Wessex Archaeology

Seabed Prehistory:
Site Evaluation Techniques (Area 240)

Palaeo-environmental Sampling

Final Report

Ref: 70753.02

November 2010

SEABED PREHISTORY:
SITE EVALUATION TECHNIQUES (AREA 240)

PALAEO-ENVIRONMENTAL SAMPLING

FINAL REPORT

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Summary

Wessex Archaeology (WA) was commissioned by English Heritage (EH), funded through the Marine Aggregate Levy Sustainability Fund (MALSF) to conduct a project concerning the application of geophysical and geotechnical/seabed sampling methodologies to marine aggregate deposits that have been demonstrated to contain potential pre-Devensian or Devensian artefactual material.

Artefactual material, including hand axes, flakes, cores and faunal remains were recovered from dredging licence Area 240 (licensed to Hanson Aggregates Marine Ltd. (HAML)) in 2008, situated approximately 11km off the coast of Great Yarmouth. The findings show that significant archaeological material can be present in deposits that are being targeted for marine aggregate extraction. The locale where the finds were dredged is relatively discrete, and the provenance of the artefacts is secure. The area where the hand axes were recovered is currently subject to a rectangular exclusion zone based on dredger trackplots, implemented voluntarily by HAML in accordance with the BMAPA/EH Protocol.

The principal aim of the project is to improve the future management of the potential effects of aggregate dredging on the marine historic environment by developing techniques to evaluate the source of prehistoric artefactual material discovered in the East Coast region.

This report presents the findings of *Stage 4: palaeo-environmental sampling* and details the acquisition and processing of a number of vibrocores, and the integration of these results with the geophysics data. The report also discusses the implications of these findings with regards to the area from which the hand axes were dredged and the wider region.

In *Stage 1: existing data review*, geophysical data (acquired in 2005) and geotechnical data (acquired between 1999 and 2007) were re-evaluated and interpreted in order to provide a broad context to the geological and archaeological characteristics of the area. Following on from the initial results of Stage 1, and based on the HAML dredge tracks, a further geophysical survey was conducted. *Stage 2: geophysical survey* was concerned with the acquisition, processing and interpretation of geophysical data from the approximately 3.5 km x 1.1 km site within Area 240 where the hand axes were discovered. *Stage 3: seabed sampling* assessed the capability of seabed sampling methodologies to enable observations of prehistoric artefacts, palaeo-environmental material, and their spatial distributions. The survey was conducted in July 2009 trialling three equipment types: clamshell grabs, video survey, and beam trawl. Samples were acquired along three transects selected on the basis of the results of Stages 1 and 2.

Based on the results of Stages 1, 2, and 3 a palaeo-environmental survey was proposed to acquire vibrocores at 10 specific locations within Area 240. These locations were selected to target locations that would elucidate the sedimentary sequence and depositional environments identified in Area 240, and, in particular, the sediments from which artefacts are thought to derive in this area. The selection targeted sediment units that would provide

palaeo-environmental material allowing for the assessment, dating and reconstruction of the former landsurfaces within Area 240.

The vibrocore survey took place between the 10th May and 13th May onboard the VOS *Baltic*. The survey was sub-contracted to Fugro Alluvial Offshore Ltd. as part of a joint coring program between Wessex Archaeology and University of Southampton National Oceanographic Centre. Two cores were acquired at each location, one in a clear liner for the purpose of geoarchaeological logging and one in an opaque liner for future OSL dating.

The vibrocores were split longitudinally, cleaned and photographed. Each core was then geoarchaeologically recorded providing details of the depth to each sediment horizon and the character of the sediment. The sediments described within the vibrocores were then grouped into a number of sedimentary units (and sub-units) based on the observed sedimentary characteristics. These results were then integrated with the geophysics data (Stages 1 and 2).

Seven geoarchaeological units were identified. The sediments identified in these units were deposited in a range of environments: shallow marine, outer estuarine, estuarine/lagoonal (restricted environment), glaciofluvial and intertidal mudflat/saltmarsh.

