DONG ENERGY

Gunfleet Sands 3 Demonstration Project

Stage 3 Geoarchaeological Assessment Report

October, 2013

MARITIME ARCHAEOLOGY LTD

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Non-technical summary

This report presents a Stage 3 geoarchaeological assessment (Sub-sampling and assessment) for the Gunfleet Sands 03 (GFS03) Demonstartion Project on behalf of the Client, DONG Energy. This work forms part of the archaeological WSI Work Package 1 - *Archaeological Assessment of Boreholes/ Vibrocores* with the aim of developing a deposit model for the development area.

The staged approach to the archaeological and palaeoenvironmental investigation of the cores is outlined below and explained in: *Historic and Offshore Geotechnical Investigations and Historic Environment Analysis guidance* (COWRIE, 2011).

The 4 Stages are:

- Stage 1 – Archaeological review of geotechnical logs and (where practical) archaeological presence during core extraction (MA Ltd., 2012b, 2012c);
- Stage 2 – Splitting and recording cores (MA Ltd. 2012b, 2012c);
- Stage 3 – Sub-sampling and assessment (This report), and;
- Stage 4 – Analysis and dating.

Prior to the installation of the Project and the offshore export cable connecting GFS03 to an onshore substation, an archaeological review of boreholes collected onshore and vibrocores collected along the offshore export cable route was undertaken (Geoarchaeological assessment Stages 1 and 2) (MA Ltd., 2012b and 2012c). The cores were collected in order to mitigate the impact of the Demonstration Project and the export cable route installation by providing archaeological information as specified in the Archaeological Written Scheme of Investigation (WSI) (MA Ltd., 2012d).

Through an initial analysis (Stage 2) of the cores a relatively uniform sequence of deposits was identified. It appears to be associated with both Holocene and Pleistocene channels and is likely to be representative of in-fill deposits that demonstrate a long sequence of development (MA Ltd., 2012b 2012c). In order to be able to fully understand the deposits and the evidence the cores provide on the palaeoenvironmental and geomorphological development of this area, further sampling and assessment was recommended in order to assess future analysis requirements.

This Stage 3 geoarchaeological assessment follows the recommendations previously made by MA Ltd. (MA Ltd., 2012c). The key aim of Stage 3 was to sub-sample and assess the sediments present in the cores for environmental indicators and identify cores and sediments that contain material that will yield useful palaeoenvironmental and geomorphological development information.

The results from the Stage 3 assessment indicate that the sub-sampled sediments contain environmental representations. This is visible in the pollen, diatom, foraminifera and plant records. The sub-samples further confirm that the sediments are generally marine sediments containing marine plants, various foraminifera, molluscs and diatoms.

This Stage 3 geoarchaeological assessment has determined that a Stage 4 geoarchaeological analysis would be beneficial to fully understand the character of the deposits and the evidence they provide on the palaeoenvironmental and geomorphological development of this area. There are clear questions over the date and nature of the deposits represented and their relationship to the known evidence of the Clacton Channel deposits.

1 Introduction

Maritime Archaeology Ltd. (MA Ltd.) has been commissioned by DONG Energy to provide an archaeological assessment of sub-samples derived from boreholes and vibrocores collected onshore and offshore along the export cable route related to the Gunfleet Sands 3 Demonstration Project. This report details the assessment of sub-samples derived from the cores with the aim to identify material that has the potential to yield results during a further, in depth analysis. The results of this assessment have been used to make recommendations for further analysis.

1.1 Brief Scheme Background

The Gunfleet Sands (GFS) offshore wind farm, is located approximately 8.5 km southeast of Clacton-on-Sea in Essex. It consists of the operational GFS 1 and GFS 2 projects. Consent was granted for GFS 1 in 2004 and for GFS 2 in 2008. The combined GFS 1 and 2 projects consist of 48 operational turbines. The development is situated within the 12 nm territorial limit of England.

In August 2010, DONG Energy was awarded a demonstration lease by The Crown Estate for a site to the south-west of the GFS 2 array to construct two demonstration turbines. This is known as the Gunfleet Sands 3 - Demonstration Project (GFS 3), (**Figure 1)**. The majority of the GFS 3 site (approximately 80%) lies within the originally consented GFS 2 site. The GFS 3 turbines required an additional export cable to connect the turbines to land as the cable associated with GFS 1&2 was not sufficient to allow maximum capacity use of the GFS 3 turbines.

An Environmental Statement (ES) was initially produced for GFS 3 when it was planned to utilise the existing export cable from GFS 1&2 (DONG Energy, 2010), this drew on works previously undertaken in relation to the GFS 1&2 sites. However, due to the requirement for an additional export cable the Marine Management Organisation (MMO) requested an addendum to the ES to cover the revised scope of works for the entire GFS 3 scheme. DONG Energy has produced two addendum reports:

- GFS 3 Onshore Addendum (considering all work above Mean High Water Spring (MHWS);
- GFS 3 Offshore Addendum (considering all work below MHWS).

The Onshore and Offshore Addendum documents identify the known and potential archaeology within the development area, review potential impacts and put forward mitigation proposals. Further survey data was gathered in 2011 in the near-shore zone and in 2012 along the cable route for the purposes of planning the final path of the export cable route. An archaeological review of the data was undertaken by Maritime Archaeology Ltd in July, 2012 (MA Ltd., 2012a).

