively mapped across the southern North Sea (Cotterill *et al*. 2017) and correlate to the Bolders Bank Formation, a subglacial diamicton laid down by the British Irish Ice Sheet (BIIS) during the late Weichselian (Davies *et al*. 2011).

6.2.4 A unique characteristic observed within many deposits interpreted as the Bolders Bank Formation, is a thin (< 2 m) lens of dense sand separating deposits of chalky clay. This

tripartite subdivision of the Bolders Bank Formation into upper, middle and lower units based on changes in lithology has been recognised across the southern North Sea and within its onshore equivalents, such as the Holderness Glacigenic Formation (Carr, *et al*. 2006; Evans and Thompson 2010). These sand layers intersecting high strength clay are interpreted as glacial outwash sands and possibly represent ice-marginal deposits developing in response to multiple phases of ice expansion and retreat during the Weichselian.

6.2.5 Despite being deposited in different glaciations, both the Swarte Bank Formation and Bolders Bank Formation have low geoarchaeological potential as they were deposited by ice during the Elsterian and Weichselian periods, repetitively, when the North Sea would have been unsuitable for hominin occupation.

6.3 Alluvium and Peat

6.3.1 In SEP and DEP, Pleistocene sediments are overlain by Holocene aged deposits and include peats, organic clay (or 'gyttja') and minerogenic deposits, laid down at a time when the southern North Sea was subaerially exposed prior to sea-level transgression. Collectively, these deposits correspond to channel infill of the Botney Cut Formation, however may potentially be equivalent to the Elbow Formation mapped further offshore (Cameron *et al*. 1992; Stoker *et al*. 2011).

6.3.2 A series of deposits comprising clayey sand and sand and gravel recovered from SEP and DEP, have been interpreted as representing deposition within a floodplain or active fluvial channel. In VC65, this coarse-grained deposit overlies the Bolders Bank Formation and as it is described as containing chalk gravel, could possibly be interpreted as glaciofluvial. Interestingly, in VC62, tidally-influenced sediments are intersected by fluvial deposits, possibly showing a fluctuating landscape, with a temporary fall in relative sea level and the reactivation of channel activity. A sub-aerially exposed North Sea intersected by channels would have formed an attractive landscape for Mesolithic communities, with floodplain deposits possibly containing *in situ* archaeological material. Therefore, this deposit is assigned medium priority status.

6.3.3 In most instances, deposits interpreted as fluvial in nature are overlain by laminated sand, silt and clay with shell, representing deposition in an environment influenced by tidal processes. These minerogenic sediments are frequently mapped within former channel systems and document the progressive inundation of the North Sea during the early Holocene. Given their potential to preserve inorganic microfossils, these deposits have been assigned a medium priority status.

6.3.4 Several vibrocores recovered from the SEP and DEP offshore areas record alluvium interbedded with peat and organic clay; the latter often termed 'gyttja' (Waller and Kirby 2021).

6.3.5 Organic clay units are recorded within a single vibrocore (VC59) as interbedding tidally influenced alluvium. Gyttja is organic fine-grained sediment which forms below water level, generally in limnic environments (Waller and Kirby 2021). Equivalent deposits were previously recorded from SEP and DEP (Brown *et al*. 2018) and following a palaeoenvironmental assessment, were suggested as showing the gradual infilling of a proglacial freshwater lake system between 12,700 and 9260 cal. BP and therefore documenting a shift from the warmer Bølling–Allerød interstadial to colder Younger Dryas stadial (Brown *et al*. 2018). However, given the age of these deposits, it is likely that the organic clay preserved in VC59 reflects localised ponding of water within an environment becoming increasingly dominated by tidal processes. Further palaeoenvironmental

assessment would be required to determine if these sediments were deposited in either freshwater or brackish conditions.

6.3.6 Peat deposits have also been recovered from five vibrocores from SEP and DEP (VC53, VC57, VC59, VC73 and VC80). Wood fragments are frequently observed within these organic sediments and likely represent deposition within a semi-terrestrial environment which developed during the Holocene and prior to final marine transgression. In VC59, a transition is observed with the deposition of peat, followed by organic clay and the reformation of peat. This demonstrates a distinct change land-ocean interactions, with peat development ceasing due to the reactivation of channel possibly as a result of rising sea levels. Such local changes in palaeogeography are likely amplified in the southern North Sea due to an extensive array of palaeochannels dissecting the landscape (**Figure 5**).