There were three areas of focus: the area from which the hand axes and associated artefacts were dredged, and each of the two channels (Channel A and B) observed within the area.

The dominant unit in the area from which the hand axes were dredged is a unit comprising sands with occasional gravel. If the hand axes were dredged *in situ* then it is likely they were recovered from this unit.

Channel A exhibits a complex infill sequence that differs in various parts of the channel. The most comprehensive of infill sequences was observed on the shoulder of the channel cut. Here, the fill sequence includes outer estuarine/shallow marine sands and gravels overlain by glaciofluvial gravel, which is, in turn, overlain by estuarine alluvium/lagoonal clayey sand deposits (restricted environment). Within the channel sediments indicate shallow marine gravels overlain by estuarine alluvium/lagoonal clayey sand deposits.

Channel B cuts into infill sediments associated with Channel A and is infilled by a transgressive sequence of sediments which comprises intertidal/saltmarsh clayey peaty silt overlain by outer estuarine sand and then shallow marine lag gravel. Based on previous radiocarbon dating, it is likely that the peats were deposited during the Early Holocene and that the overlying sediments were deposited during the last transgression.

Work carried out under Stage 4 of the project has furthered the understanding of Area 240, namely in establishing the likely depositional environments of the sediments from which the hand axes were likely dredged and also in furthering the understanding of the development of the channel features that were identified in the geophysics data.

Recommendations for palaeo-environmental assessment, analysis and dating are made.

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Acknowledgements

The Seabed Prehistory: Site Evaluation Techniques (Area 240) Project was commissioned by English Heritage, funded through the Marine Aggregate Levy Sustainability Fund (MALSF).

Wessex Archaeology (WA) would like to thank Helen Keeley and Gareth Watkins of English Heritage for their assistance throughout the project.

The vibrocore survey was conducted as a joint venture with the University of Southamton National Oceanographic Centre (NOC). WA would like to thank Dr Justin Dix and Dr Fraser Sturt. WA are grateful to Fugro Alluvial Offshore Ltd and Fugro Survey Ltd, who were sub-contracted to acquire the vibrocores. Thanks are also extended to the Captain and crew of the Vos *Baltic* for their professionalism and assistance during the course of the survey. The fieldwork was carried out by Dr Louise Tizzard, Jack Russell and Patrick Dresch from WA and Dr Justin Dix, Casey Nixon and Dr Kieran Westley from the NOC.

WA would also like to thank Mr Jan Meulmeester, Mr Hans Peeters formerly of Rijksdienst voor Archeologie, Cultuurlandschapp en Monumenten (RACM) - Dutch government organization for archaeology, culture landscapes and monuments -, and Dr Jan Glimerveen for their contributions concerning the artefacts and faunal remains.

Jack Russell and Louise Tizzard prepared the report with contributions from Patrick Dresch. Karen Nichols and Kitty Brandon prepared the illustrations. The project was managed for Wessex Archaeology by Louise Tizzard and Antony Firth developed the project design.

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1. INTRODUCTION

1.1. PROJECT BACKGROUND

1.1.1. Wessex Archaeology (WA) was commissioned by English Heritage (EH), funded through the Marine Aggregate Levy Sustainability Fund (MALSF), to conduct a project concerning the application of geophysical and geotechnical/seabed sampling methodologies to marine aggregate deposits that have been demonstrated to contain potential pre-Devensian or Devensian artefactual material.

1.1.2. Artefactual material, including hand axes, flakes, cores and faunal remains were recovered from dredging licence Area 240 (licensed to Hanson Aggregates Marine Ltd. (HAML)) in 2007/2008. Area 240 is situated approximately 11km off the coast of Great Yarmouth situated towards the west of a large area of aggregate licence areas covering an area of around 250km^2 (**Figure 1**).