The geoarchaeological and palaeoenvironmental potential has previously been assessed in two separate Stage 1 and 2 reports; *Gunfleet Sands 3: Demonstration Project- Assessment of Onshore Core Samples* (MA Ltd., 2012b) focused on Stage 2 assessment of the cores collected from the onshore area and *Gunfleet Sands 3: Demonstration Project-Archaeological Assessment of Offshore Geotechnical Cores* (MA Ltd., 2012c) assessed the 18 vibrocores collected in the offshore zone for Stage 2 archaeological potential. This report

is following the recommendations put forward by MA Ltd. in 2012 (MA Ltd., 2012c) regarding the deposits identified during the geoarchaeological campaign Stages 1 and 2.

1.2 PROJECT DESIGN DETAILS

The GFS 3 project involved the construction of two steel monopiles with a 6 m diameter within the previously consented area of GFS 2. The test turbines were installed in January 2013 and officially inaugurated In September 2013. The construction is using one layer of scour protection around the turbine bases up to a radius of 20-25 m. The turbines are connected to land through an export cable route which reaches land at the Martello Bay coach and car park to the east of the junction of West Road and Hastings Avenue. An initial archaeological and palaeoenvironmental review of the onshore cable route and transition jointing bay was undertaken by MA Ltd. in 2012 (MA Ltd., 2012b).

Installation of the proposed GFS 3 Export cable between the marine and terrestrial area required Horizontal Directional Drilling (HDD) to establish a landfall under the beach. The export cable is connected to the substation with a three core export transmission cable. From this point the cable was laid for approximately 9 km until it reached the wind turbines located circa 8.5 km southeast of Clacton-on Sea.

Through the archaeological assessment works undertaken in support of the production of the ES it has been largely possible to avoid direct physical impacts on known archaeological sites.

During the two geotechnical campaigns, a total of five cone penetration tests (CPTU), one MOSTAP, seven boreholes and 18 offshore vibrocores were collected in the development area (**Figure 2**).

Four boreholes (101A_1, 101A_2 101B and 103) and two CPTU tests (101 and 101a) were drilled within the Transition Jointing Bay (TJB) and the associated mudpit. Within the northern area of the terrestrial cable trench three boreholes (104-106) were drilled to a depth that reached the London Clay. Four CPTU tests (112B, 112C, 112D and 112E) were collected within the intertidal zone (sea defence to surf zone). A MOSTAP sample was taken coincident with CPTU 112D.

Along the export cable route, three vibrocores (113, 114 and 115) were drilled within the area of the planned HDD works. The vibrocores were drilled to depths between 2.10 - 2.22 m. Seven vibrocores (201-207) were positioned along the export cable route based on the seismic interpretation undertaken by Wessex Archaeology (Dong Energy, 2011b) to target potential pre-historic channel deposits.

Further, five vibrocores (301-305) were collected for geotechnical purposes; the locations of the cores have been determined by engineering requirements. All the geotechnical cores stated above were reviewed for archaeological potential (MA Ltd., 2012b, 2012c).

Sub-samples from the above cores were gathered as a part of this assessment based on the results previously recommended (MA Ltd., 2012c).

1.3 AGREED MITIGATION APPROACH

This Stage 3 geoarchaeological assessment follows the recommendations previously made by MA Ltd. (MA Ltd., 2012c).

This work forms part of Work Package 1 - *Archaeological Assessment of Boreholes/ Vibrocores* with the aim of developing a deposit model for the development area. The staged approach to the archaeological and palaeoenvironmental investigation of the cores is outlined below and within the agreed WSI for the development (MA Ltd., 2012d).

The 4 Stages are:

- Stage 1 – Archaeological review of geotechnical logs and (where practical) archaeological presence during core extraction (MA Ltd., 2012b, 2012c)
- Stage 2 – Splitting and recording geotechnical/ archaeological cores (MA Ltd. 2012b, 2012c)
- Stage 3 – Sub-sampling and assessment (This report)
- Stage 4 – Analysis and dating

The compensatory mitigation of impact on palaeoenvironmental deposits is based on the idea that while the deposits will be impacted by the development, the sediments recovered as a result of such impact contain a potential for increased human knowledge in relation to palaeolandscapes. Such increased knowledge is deemed to offset low level impact if the assessment results are used to develop a deposit model (or sedimentary sequence model) and are released into the public domain .

The sub-samples were reviewed and evaluated following the methodlogy described in **Section 2**.

1.4 PROJECT AIMS AND OBJECTIVES

Sub-samples from the cores collected from the Gunfleets Sands 3 project have been reviewed for their potential to contain and preserve material that can be used for further palaeoenvironmental analysis. Such analysis is deemed to be of value if it is likely to enhance the complexity of the resulting deposit model.

The objectives of the Stage 3 assessment are to:

- Determine potential of samples, through basic lab analysis, to yield results through detailed specialist analysis during Stage 4;
- Make recommendations for further assessment, potential analysis requirements, and dating of the material recovered within the cores.

2 Methodology

2.1 APPROACH

MA Ltd. is a Registered Organisation with the Institute for Archaeologists (IfA). MA Ltd. conducts all projects and negotiations in accordance with the guidance and principles established in the IfA's *Code of Conduct* (2013) and *Code of approved practice for the regulation of contractual arrangements in archaeology* (2008).