6.3.7 Peat deposits have the highest potential for preserving material for radiocarbon dating, along with a range of palaeoenvironmental remains (e.g. pollen and plant macrofossils) suitable for reconstructing past landscape and environmental change, and investigating evidence for human activity during the Upper Palaeolithic and Early Mesolithic (e.g. evidence for burning).

6.4 Shallow marine

6.4.1 Extensive deposits occasionally exceeding 6 m (e.g. VC49) comprising shallow marine sands have been recovered across SEP and DEP offshore areas (**Appendix 1**). Where present, these sands are either underlain by bedrock or Bolders Bank Formation, or alternatively cap alluvium. Although not mapped using sub-bottom profiler (SBP) geophysical data (**Figure 5**), it is possible these extensive sand deposits reflect the formation of sand waves or ripple/dune features on the seabed. Shallow marine sands are considered low geoarchaeological potential.

6.5 Seabed sediments

6.5.1 As sea levels stabilised during the Mid-Holocene, marine processes began to rework the uppermost deposits in places, forming gravelly sands with frequent shell and shell fragments that are observed in a number of vibrocores across SEP and DEP. Although there is potential for these deposits to contain reworked archaeology or bury palaeolandscape features, their archaeological potential is considered low.

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

7.1.1 The lithostratigraphic framework defined based on deposits recovered from vibrocores within SEP and DEP is presented in **Table 5**. Two deposits, including tidally influenced and fluvial minerogenic alluvium, have been assigned a medium geoarchaeological potential. Organic clay and peats have been assigned high geoarchaeological potential. No further palaeoenvironmental assessment is recommended for the following units which have low geoarchaeological potential: seabed sediments, shallow marine sand, Bolders Bank Formation and Swarte Bank Formation.

7.1.2 Based on the results of the Stage 1 marine geoarchaeological assessment of 2021 geotechnical data, recommendations are made for Stage 2 geoarchaeological recording and deposit modelling as outlined below, taking into account the prehistoric research management framework for the North Sea (Peeters 2009) and the national maritime research framework (Ransley *et al*. 2013).

7.1.3 This review has been undertaken in parallel with scheduled engineering testing on selected samples from SEP and DEP. To ensure samples were secured for archaeological purposes, X-Ray images and MSCL data from vibrocores identified as having high geoarchaeological potential based on preliminary geotechnical logs were reviewed by a trained geoarchaeological consultant and entire cores sections were requested from VC74, VC79 and VC80. These samples were shipped to Wessex Archaeology and are currently stored awaiting Stage 2 geoarchaeological recording. The remaining cores identified as having high and medium priority status during the review of final geotechnical logs are outlined below and access to these cores will be required to support Stage 2 geoarchaeological recording.

7.2 Organic clay and peat

7.2.1 Peat was recovered in five vibrocores (VC53, VC57, VC59, VC73 and VC80) and organic clay from a single vibrocore (VC59). Peat and organic clay have been assigned high priority status and have high potential to preserve palaeoenvironmental and dating material. It is recommended all samples containing peat and organic clay are recorded by a geoarchaeologist to determine their suitability for further palaeoenvironmental assessment to improve current understanding of age, environment and vegetation history.

7.3 Alluvium – minerogenic

7.3.1 A series of minerogenic deposits characterised by laminated sand, silt and clay often with shell fragments, and gravelly and clayey sands, have been interpreted to represent the Botney Cut Formation, with deposition in tidally influenced and fluvial environments, respectively. These deposits likely reflect a transition from a sub-aerially exposed southern North Sea to increasing marine conditions under the influence of early Holocene rising sea levels. Given their potential to preserve inorganic microfossils, these deposits are considered to have medium priority status. Given most vibrocores containing medium priority deposits are located within previously mapped palaeochannels or localised depressions, it is recommended that all medium priority cores are recorded by a geoarchaeologist, in order to ground-truth the interpretations based on geotechnical logs and assess potential for further palaeoenvironmental assessment (VC35, VC37, VC41, VC44, VC48, VC61, VC62, VC65, VC68, VC69, VC70, VC71, VC74, VC76, VC77, VC79 and VC82).