1.1.3. The discoveries showed that significant archaeological material can be present in deposits that are being targeted for marine aggregate extraction. However, major questions remained about the complexity of deposits within Area 240; the susceptibility of such deposits to geophysical investigation; and the capability of various seabed sampling methods to enable observations of prehistoric artefacts, palaeo-environmental material and their spatial distributions.

1.1.4. The geological and geophysical questions were answered in *Stage 1: Existing Data Review* and *Stage 2: Geophysical Survey* project reports (Wessex Archaeology 2009; 2009a). The Stage 1 report comprised a re-interpretation of geophysical and geotechnical data that were acquired on behalf of HAML for the assessment of aggregate reserves and provided an overarching interpretation of Area 240. The Stage 2 report was concerned with the acquisition, processing and interpretation of geophysical data from the approximately 3.5 km x 1.1 km site within Area 240 where the hand axes were discovered (**Figure 2**). The datasets were also used to identify changes at the hand axe site since the 2005 dataset was acquired and to provide information on the current distribution of sub-surface sediments to a high vertical and lateral resolution.

1.1.5. *Stage 3: Seabed sampling* assessed the capability of seabed sampling methodologies to enable observations of prehistoric artefacts, palaeo-environmental material, and their spatial distributions (Wessex Archaeology 2010). The survey was conducted in July 2009 trialling three equipment types: clamshell grabs, video survey, and beam trawl. Samples were acquired along three transects selected on the basis of the results of Stages 1 and 2 (**Figure 2**).

1.1.6. This report discusses the methodology and results of *Stage 4: Palaeo-environmental sampling* survey conducted in May 2010.

1.2. PROJECT RATIONALE

1.2.1. The project rationale has been discussed in detail in the Stage 1 report (Wessex Archaeology 2009) and is only briefly summarised here.

1.2.2. In 2007/2008, 75 Palaeolithic artefacts, including hand axes, flakes and cores as well as a series of bones (woolly mammoth, woolly rhino, bison, reindeer and horse) were discovered by Mr Jan Meulmeester in stockpiles of gravel at the SBV Flushing Wharf. The condition of the hand axes implies that they were recovered in three different environments: mint (from a primary context), fresh (from an eroding surface) and weathered (from secondary contexts, mainly from the seafloor). Dating has proven difficult – the hand axes are thought to date to a wide time period of between 500ka to 22,000 BP, although a possible smaller time period of 250ka to 40,000 BP has also been suggested (Wessex Archaeology 2009). At the time of writing, the lithics are still undergoing investigation at Leiden University.

1.2.3. The faunal remains were also dated; the majority are of Devensian age and the remainder are heavily fossilised and thought to be older than 500ka (Mr Jan Glimmerveen, pers. com. 30/03/09), although the degree of fossilisation may vary on depositional environment.

1.2.4. The area where the hand axes were recovered is currently subject to a rectangular exclusion zone based on dredger trackplots, implemented voluntarily by HAML in accordance with the Protocol for Reporting Finds of Archaeological Interest (BMAPA and English Heritage 2005; **Figure 2**).

1.2.5. The recovery of Palaeolithic stone artefacts and Pleistocene faunal remains from the southern North Sea has a long history predominantly associated with the fishing industry and, more recently, the dredging industry (Godwin and Godwin 1933; Glimmerveen *et al.* 2004; Mol *et al.* 2006). In 2001 a portion of frontal bone belonging to a *Homo Neanderthalensis* was discovered in sediments extracted from the North Sea (Hublin *et al*. 2009). Numerous mammal remains have been reported from a relatively restricted area in the southern North Sea between the Brown Bank area and the Norfolk coast which yield Early and Middle Pleistocene mammal fossils (van Kolfschoton and Laban 1995, De Wilde 2006). Isolated finds of artefacts such as flints, spear-heads, and reworked or carved fossil mammal bones are also documented (Long *et al*. 1986, Coles 1998, Flemming 2002) and a number of finds and faunal remains have been, and are continually being, reported from aggregate dredging areas via the BMAPA/EH protocol for reporting finds of archaeological interest (BMAPA and English Heritage 2005).