This project has been formulated according to the approach and best-practice contained in IfA *Standard and Guidance for historic environment desk-based assessment* (2012), *Offshore Geotechnical Investigations and Historic Environment Analysis: Guidance for the Renewable Energy Sector* (COWRIE, 2011) and English Heritages' documents; *Geoarchaeology- Using Earth Sciences to understand the archaeological record* (English Heritage, 2007), *Guidelines for the Curation of Waterlogged Macroscopic Plant and Invertebrate Remains* (English heritage, 2008) and *Environmental Archaeology – A guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation* (English Heritage, 2011).

2.2 SELECTION OF SUB-SAMPLES

The selection of sediment to use for Stage 3 sub-sampling was based on recommendations made by MA Ltd. (2012c). Sub-samples from vibrocore 202A have also been included as the sediments in the vibrocore showed very good preservation and ideal conditions for pollen identification and recovery.

2.3 POLLEN

Pollen is a valuable tool for reconstructing past environments. It can help us understand the environmental landscape, economy and prehistoric human culture (English Heritage, 2011). Pollen are produced by higher plants (Vascular plants) and can, with the help of wind and/or water, travel relatively far. Pollen should therefore ideally be analysed with other environmental proxy evidence in order to gain a comprehensive understanding of the deposits (English Heritage, 2011).

For this Stage 3 assessment, the rapid scan method for the pollen assessment focused on identifying samples where pollen was present. A method based on the "fine sieving" methodology (More, Webb & Collinson, 1991:50) was applied to all sub-samples. The samples were sieved through a 180 µm and a 10 µm sieve. Analysis to quantify and identify the pollen present in the sub-samples was not undertaken at this stage.

The results from the pollen assessment are presented in **Section 3.1**.

2.4 DIATOMS

Diatoms are freshwater and marine algae, as the species are habitat-specific they can be used to indicate water quality, water temperature and salinity, nutrient and mineral levels, acidity and degree of oxygenation. Diatoms are most useful in when investigating coastal and estuarine sites, providing data on marine influence and phases of sea-level change (English Heritage, 2011)

A total of nine sub-samples were examined for their diatom content. Examination of these was undertaken primarily to establish whether diatoms were present in the sediments and, if so, to indicate the depositional environment. That is, to establish freshwater, brackish or marine and potential for a fuller analysis to elucidate these in detail, as well as changes which may have been associated with eustatic change.

Samples of 0.5 ml volume were processed using Hydrogen peroxide for digestion of humic/organic material. Samples were placed in small glass tubes to which 5 ml. of Hydrogen peroxide was added. This was warmed and left to stand for 24 hours. The samples were then gently centrifuged and distilled water was added. Sample/aliquots were placed on microscope cover slips, allowed to dry and subsequently mounted on microscope slides using a Naphrax mounting medium. Examination was carried out at high power (x400 and x1000) using an Olympus biological microscope with phase contrast. For the purposes of the assessment, scans of the microscope slides were made No counts of the diatoms were made at this stage. Identification was aided by the floras of Van der Werff and Huls (1958-1974) and (Hartley, 1996).

2.5 FORAMINIFERA

Foraminifera are particularly valuable at coastal sites where changes in freshwater and marine influence are important. Foraminifera are marine protists that survive best in non-acidic conditions. They are found in habitats ranging from salt marshes to the deep oceans. Ideally foraminifera should be analysed in conjunction with diatoms (English Heritage, 2011).

For the Stage 3 assessment, a rapid scan assessment was used on the sub-samples likely to contain foraminifera. The foraminifera sub-samples were washed through a 63 µm sieve to remove clay fractions. The samples were then air dried at 40°C. Once dry, the sediment was examined using a Leica MZ16 binocular microscope at x10–x16. A quantitative or identification analysis of the foraminifera present in the sub-samples was not undertaken at this stage.

The results from the foraminifera assessment are presented in **Section 3.3.**

2.6 MACROSCOPIC PLANTS AND INSECT REMAINS

Macroscopic plant remains are most commonly preserved by waterlogging or by mineralisation. Fruits, seeds, flowers, leaves, stems, insects, molluscs etc. are all valuable indicators when reconstructing past landscape.

The review of the macroscopic plant and insect remains for this Stage 3 assessment was undertaken to ensure there is sufficient record of material for further analysis. On occasion the assessment includes semi-quantities but as these have derived from a rapid scan method (Kenward & Large, 1998) they should not be used as reliable statistics.

The samples were prepared by initial disaggregation in water and then sieved in a 1000 µm sieve. Material larger than 1000 µm was inspected for large plant and organic remains and the residual was saved. Sediments smaller than 1000 mm were sieved using 180 µm mesh. The resultant material was collected and assessed. The sub-sample collected was checked under a binocular microscope for macroscopic plant, insect remains and molluscs.

Quantity and quality of plant and mollusc preservation was recorded using a semi-quantitative scale: (F - few (up to 3 individuals); S - some (4 to 20); M - many (21 to 50); V -

very many (more than 50) with accompanying descriptions. Insect preservation was recorded using the scheme of Kenward & Large (1998).

The results from the macroscopic plant and insect remain assessment is presented in **Section 3.4**.

2.7 INTERPRETATION OF THE RESULTS

The environmental information extracted from each of the sub-samples was evaluated for potential to yield results through detailed specialist analysis during Stage 4 and to produce an enhanced deposit model.