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APPENDICES

Appendix 1 – Vibrocore locations

Hole id	Easting (m)	Northing (m)	Elevation (m OD)
EQ22451-VC-31	384200.49	384201.27	26.08
EQ22451-VC-32	383949.22	383949.22	21.88
EQ22451-VC-33	383511.66	5881502.5	22.52
EQ22451-VC-34	383132.47	5878613.71	21.19
EQ22451-VC-35	383132.47	5878613.71	21.19
EQ22451-VC-36	382969.97	5878136.61	21.42
EQ22451-VC-37	382689.61	5877185.37	20.07
EQ22451-VC-38	382278.27	5876087.32	22.9
EQ22451-VC-39	381597.7	5875133.77	19.33
EQ22451-VC-40	381016.8	5874311.26	18.38
EQ22451-VC-41	379777.93	5873138.04	16.36
EQ22451-VC-42	379164.79	5872432.54	14.8
EQ22451-VC-43	378236.47	5871378.36	12.65
EQ22451-VC-44	377571.83	5870490.4	10.2
EQ22451-VC-45	377343.9	5870131.88	11.43
EQ22451-VC-46	376433.79	5869696.11	10.38
EQ22451-VC-47	375703.01	5869373.72	9.43
EQ22451-VC-48	384453.63	5909367.85	14.73
EQ22451-VC-49	384776.29	5910850.2	13.96
EQ22451-VC-50	384453.63	5909367.85	14.73
EQ22451-VC-51	384070.97	5907303.85	20.8
EQ22451-VC-52	383789.63	5906656.06	20.99
EQ22451-VC-53	383700.2	5905571.38	22.41
EQ22451-VC-54	383470.78	5904497.46	21.78
EQ22451-VC-55	382893.95	5901797.08	19.93
EQ22451-VC-56	382486.57	5900219.72	19.66
EQ22451-VC-57	382231.97	5899010.75	19.07
EQ22451-VC-58	381924.98	5897997.37	18.96
EQ22451-VC-59	381770.01	5896883.59	25.26
EQ22451-VC-60	381601.85	5896146.39	22.77
EQ22451-VC-61	381405.3	5895238.46	26.87
EQ22451-VC-62	381285.34	5894634.87	26.9
EQ22451-VC-63	381096.03	5893778.88	19.67

Hole id	Easting (m)	Northing (m)	Elevation (m OD)
EQ22451-VC-64	380784.98	5892353.73	19.34
EQ22451-VC-65	381952.45	5891348.31	20.14
EQ22451-VC-66	382639.93	5891921.9	21.32
EQ22451-VC-67	383436.14	5892207.09	21.53
EQ22451-VC-68	384435.93	5892567.59	26.71
EQ22451-VC-69	384652.45	5892645.41	25.45
EQ22451-VC-70	385051.06	5892785.67	22.41
EQ22451-VC-71	385658.03	5893002.58	20.21
EQ22451-VC-72	386304.93	5893236.36	22.33
EQ22451-VC-73	387012.54	5893491.99	24.01
EQ22451-VC-74	387889.37	5893806.77	24.08
EQ22451-VC-76	389783.94	5894486.98	23.23
EQ22451-VC-77	390637.6	5894791.61	23.03
EQ22451-VC-78	391385.63	5895050.78	23.03
EQ22451-VC-79	392561.54	5895472.79	20.47
EQ22451-VC-80	393408.61	5895776.38	22.56
EQ22451-VC-81	394360.7	5896214.03	23.56
EQ22451-VC-82	395427.44	5896435.51	22.58