1.2.6. Between 2005 and 2010 (at the time of writing), 60 finds have been reported as part of the Protocol within aggregate dredging areas offshore East Anglia and comprise a variety of archaeological material covering prehistoric, marine and aviation archaeology. Prehistoric finds reported through the protocol are summarised in **Table 1**. Further details of these finds are provided in the Stage 1 report (Wessex Archaeology 2009).

Find	Dredging Areas
Hand axes	240 (this project)
Flint	240, 360
Bones	251, 254, 296, 319, 360, 361, 430
Mammoth teeth/tusks	240, 296, 319, 361
Peat	240, 251, 360, 430

Table 1. Summary of prehistoric finds reported within the East Coast aggregate dredging areas

1.2.7. Additionally, during the East Coast REC survey a flint artefact, identified as a broken secondary flake, was identified during onboard processing of a clamshell sample at station CG6, which is situated to the west of the HAML exclusion zone (**Figure 2**).

1.3. Aim and Objectives

1.3.1. The aim of the project is to improve the future management of the potential effects of aggregate dredging on the marine historic environment by developing techniques to evaluate the source of prehistoric artefactual material discovered in the East Coast region.

1.3.2. In order to achieve this aim the following objectives were devised (Wessex Archaeology 2009b):

O1 Refine practical techniques for establishing the presence or absence of prehistoric archaeological material (artefacts, deposits, faunal and other palaeo-environmental material) on the seabed and for establishing the character, date, extent, quality, preservation and special interest of such material, if present;

O2 Improve the understanding of the character of the historic environment in the East Coast region, specifically its potential for prehistoric material;

O3 To pass on the knowledge gained to the archaeological and scientific community, to industry, and to the general public.

1.3.3. The structure of the project has been split into nine stages, as detailed in **Table 2**.

Stage	Task description
1	Review of existing geophysical and geotechnical data
2	Geophysical survey
3	Seabed sampling
4	**Visual inspection/palaeo-environmental sampling**
5	Palaeo-environmental assessment and dating
6	Palaeo-environmental analysis
7	Synthesis
8	Dissemination, knowledge transfer and outreach
9	Archive deposition

Table 2. Project stages

1.3.4. This report presents the findings of *Stage 4: Palaeo-environmental sampling*. The intention of Stage 4 was to acquire a series of vibrocores that would provide palaeo-environmental material allowing for assessment, analysis and scientific dating. In turn, this will enable with the reconstruction of the landsurfaces within Area 240, and in particular the area in which the hand axes and flint flakes were recovered.

1.3.5. The palaeo-environmental sampling survey was intended to contribute to the project objectives as follows:

- The survey would further assess the application of vibrocores as suitable sampling methods and generate methodological conclusions;
- The logging of the vibrocore sediments would corroborate the geophysical results and improve the understanding of the artefact site and its relation to the wider area;
- Processing of the vibrocores would provide a detailed log of sediment types which would allow decisions to be made on palaeo-environmental assessment and dating;
- The results are likely to be of considerable interest to the different stakeholder audiences and the wider public.

1.3.6. As part of a planned series of meetings, English Heritage attended a progress meeting on 19th July 2010 to discuss the results of the palaeo-environmental sampling survey and to discuss the proposed palaeo-environmental assessment, analysis and dating (Stages 5 and 6).

1.3.7. Furthermore, Peter Murphy (English Heritage) visited WA office on 9th June 2010 to attend whilst some of the vibrocores were geoarchaeologically logged.

2. SUMMARY OF STAGES 1, 2 AND 3

2.1.1. The results of each previous stage of the project are presented in stand alone reports (Wessex Archaeology 2009; 2009a; 2010). A summary of the results are presented here to provide a background to Stage 4.