The results from the sub-samples were assessed and then reviewed against the current understanding of the potential Pleistocene and Holocene sediments within the development area to improve understanding of the deposits represented (MA Ltd., 2012b & c)

Based on this information further recommendations (**Section 5**) were developed for additional assessment and analysis work on samples from the cores.

3 Results

3.1 POLLEN

Pollen was identified in all of the six sub-samples assessed. Of the six samples there are three samples where further analysis would allow numerical counts to be made whilst other samples provide useful environmental indicators. The presence of pollen is presented in **Table 1.**

Table 1 summary of sub-samples assessed for pollen content.

Core	Depth (m)	Unit	Pollen sample ID	Presence/absence and abundance * - *****
304	1.14-1.68	Unit 6	001	*
305	2.25-2.44	Unit 7	002	*
202A	1.55-2.76	Unit 6	003	****
202A	3.10-3.37	Unit 5	004	****
202A	3.90-4.35	Unit 3	005	*
104	2.66-2.78	Unit 7	006	**

A scan of the microscope slides produced some identifiable pollen (**Table 2**). The material comprises of taxa that is indicative of plants that can tolerate acidic, well drained and sandy conditions (*Pinus, Ericaceae, Corylus, Alnus, Pteridophyte*).

Table 2 summary of pollen identified in the sub-samples.

Core number:	304	202A	202A	104
Sample ID	001	003	004	006
Depth	1.14-1.68	1.55-2.76	3.10-3.37	2.66-2.78
Abundance (*-*****)				
Pinus	*			
Corylus avellana		*	* (possibly)	
Ulmus or Alnus		*		
Cyperaceae			*	
Pteridophyte				*
Poaceae			*	*
Ericaceae				* (possibly)

3.2 DIATOMS

Diatoms were absent in four of the nine samples examined. Of the remaining samples, only three have useful numbers which would allow numerical counts to be made, whilst other samples provide useful environmental indicators (**Table 3**).

Table 3 Summary of sub-samples assessed for diatom content.

Core	Depth	Unit	Diatom sample ID	Presence/absence and abundance * - *****
101B	3.20-3.40	Unit 5	301	****
304	1.14-1.68	Unit 6	302	*
304	1.68-3.60	Unit 6	303	***
304	3.97-4.20	Unit 5	304	0
305	2.25-2.44	Unit 7	305	0
202A	1.55-2.76	Unit 6	306	**
202A	3.10-3.71	Unit 5	307	* (trace)
202A	3.90-4.35	Unit 3	308	0
104	2.66-2.78	Unit 7	310	0

Detailed scanning of the microscope slides produced a range of taxa including centric and linear frustules of brackish and marine affinity. These are detailed in **Table 4**.

The identified material is comprised of taxa that are largely indicative of saline/brackish water environments with no apparent freshwater input. These include the diagnostic centric, *Paralia sulcata* and *Actinoptychus senarius*. Other brackish water indicators include; *Nitzschia navicularis*, *Rhaphoneis amphiceros* and *Diploneis spp*. the latter especially, a mesohalabous taxon of brackish water habitats and is especially abundant in (101B).

Table 4 summary of diatoms identified in the sub samples.

Core	*202A*	*304*	*304*	*202A*	*101B*
Sample ID	307	303	301	306	301
Depth	3.0 - 3.71m	1.68 -3.60m	1.14 -1.68m	1.55 -2.76m	3.20 -3.40m
Abundance (*-*****)					
Centrics					
Actinoptychus senarius		*			
Paralia sulcata		*			*
Thalassiosira cf rotula			*		
Broken centrics/unident.		*			
Linear forms					
Achnanthes brevipes		*			
Cocconeis scutellum			*		
Diploneis didyma		*			***
Diploneis interupta					***
Diploneis ovalis					**
Diploneis sp. Indet.	* (frag.)				
Navicula navicularis		*		*	
Navicula sp. Indet.		*	**		*
Nitzschia cf acuta					*
Nitzschia navicularis	* (single)		*		
Nitszschia punctata		*	*	*	
Nitzschia sp. Indet.					
Rhaphoneis amphiceros			*		
Rhopalodia sp.					
cf Stauroneis				*	
Surirella sp.		*			

3.3 FORAMINIFERA

Varieties of benthic foraminifera, probably hyaline, were identified. This indicates that the foraminifera live on and in the substrate and not by floating in the water column. Foraminifera were identified in four sub-samples collected from two cores (304 and 101B). Foraminifera were absent from 15 of the sub-samples collected. The results are presented in **Table 5**.

Table 5 summary of sub-samples assessed for foraminifera.

Core	Depth	Unit	Foraminifera sample ID	Presence/absence and abundance * - *****	Foraminifera results
101B	3.20-3.40	Unit 5	115	**	Sample consisted of organic material (mostly wood), few quartz grains and occasional fragments of insect remains. Benthic calcareous foraminifera species were present.
101B	3.40-3.42	Unit 5	101	0	Sample consisted of quartz grains, lithic grains and plant remains.
101B	5.10-5.20	Unit 5	104	0	Sample consisted of quartz grains, lithic grains and plant remains.
101B	5.57-5.65	Unit 4	105	0	Sample consisted of in quartz grains.
304	0-1.14	Unit 6	102	***	A variety of benthic forams present.
304	1.14-1.68	Unit 6	103	*	Sample consisted of some forams as well as sand grains and shell fragments.
304	1.68-3.60	Unit 6	107	***	A variety of benthic forams present.
304	3.60-3.97	Unit 5	114	0	Sample consisted of quartz grains, rare minute lithic fragments, wood fragments and abundant gastropod shells.
304	4.20-4.94	Unit 4	106	0	Sample consisted of quartz and grains, rare minute lithic fragments.
305	1.98-2.25	Unit 7	113	0	Sample consisted of quartz grains and rare shell fragments.
305	2.25-2.44	Unit 7	112	0	Sample consisted of quartz grains and rare shell fragments.