Appendix 2 – Stage 1 geotechnical review

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-31	0	0.3	Loose slightly gravelly sand with rare shell and shell fragments	Seabed sediments	Low
EQ22451-VC-31	0.3	1.1	Medium to high strength brown sandy clay with occasional shell fragments and clasts of chalk	Bolders Bank Formation	Low
EQ22451-VC-31	1.1	6.2	Chalk	Bedrock	Low
EQ22451-VC-32	0	0.5	Sand with occasional gravel and shell fragments	Seabed sediments	Low
EQ22451-VC-32	0.5	3.1	Brown high to very high strength clay with few pockets of sand and shell fragments and traces of chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-32	3.1	4.6	Medium dense to very dense gravelly sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-32	4.6	6.2	High strength sandy clay with few fine to medium chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-33	0	0.3	Dark brown high strength clay with few clasts of chalk	Bolders Bank Formation	Low
EQ22451-VC-33	0.3	1.8	Medium to very dense light grey sand with traces of organic material and fine to medium gravel	Bolders Bank Formation - sand unit	Low
EQ22451-VC-33	1.8	2.6	Very high strength clay with few chalk gravel clasts	Bolders Bank Formation	Low
EQ22451-VC-33	2.6	6.3	Chalk	Bedrock	Low
EQ22451-VC-34	0	0.8	Loose sand with few shell fragments	Shallow marine sands	Low
EQ22451-VC-34	0.8	4.7	Brown medium to very dense sand with few shell fragments and fine to coarse flint gravel	Shallow marine sands	Low
EQ22451-VC-34	4.7	5.6	Chalk	Bedrock	Low
EQ22451-VC-35	0	0.2	Sand with few shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-35	0.2	1.7	Very dark grey medium to high strength clay with thin laminae of fine sand and silt with few shell and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-35	1.7	6.3	Chalk	Bedrock	Low
EQ22451-VC-36	0	0.7	Loose to very loose brown clayey gravelly sand with few shells and shell fragments	Seabed sediments	Low
EQ22451-VC-36	0.7	3.3	Light olive grey high to very high strength clay with few coarse chalk gravel and pockets of sand	Swarte Bank	Low
EQ22451-VC-36	3.3	5.3	Dense gravelly sand with traces of fine to medium chalk gravel	Swarte Bank	Low
EQ22451-VC-37	0	0.15	Sand with many shell fragments and traces of gravel	Seabed sediments	Low
EQ22451-VC-37	0.15	1.5	Very dark grey low to medium strength clay with closely spaced thin laminae of fine sand and silt with few shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-37	1.5	2.35	Brown silty sandy clay with few shell fragments and traces of organic matter	Alluvium - tidally influenced	Medium
EQ22451-VC-37	2.35	2.75	Very dark greyish brown sand with few fine to coarse flint gravel and fine to medium chalk clasts	Alluvium - fluvial	Medium

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-37	2.75	3.3	Dark greyish brown very high strength clay with traces of fine to medium chalk gravel, shell fragments and organic material	Swarte Bank	Low
EQ22451-VC-37	3.3	3.55	Dark yellowish grey clayey sand with fine to medium chalk gravel	Swarte Bank	Low
EQ22451-VC-37	3.55	6.3	Light olive grey to dark grey very high strength clay with fine to medium chalk gravel and shell fragments and organic matter	Swarte Bank	Low
EQ22451-VC-38	0	0.2	Loose dark brown gravelly sand with few shell fragments	Seabed sediments	Low
EQ22451-VC-38	0.2	0.6	Medium to high strength clay with few fine to medium chalk gravel and sand pockets and shell fragments	Bolders Bank Formation	Low
EQ22451-VC-38	0.6	6.3	Chalk	Bedrock	Low
EQ22451-VC-39	0	1.4	Very high strength clay with traces of organic matter and few fine to medium flint and chalk gravel clasts	Bolders Bank Formation	Low
EQ22451-VC-39	1.4	6.3	Chalk	Bedrock	Low
EQ22451-VC-40	0	3.1	Low to very high strength clay with pockets of sand, few chalk gravel clasts and organic material	Bolders Bank Formation	Low
EQ22451-VC-40	3.1	6.1	Chalk	Bedrock	Low
EQ22451-VC-41	0	3.7	Very dark grey low to high strength clay with many thin laminae of sand and few pockets of sand with shell fragments and organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-41	3.7	6.3	Chalk	Bedrock	Low
EQ22451-VC-42	0	0.4	Loose to medium dense gravelly sand	Seabed sediments	Low
EQ22451-VC-42	0.4	3	High to very high strength brown silty clay with few fine to coarse flint and chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-42	3	3.5	Medium dense silty sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-42	3.5	6.3	Chalk	Bedrock	Low
EQ22451-VC-43	0	1.2	Medium to very high strength brown clay with few fine to medium chalk and flint and organic matter and shell fragments	Bolders Bank Formation	Low
EQ22451-VC-43	1.2	2.1	Loose to dense dark brown fine to medium silty sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-43	2.1	6.2	Chalk	Bedrock	Low
EQ22451-VC-44	0	1.1	Very dark grey sand with thin diagonal laminae of clay, few shell fragments and medium to coarse gravel	Alluvium - tidally influenced	Medium
EQ22451-VC-44	1.1	1.3	Dark grey medium strength sandy clay with black minerogenic specks	Alluvium - tidally influenced	Medium
EQ22451-VC-44	1.3	3.1	Medium dense to very dense dark greenish grey sand with fine to coarse gravel and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-44	3.1	6.1	Chalk	Bedrock	Low
EQ22451-VC-45	0	0.8	Sand with few fine to coarse gravel and shell fragments	Seabed sediments	Low
EQ22451-VC-45	0.8	5.3	Chalk	Bedrock	Low