2.1.2. The review of the 2005 (Stage 1) and 2009 (Stage 2) geophysical data and the vibrocore logs (acquired 1999 – 2007) indicate a complex history of deposition and erosion within Area 240. This history is further complicated by dredging operations conducted over the last 20 years.

2.1.3. Eight major seismic units were identified in the sub-bottom profiler (Stage 1 and Stage 2) datasets. **Table 3** provides a summary of these sediment units and **Figure 3** illustrates the geophysics interpretation.

Unit	Interpretation
Unit 8	Holocene seabed sediments
Unit 7	Fine-grained sediments and peat deposits
Unit 6	Estuarine fine-grained sediments
Unit 5	Fine-grained sediments (estuarine/freshwater) (Brown Bank Formation)
Unit 4	Sands and gravels (?Brown Bank Formation)
Unit 3	?Deltaic fine-grained sediments (Yarmouth Roads Formation)
Unit 2	Shallow marine sands and gravels (Yarmouth Roads Formation)
Unit 1	Open marine clays and sands (Westkapelle Ground Formation)

Table 3. Summary of geophysical sediment units (Stage 1 and 2 reports)

2.1.4. A series of sediment units dating from the Late Pliocene/Early Pleistocene (**Unit 1**) to the last marine transgression (*c.* 7500 BP (Shennan and Horton 2002); **Unit 8**) were interpreted, although not as a complete sequence.

2.1.5. The deepest unit (**Unit 1**) is observed across Area 240 and is interpreted as the Westkapelle Ground Formation deposited during the Late Pliocene/Early Pleistocene. **Units 2** and **3** overlie **Unit 1** and are interpreted as the Yarmouth Roads Formation, deposited during the Cromerian Complex and may be as young as MIS 25, the possible time of the earliest occupation of Britain (Parfitt *et al*. 2010).

2.1.6. **Unit 4** overlies **Unit 2** throughout most of Area 240 and is generally observed as a unit of high amplitude, irregular and chaotic reflectors interpreted as coarse sands and gravels, as confirmed by the vibrocore logs. Due to the similarity in the sediments of **Units 2** and **4**, often there is no distinct boundary observed between the two units. **Unit 4** is divided into 3 seismic facies (**Unit 4a**, **4b** and **4c**) as is shown in **Figure 4**. Where the subunits cannot be differentiated the unit is referred to as **Unit 4**.

2.1.7. The area is dominated by two channel features, Channel A and Channel B (**Figure 3**). Channel A is observed to the north of where the artefacts were dredged, orientated north-west to south-east. The channel cuts into the underlying **Unit 2**. The southern edge of the channel is prominent and is observed as a 5m deep cut. The northern edge of the channel is less obvious and is observed as gently shoaling, rather than being a steep cut. The sediment infilling this buried channel varied in composition and is indicative of a changing flow regime of high-energy and low-energy sediment deposition. The high-energy depositional sediments comprise sands and gravels and are observed on the sub-bottom profiler as units of strong reflectors (**Unit 4b** and **c**). Fine-grained sediment units, indicative of lower-energy depositional environments are observed as seismically transparent units and are observed infilling broad shallow depressions or forming small bank structures up to 3m high (**Unit 5**). The vibrocore data indicate that this unit comprises clay with occasional shells overlain by a thin unit of clayey sand. There is also some evidence of oxidation which may be a result of weathering and exposure to oxygen and the formation of a gley type soil. A strong reflector (**Reflector A**) is a observed associated with localised areas of the channel and channel edges. And is interpreted as marking a hiatus in the infilling of the channel. Often it is observed as an internal reflector within **Unit 4** marking the boundary between **Unit 4b** and **c**, but also locally coincides with the base of **Unit 5**.