Core	Depth	Unit	Foraminifera sample ID	Presence/absence and abundance * - *****	Foraminifera results
202A	1.55-2.76	Unit 6	111	0	Sample consisted of quartz grains, occasional shell fragments and ~1% other small lithic grains.
202A	3.10-3.37	Unit 5	109	0	Sample consisted of quartz grains and ~1% small lithic fragments, also occasional minute wood fragments.
202A	3.90-4.35	Unit 3	110	0	Samples consisted of quartz grains and very rare lithic grains.
104	2.66-2.78	Unit 5	108	0	Sample consisted of quartz grains and abundant wood fragments.

3.4 MACROSCOPIC PLANTS AND INSECT REMAINS

The macroscopic plant and insect remains rapid scan assessment (**Table 6**) confirmed that the sediments are generally indicative of marine and wetland environments. Marine plants, seaweed, crustaceans, molluscs, worm shell and gastropod shell remains were identified in all of the sub-samples. Samples from 201A and 104 also contained wood fragments.

Table 6 summary of sub-samples assessed for plant remains.

Core	Depth	Unit	Sample ID	Plant/Insect/mollusc results
101B	3.20-3.40	Unit 5	206	Some/many marine plants, molluscs, seaweed, shell.
101B	5.10-5.20	Unit 5	205	Many marine plants, seagrass, Few molluscs, few worm shell and shell fragments.
101B	5.57-5.65	Unit 4	204	Some plants, few insects.
304	0-1.14	Unit 6	210	Some plants, non-identifiable, many molluscs.
304	1.14-1.68	Unit 6	201	Some plant remains, some molluscs. Shell and shell fragments.
304	1.68-3.60	Unit 6	208	Some/many marine plants, seagrass. Some molluscs. Some shell and shell remains.
304	3.60-3.97	Unit 5	203	Marine plants, seagrass, shell remains, molluscs.
304	4.20-4.94	Unit 4	207	Some Plants, some molluscs.
305	1.98-2.25	Unit 7	209	Some marine plants, shell fragments; few molluscs.
305	2.25-2.44	Unit 7	202	Some marine plants.

Core	Depth	Unit	Sample ID	Plant/Insect/mollusc results
202A	1.55-2.76	Unit 6	211	Organic deposit with large> 1000m remains of wood and shell. Some plants (leaf) and some molluscs.
202A	3.10-3.37	Unit 5	213	Some large, wood fragments >1000 mm. Few plant remains-non identifiable; many molluscs.
202A	3.90-4.35	Unit 3	212	Some large >1000 mm shell remains and wood. Some wood, molluscs and shell and shell fragments.
104	2.66-2.78	Unit 5	214	Large, wood fragments >1000 mm; many plant remains. Many molluscs.

4 Interpretation

This Stage 3 interpretation is based on the results from this assessment and previous knowledge of the area presented by MA Ltd. (2012b, 2012c). The sediments are summarised in **Table 7** for details refer to the Stage 2 reports. (MA Ltd., 2012b, 2012c).

Table 7 Summary of sedimentary units.

Unit	Interpretation	Present in cores
8. Marine sand	Seabed sediment	201, 202, 202a, 203, 204a, 205, 206, 113, 114, 115.
7. Holocene deposit	Holocene seabed sediments	115, 301, 302, 303, 305, 101A, 101B, 103, 104, 105, 106
6. Holocene marine deposits/estuarine alluvium	Marine and estuarine deposits laid down in the Holocene	201, 202, 202a, 203, 204a, 205, 206, 207, 304
5. Holocene humic clays	Peat forming due to rising ground water levels during the Holocene	202, 202A, 205, 206, 207, 304, 101A_2, 101B, 103, 104, 105, 106
4. Holocene lag deposit	Concentration of gravel enhanced by the removal of fine sediment, water accumulated during the Holocene	201, 203, 204A, 207, 304 101A_2, 101B, 103, 104,105, 106
3. Pleistocene marine deposits/estuarine alluvium	Pleistocene marine and estuarine deposits. Low energy in nature	201, 202, 202A, 203, 204A, 205
2. Pleistocene lag deposit	Concentration of gravel enhanced by the removal of fine sediment, water accumulated during the Pleistocene	202A, 203, 204A
1. London Clay	Ypresian (Lower Eocene Epoch)	113, 114, 115, 207, 305, 101A, 101B, 103, 104, 105, 106

This assessment has added to our understanding of the components in the sediments recovered from the study area through the assessment of sub-samples taken from five of the sedimentary units. The results and the interpretation of the sediment sequence are summarised in **Table 8**.

Table 8 Results from Stage 3 assessment compared to previous understanding of the sediment sequence.