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-46	0	0.2	Loose to dense gravelly sand	Seabed sediments	Low
EQ22451-VC-46	0.2	6.2	Chalk	Bedrock	Low
EQ22451-VC-47	0	6.2	Chalk	Bedrock	Low
EQ22451-VC-48	0	5.9	Loose to dense sand with closely spaced thin laminae of clay and pockets of organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-49	0	6	Loose to very dense sand with traces of shell fragments	Shallow marine sands	Low
EQ22451-VC-50	0	3	Loose to very dense sand with few shell fragments	Shallow marine sands	Low
EQ22451-VC-50	3	6.3	High strength slightly gravelly clay with traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-51	0	0.2	Sand with shells and shell fragments	Seabed sediments	Low
EQ22451-VC-51	0.2	6.3	High strength clay with chalk gravel and few shell fragments	Bolders Bank Formation	Low
EQ22451-VC-52	0	6.2	High strength clay with pockets of sand and shell fragments and chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-53	0	4.4	Medium strength clay with thick laminae of sand and traces of shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-53	4.4	4.7	Very dark brown peat with some wood fragments	Peat	High
EQ22451-VC-53	4.7	6.3	Very dark greyish brown sandy fine to medium gravel with few shell and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-54	0	6.3	High strength dark brown clay with chalk gravel and shell fragments	Bolders Bank Formation	Low
EQ22451-VC-55	0	0.3	Sand with shell fragments	Seabed sediments	Low
EQ22451-VC-55	0.3	2.8	High strength clay with chalk gravel and shell fragments and traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-55	2.8	3.2	Medium dense sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-55	3.2	6.3	High strength sandy clay	Bolders Bank Formation	Low
EQ22451-VC-56	0	0.4	Dark yellowish brown clayey sand with shell fragments and few gravel clasts	Seabed sediments	Low
EQ22451-VC-56	0.4	2.1	Medium to high strength clay with chalk gravel and pockets of sand with shell fragments	Bolders Bank Formation	Low
EQ22451-VC-56	2.1	2.4	Loose to medium dense sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-56	2.4	6.3	High strength sandy clay with sand layer and chalk gravel clasts	Bolders Bank Formation	Low
EQ22451-VC-57	0	0.4	Dark brown clayey peat with traces of fine to medium gravel	Peat	High
EQ22451-VC-57	0.4	6.3	Medium to very high strength clay with fine to medium chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-58	0	0.9	Sand with few shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-58	0.9	6.2	Medium to very high strength dark brown clay with chalk gravel and few pockets of sand and silt with shell fragments and traces of organic matter	Bolders Bank Formation	Low