2.1.8. The floodplain of Channel A is extensive, encompassing the majority of Area 240 and comprising sands and gravels (**Unit 4**). The age of the channel cut-and-fill deposits is, at present, unknown, but the channel may have been cut as early as the Late Anglian Glacial (*c.* 430ka). Studies carried out in Area 254 to the north of Area 240 (Wessex Archaeology 2008) indicate that the coarse-grained fill may have been deposited during the Wolstonian (*c.* 300, – 130ka) with the finer-grained sediments deposited at the onset of the Ipswichian Interglacial (*c.* 130 – 110ka). However, further dating would be needed to confirm these dates.

2.1.9. Channel B is broad and shallow, situated in the north-western corner of the survey area, and is orientated north-east to south-west (**Figure 3**). Regional bathymetry indicates that this is part of a southerly flowing, meandering channel. Channel-fill deposits are observed on the sub-bottom profiler data and a topographic trace of the channel is also observed on the bathymetric data. The topographic trace indicates a broad feature, approximately 1 km wide and up to 4m deep. Sub-bottom profiler data indicate that the infill sediments are up to 6.5m thick and the vibrocore data indicates a fill sequence including peats and other organic sediments, which are indicative of low-energy deposition in a fluvial or marshland environment (**Unit 7**). Results of independent dating of the bottom and top of the peat layer from a vibrocore situated within Channel B dates the peat between 10,470+/-35 BP (10,710 – 10,280 cal. BC, SUERC-11978) and 8370+/-25 (7530 – 7350 cal. BC, SUERC 11975) (Hazell in preparation) at depths of 30.80mbOD and 30.05mbOD, respectively.

2.1.10. An uppermost fill unit (**Unit 6**) is observed throughout the area cutting into the underlying **Unit 4**. These depressions are predominantly situated in the central and southern areas and are infilled with finer-grained deposits (clays and fine-grained sands) and suggest an outer estuarine or near coastal depositional environment. The relative chronology of these deposits to the early Mesolithic peats (**Unit 7**) is unknown as there are no areas where these units coincide to provide any direct stratigraphic relationship.

2.1.11. A unit of Holocene surficial sediment (**Unit 8**) is observed throughout Area 240. This comprises sands and gravels indicative of a seabed lag deposit and finer sediments varying from less than 1m thick to 6m thick where sandwaves are present.

2.1.12. Based on the results of Stages 1 and 2, Stage 3 was developed. The aim of Stage 3 was to assess the capability of seabed sampling methodologies to enable observations of prehistoric artefacts, palaeo-environmental material, and their spatial distributions. The survey was conducted in July 2009 trialling three equipment types: clamshell grabs, video survey, and scientific beam trawl. Samples were acquired along three transects selected on the basis of the geophysical interpretation (**Figure 3**).

2.1.13. In total, fifteen flint flakes and ten pieces of bone were recovered from the clamshell grab samples. The recovered flint consisted entirely of flint flakes. Although it is difficult to distinguish humanly produced flint flakes from those that occur naturally, of the 15 flakes recovered all are of probable anthropogenic origin, but eight are more obviously genuine artefacts. These eight flakes were recovered from Transect 1.

2.1.14. A summary of the identification of the flakes is provided in **Table 4**.

Transect	Sample	Flint flake description
T1	T1_G22; T1_G25	Broken mid-sections of tertiary flakes with well-defined flake scars and are characteristic of hand axe thinning flakes
T1	T1_G23	Primary flake of clear anthropogenic origin with a striking platform and point of percussion
T1	T1_G5	Evidence of platform preparation
T1	T1_G5a and T1_G21a	Evidence of deliberate, systematic debitage
T1	T1_G6 and T1 G9	Hard hammer struck and although less convincing than the other flint flakes, are probably of human workmanship
T1; T2	T1_G7; T1_G9; T1_G25 (3); T2_G1b; T2_G5	Possible artefacts but open to doubt and may have been formed by natural processes

Table 4. Summary of flint flake finds sampled during the *Stage 3: Seabed Sampling* survey

2.1.15. Ten pieces of bone were recovered from the clamshell grab samples: nine from Transect 1 and one from Transect 3. The faunal finds are summarised in **Table 5**.