Unit	Interpretation Stage 2	Interpretation Stage 3	Stage 3 sub-sample reference
8. Marine sand	Seabed sediment	n/a	Not sub-sampled
7. Holocene deposit	Unit 7 comprises of sandy silts and clays. The unit refers to alluvial deposits where obvious channel features are not clearly noticeable within the core.	The Stage 3 sub-sampling assessment indicates that Unit 7 is a marine deposit containing a low amount of marine plants and shell fragments. A low amount of pollen and no diatoms.	002, 112, 113, 202, 209, 305
6. Holocene marine deposits/estuarine alluvium	The alluvium consists mostly of silty clay and is at times underlain and/or overlain by a humic Holocene deposit (Unit 5).	The Stage 3 sub-sampling assessment confirms that this is a marine/ wetland deposited sediment with a high amount of marine plants, shell fragments, diatoms, pollen and molluscs.	001, 003, 102,103,111, 201, 208, 2010, 211, 302, 303, 306
5. Holocene humic clays	This alluvial unit comprises of Holocene silty clays with significant bands or pockets of peat and organic material within the alluvial sequence.	The Stage 3 assessment indicates that unit 5 is a marine deposit containing marine plants, shell remains molluscs, few foraminifera, pollen from grass and hazel as well as spores. The pollen are most likely to be secondary dispersed or inwashed components.	004, 101, 104, 108, 109, 114, 115, 203, 205, 206, 213, 214, 301, 304, 307
4. Holocene lag deposit	The lag deposit consist of sands, pebbles and gravels and can indicate the base of a Holocene channel. The unit is significantly coarser than the overlaying silt and clay deposits.	Stage 3 sub-sampling showed that as expected very little organic or environmental material is preserved in the deposit.	105, 106, 204, 207

Unit	Interpretation Stage 2	Interpretation Stage 3	Stage 3 sub-sample reference
3. Pleistocene marine deposits/estuarine alluvium	This unit is comprised of a series of sandy clays and silts and clayey sands. Horizontal ripples and laminated bedding of sands and clays is frequently visible, along with marine shell fragments.	The Stage 3 sub-sampling showed that the preservation of pollen in this sandy layer is not ideal. Some plants remains were identified but no diatoms or foraminifera were present.	005, 110, 212, 308
2. Pleistocene lag deposit	Unit 2 is a concentration of gravel enhanced by the removal of fine sediment, water accumulated during the Pleistocene.	n/a	Not sub-sampled
1. London Clay	Ypresian (Lower Eocene Epoch)	n/a	Not sub-sampled

An initial interpretation of the cores (MA Ltd., 2012b, 2012c) suggested that the Holocene alluvial sediments and channel systems are extending in a southerly direction underwater. The sediments were located along the export cable route together with the Pleistocene channel sequence identified from the geophysical survey data and visible in the vibrocores.

The alluvial sequence (Unit 6), including the alluvial deposit with organic banding (Unit 5) and the basal gravely sequence (Unit 4), appears to be comparable to the Holocene sediments also encountered on the onshore area (MA Ltd., 2012b). The Stage 3 assessment has shown that Unit 6 and 5 are probably a marine/wetland deposited sediment, containing a high amount of environmental indicators, in contrast to Unit 4 which appears to contain little material worthy of further analysis.

However, the alluvial Unit 3 and the basal gravel Unit 2 that appear to be extending for c. 2.5-4 km offshore along the export cable route are more likely to be related to the earlier Pleistocene Clacton Channel deposit. The Stage 3 assessment located a few environmental remains in Unit 3 but as the preservation conditions in the sediment are poor it is doubtful if further analysis will be beneficial for the deeper sediments.

The Holocene and Pleistocene dates of the channels and possible areas of stable land surface provide the potential for this area to have been used by human populations during the Mesolithic and Neolithic periods. No archaeological material was noted within the cores, though artefacts of this date have been found in the surrounding areas (Bridgeland, 1999) and may therefore be dispersed across the land surface. Their potential presence should therefore not be discounted, especially in the basal gravelly deposits (Unit 2 and Unit 4).

5 Recommendations

The Stage 3 geoarchaeological assessment of sub-samples from the collected cores has determined that a Stage 4 geoarchaeological analysis would be beneficial to fully understand their character and the evidence they can provide on the palaeoenvironmental and geomorphological development of this area. There are clear questions over the date and nature of the deposits represented and their relationship to the known evidence of the Clacton Channel deposits.

Stage 4 - Analysis and dating, will aim to subject selected samples extracted to detailed laboratory analysis.

Specialist analysis for a range of palaeoenvironmental and archaeological indicators may include:

- Pollen;
- Diatoms;
- Ostracods and/or foraminifera;
- Waterlogged plants;
- Insects and molluscs;
- Charcoal;
- Radiocarbon dating (C14) and
- Optically Stimulated Luminescence (OSL).

It is recommended that further specialist assessment and analysis of the cores be undertaken, now that an initial review of both the onshore and offshore cores has been conducted and a Stage 3 sub-sampling and assessment stage has been completed. It should be noted that the sub-samples for Stage 3 were collected from a broad stratigraphic range. For worthwhile results, Stage 4 samples should be of a volume of 1-2 ml for pollen, diatoms and foraminifera, taken at regular and defined intervals to give adequate stratigraphic resolution.

Stage 4 Radiocarbon (C14) testing is recommended from borehole 101B (top, middle and bottom) and two more samples from either 104 or 304 (top and bottom). The sampling will allow temporal comparison between the evolutions of the more substantial deposit.