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-59	0	0.8	Loose fine to coarse sand with shell fragments and few fine to medium gravel	Seabed sediments	Low
EQ22451-VC-59	0.8	1.6	Very dark greyish brown sandy clay with thin laminae of silt with traces of organic material and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-59	1.6	1.75	Very dark greyish brown clayey sand with many shells and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-59	1.75	2.05	Very dark brown peat with a thick 10-13mm piece of wood	Peat	High
EQ22451-VC-59	2.05	2.75	Olive brown sandy clayey gyttja with a few shells and shell fragments	Organic Clay	High
EQ22451-VC-59	2.75	3.1	Very dark brown clayey peat with many thin laminae	Peat	High
EQ22451-VC-59	3.1	4.8	Very dark grey clay with thin laminae of fine sand and silt with traces of organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-59	4.8	5.45	Very dark brown gyttja with thin laminae of fine sand and traces of organic material	Organic Clay	High
EQ22451-VC-59	5.45	5.8	Dark grey clay with thin laminae of fine sand and traces of shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-59	5.8	6.3	Medium dense clayey sand	Alluvium - fluvial	Medium
EQ22451-VC-60	0	6.3	High strength dark brown clay with chalk gravel and pockets of sand with shell fragments and traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-61	0	0.5	Sand with traces of gravel and shell fragments	Seabed sediments	Low
EQ22451-VC-61	0.5	6.3	Medium strength dark grey clay with thin laminae of sand and silt with traces of organic material and pockets of sand with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-62	0	0.5	Dark brown sand with few fine to medium gravel	Seabed sediments	Low
EQ22451-VC-62	0.5	1	Dark brown sand with closely spaced thin laminae of clay	Alluvium - tidally influenced	Medium
EQ22451-VC-62	1	1.34	Very dark grey sandy clay with few shells and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-62	1.34	1.68	Dark brown sand with thin laminae of clay and traces of fine to medium flint gravel	Alluvium - fluvial	Medium
EQ22451-VC-62	1.68	1.88	Sandy fine to medium gravel	Alluvium - fluvial	Medium
EQ22451-VC-62	1.88	2	Dark yellowish brown sand	Alluvium - fluvial	Medium
EQ22451-VC-62	2	4.5	Very dark clay medium strength clay with laminae of sand and silt with few shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-62	4.5	6.3	Very dark grey clayey sand with traces of shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-63	0	5.8	Very high strength clay with few chalk gravel clasts and traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-64	0	0.3	Clayey sand with shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-64	0.3	3.8	Medium to high strength very dark grey clay with pockets of sand with shell fragments and chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-64	3.8	4.5	Medium dense to dense clayey sand	Bolders Bank Formation - sand unit	Low

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-64	4.5	6.3	Very high strength sandy silty clay	Bolders Bank Formation	Low
EQ22451-VC-65	0	0.7	Loose sand with few shell fragments and traces of clay pockets	Seabed sediments	Low
EQ22451-VC-65	0.7	1.2	Dark brown medium to high strength clay with thin laminae of sand and silt with very few fine chalk gravel	Alluvium - tidally influenced	Medium
EQ22451-VC-65	1.2	2.2	Dense sand with few fine to medium chalk gravel	Alluvium - fluvial	Medium
EQ22451-VC-65	2.2	6.3	Very high strength clay with chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-66	0	1.1	Loose to dense gravelly sand with shell fragments	Seabed sediments	Low
EQ22451-VC-66	1.1	6.3	Very high strength clay with few chalk gravel clasts and layers of sand	Bolders Bank Formation	Low
EQ22451-VC-67	0	2.1	High strength dark brown clay with few chalk gravel clasts and pockets of sand with shell fragments	Bolders Bank Formation	Low
EQ22451-VC-67	2.1	2.8	Dark brown sand with few fine to medium gravel	Bolders Bank Formation - sand unit	Low
EQ22451-VC-67	2.8	6.3	Medium to high strength sandy clay with chalk gravel	Bolders Bank Formation	Low
EQ22451-VC-68	0	2.1	Sand with shell and gravel	Seabed sediments	Low
EQ22451-VC-68	2.1	6.3	Dark greenish grey medium to high strength clay with laminae of fine sand and silt with shell fragments and thin layers of organic matter	Alluvium - tidally influenced	Medium
EQ22451-VC-69	0	0.4	Loose sand with few shells and shell fragments and traces of gravel	Seabed sediments	Low
EQ22451-VC-69	0.4	6.3	Low to high strength silty clay with laminae of fine sand and silt and pockets of sand with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-70	0	2.8	Loose to medium dense gravelly sand	Seabed sediments	Low
EQ22451-VC-70	2.8	6.3	Very dark grey clay with thin to thick laminae of fine sand and silt	Alluvium - tidally influenced	Medium
EQ22451-VC-71	0	2	Dark greenish grey sand with laminae of clay and pockets of shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-71	2	6.3	Medium to high strength clay with laminae of sand and silt with occasional traces of shells and organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-72	0	1	Dark brown high strength clay with pockets of sand with shell fragments chalk gravel and traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-72	1	2	Dense dark brown clayey sand with traces of chalk gravel and pockets of sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-72	2	5.1	High strength dark brown clay with chalk gravel and sand layers	Bolders Bank Formation	Low
EQ22451-VC-72	5.1	6.2	Dense clayey sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-73	0	0.2	Loose gravelly sand	Seabed sediments	Low