Vibrocore 203 has been recommended for OSL testing as it contains 2.59 m of Unit 3, interpreted as Pleistocene marine alluvium, made up by sandy clays and silts. Unit 3 sub-samples collected from 201, 202, 202A, 203, 204A and 205 has shown very sparse environmental evidence in form of pollen, diatoms and foraminifera which is why an OSL sample would add information about the sediments not accessible through the sample techniques used. Vibrocore 203 was not sub-sampled for the Stage 3 assessment and has not been recommended for other Stage 4 analyses as the untouched liner should not be disturbed before the OSL sample has been collected.

Optically Stimulated Luminescence (OSL) dating is dependent on acquiring enough material for the control samples. The method is based on the emission of light, or luminescence, by commonly occurring minerals, principally quartz, in order to date sediments. This method is often used when other sample methods are not possible. In this case OSL dating is the only method that would be useful on the sandy sediments believed to be coherent with the Clactonian period (Pleistocene).

The samples cannot be subjected to light after extraction. Ideal sampling conditions for splitting vibrocore liners and sub-sampling are under controlled conditions. As the liners are already opened, this is not a possibility. However, as opaque liners were used and half of the cores have not been disturbed it is possible that these will contain enough material for successful OSL dating. The sub-samples will have to be collected by an OSL specialist in the lab where the cores are stored and sent to an external laboratory for further testing.

Table 9 summarises the cores recommended for Stage 4 analysis.

Table 9 Summary of cores recommended for Stage 4 analysis

Recommendations for Stage 4 analysis	202A	304	203	104	101B
Waterlogged plants (8-32 samples)	x	x		x	
Pollen analysis (8-16 samples)	x				
Diatoms (8-32 samples)	x				
Foraminifera (8-32 samples)	x				
Ostracods (8-32 samples)	x				
Molluscs (8-32 samples)	x				
C14 dating (5 samples)		x		x	x
OSL dating (3- 6 samples)			x		

6 Conclusions

The results presented in this Stage 3 report demonstrates that the sub-sampled sediments contain environmental proxies. This is visible in the pollen, diatom, foraminifera and macro-fossil records. The sub-samples confirm that the sediments are mostly marine sediments containing the following: marine plants and various foraminifera, molluscs and diatoms. The diatoms provide clear evidence of the depositional environment and more detailed analysis has the potential for informing on the changing saline status, possibly in relation to changes in past sea level. Identification and numerical counts of the environmental material found in the Stage 3 sub-samples has not been undertaken. This will form part of the Stage 4 analysis.

The Stage 3 assessment concludes that a Stage 4 analysis of the cores should seek to gain more detailed information on the environment of deposition throughout the sequence, confirming whether there were marine, brackish or freshwater conditions. Obtaining a date for the organic rich sediments within the cores will refine the understanding of channel development. The Stage 4 analysis is deemed to be of value to enhance the complexity of the resulting deposit model.

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8 Figures

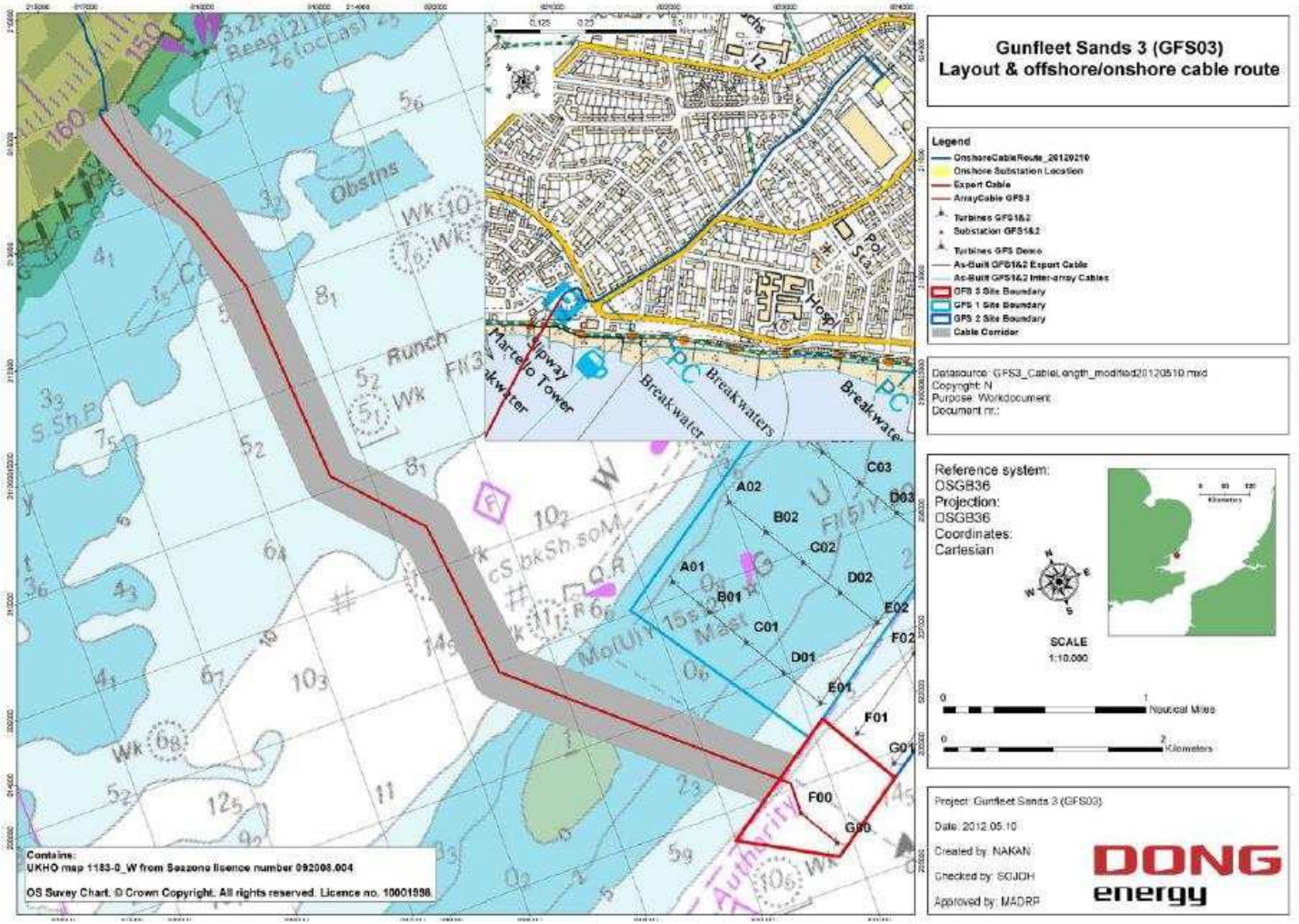

Figure 1 Detail of the scheme plan

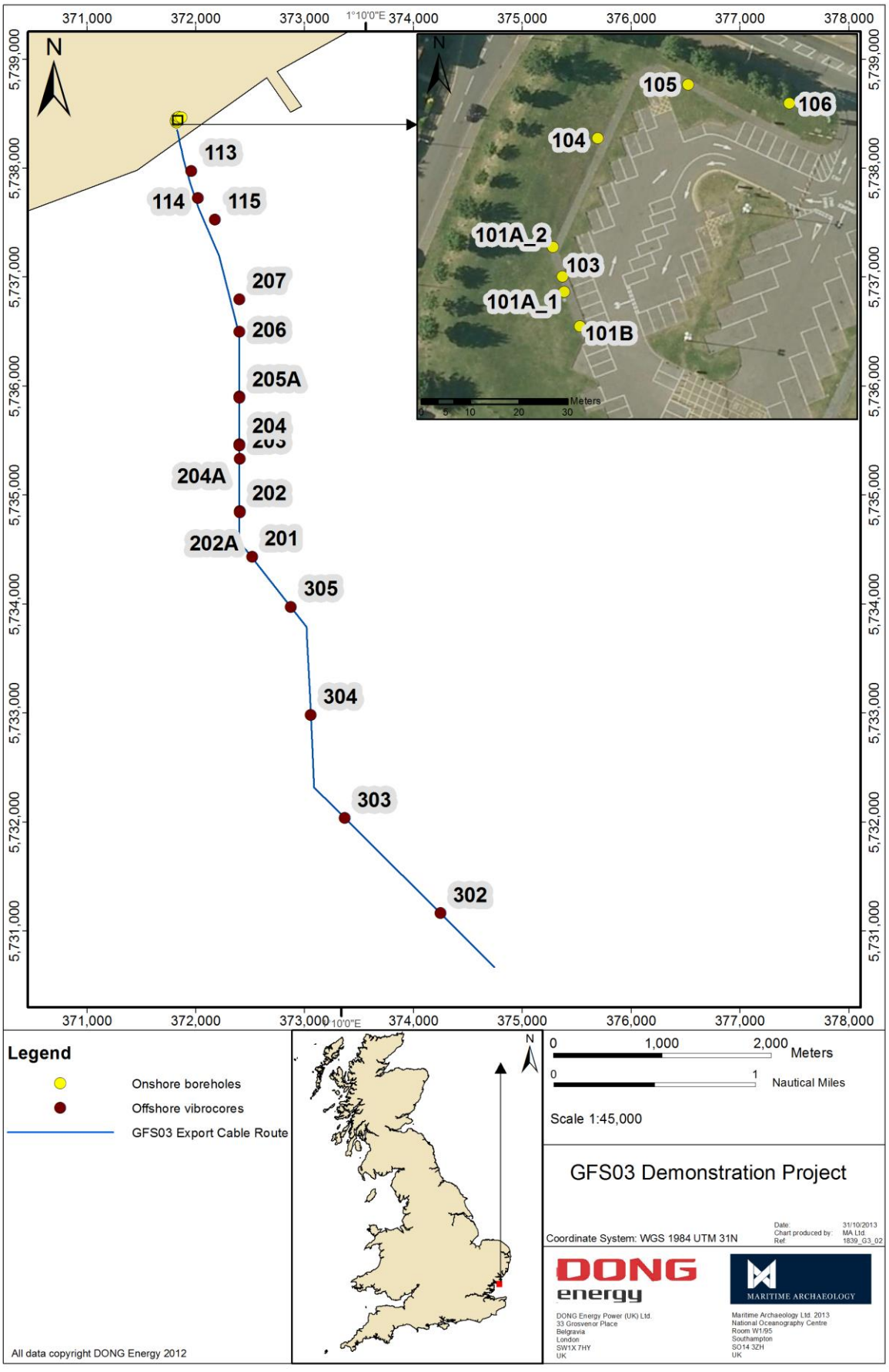

Figure 2 Location of all boreholes and vibrocores