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-73	0.2	1.85	Dark greenish grey clay with extremely closely spaced thin laminae of organic matter (sea weeds) fine silt with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-73	1.85	1.98	Very dark brown peat with few shell fragments	Peat	High
EQ22451-VC-73	1.98	4	Very dark greyish brown clay with traces of organic material and slightly sandy thick laminae of clayey sand and shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-73	4	6.2	High strength brown clay with chalk gravel and thin laminae of fine to coarse sand	Bolders Bank Formation	Low
EQ22451-VC-74	0	0.5	Loose to dense dark grey gravelly sand with traces of shell and shell fragments	Seabed sediments	Low
EQ22451-VC-74	0.5	3.6	Light brown to grey fine to coarse sand with shell fragments and occasional thin laminae of organic matter	Shallow marine sands	Low
EQ22451-VC-74	3.6	5	Medium to very high strength sandy clay	Alluvium - tidally influenced	Medium
EQ22451-VC-74	5	6.2	Medium to very dense gravelly sand	Alluvium - fluvial	Medium
EQ22451-VC-76	0	0.4	Sand with few shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-76	0.4	1.3	Medium strength clay with laminae of sand and silt and few pockets of sand with shell fragments and traces of organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-76	1.3	3.7	High strength clay with chalk gravel and traces of organic material	Bolders Bank Formation	Low
EQ22451-VC-76	3.7	5.6	Medium dense to dense gravelly sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-77	0	0.4	Very dark grey slightly clayey sand with few shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-77	0.4	3.3	Medium strength clay with laminae of sand with some oxidised organic material and pockets of sand with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-77	3.3	6.2	High strength clay with chalk gravel and sand layers	Bolders Bank Formation	Low
EQ22451-VC-78	0	0.2	Loose gravelly sand	Seabed sediments	Low
EQ22451-VC-78	0.2	4.2	Dark brown high to very high strength clay with chalk gravel and pockets of sand with shell fragments	Bolders Bank Formation	Low
EQ22451-VC-79	0	1.1	Sand with shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-79	1.1	5	Medium strength very dark grey clay with thin laminae of sand and silt with organic material and traces of shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-79	5	6.3	Clayey sand with traces of fine to medium gravel and shell fragments and organic material	Alluvium - tidally influenced	Medium
EQ22451-VC-80	0	0.2	Loose sand with traces of shell fragments and organic matter	Seabed sediments	Low
EQ22451-VC-80	0.2	0.66	Very dark brown peat with traces of shell fragments and few pockets of sand	Peat	High
EQ22451-VC-80	0.66	1.3	Very dark grey sand with traces of organic material	Alluvium - fluvial	Medium
EQ22451-VC-80	1.3	5.2	Medium to high strength dark brown clay with gravel and organic material	Bolders Bank Formation	Low

id	Depth from (m)	Depth to (m)	Description	Interpretation/ Unit	Priority
EQ22451-VC-80	5.2	5.4	Medium dense sand	Bolders Bank Formation - sand unit	Low
EQ22451-VC-81	0	0.3	Loose sand with shell fragments and gravel	Seabed sediments	Low
EQ22451-VC-81	0.3	0.8	Medium to high strength clay with chalk gravel and pockets of sand with shell fragments	Bolders Bank Formation	Low
EQ22451-VC-81	0.8	2.2	Dense gravelly sand with few shell fragments and pockets of clay	Bolders Bank Formation - sand unit	Low
EQ22451-VC-81	2.2	5.8	High strength dark brown sandy clay with few pockets of sand with shell fragments	Bolders Bank Formation	Low
EQ22451-VC-82	0	0.3	Loose sand with few shell fragments	Seabed sediments	Low
EQ22451-VC-82	0.3	1.1	Medium to high strength dark greyish brown silty clay with few pockets of sandy and silty clay	Alluvium - tidally influenced	Medium
EQ22451-VC-82	1.1	2.6	Very dark greyish brown clayey sand with thin diagonal laminae of clay and sand and few pockets of clay with blocky structure	Alluvium - tidally influenced	Medium
EQ22451-VC-82	2.6	4.3	Dark brown clay with laminae of sand with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-82	4.3	4.5	Dark greyish brown sandy clay with laminae of sand with shell fragments	Alluvium - tidally influenced	Medium
EQ22451-VC-82	4.5	6.3	Medium dense to dense sand	Alluvium - fluvial	Medium