Transect	Sample	Faunal description
T1	T1_G5	Centrotarsal. Bovine/Cervid. Fossilised.
T1	T1_G5; T1_G5a (2); T1_G8	Fossilised, unidentifiable bone
T1	T1_G22	Vertebra. Fish. Salmonid?
T1	T1_G27	2x bone pieces. The internal structure is mammalian, possibly a terrestrial mammal.
T3	T3_G5	Vertebra. Aquatic mammal ?dolphin. Recent.

Table 5. Summary of faunal remains sampled during the *Stage 3: Seabed Sampling* survey

2.1.16. The occurrence of terrestrial mammal bone from the north-eastern end of the T1 is of interest given that Mr Meulmeesters original discovery included terrestrial mammal bone.

2.1.17. The flint flakes with the clearest diagnostic features and the faunal remains were mostly recovered from Transect 1 and are associated with the unit identified on the geophysics data as the sand and gravel unit forming the floodplain of Channel A (**Unit 4a**), in close proximity to the unit identified as fine-grained outer estuary sediments (**Unit 6**).

3. SURVEY METHODOLOGY

3.1. SAMPLING RATIONALE

3.1.1. Although *Stage 3: Seabed Sampling* proved successful in that sampling techniques were used to recover flint flakes thought to be formed by tool manufacture, and that these were predominantly grouped in one area, no definitive evidence of a hand axe presence was established through the course of the sampling survey. Given the area over which the flint flakes were found, no definitive localised site and the poor visibility in the area, video inspection by diver or ROV was not considered appropriate as the next stage in the investigation.

3.1.2. Rather, at the end of *Stage 3: Seabed Sampling* it was recommended that vibrocores were taken at key locations within the area in order to gain detailed sedimentary, chronological and environmental data. This would also include provision for cores to be taken for OSL dating.

3.1.3. Prior to the survey, 10 vibrocore locations were selected, targeting sediment units that would provide palaeo-environmental material allowing for the assessment, dating and reconstruction of the former landsurfaces within Area 240. The locations of the vibrocores previously acquired within the area, and those acquired as part of the ongoing East Coast Regional Characterisation project have been taken into consideration. The proposed vibrocore locations and reasons for selection are listed in **Table 6.**

Proposed vibrocore	Easting	Northing	Target
WA_VC1	426296	5821835	Targeting the stratification observed in T1_G3 and G7. If this is **Unit 6** identified on the 2005 geophysics data the age and depositional environment of this unit is needed to fully understand the context of the sediments in the area
WA_VC2	426321	5821851	Target the central region of T1, around G22 and 23 where the most promising flint artefacts were grabbed. Targets **Unit 4**.
WA_VC3	426501	5821895	Target the eastern end of T1, around station G5 where the fossilised bone and flint artefacts were grabbed.
WA_VC4	426918	5824016	Target the silty sand observed in the sample at T3_G1 to establish if this is the same unit to the silty sand observed in T1_G3 and G7, or if this represents an older unit, as interpreted in the geophysics. Also targets the area in which FeO sheets were recovered.
WA_VC5	426430	5825807	Target **Unit 5** identified in the 2005 geophysics dataset
WA_VC6	424922	5826205	Target **Unit 5** identified in the 2005 geophysics dataset and can be tied into the previous work carried out in dredging Area 254
WA_VC7	429834	5825585	Targeting the strong geophysical **Reflector A** and associated fine-grained deposit (**Unit 5**)
WA_VC8	424948	5824882	Target **Unit 7** – possible peats in the submerged channel observed in the 2005 bathymetry dataset. Close to WA_VC61.
WA_VC9	426553	5819779	Target **Unit 5** to the south. No precious cores in this area. Aims to compare **Unit 5** outlier in the south to units of similar seismic characteristics in the north

Proposed vibrocore	Easting	Northing	Target
WA_VC10	431156	5824543	Target channel deposits in the northeast.

Table 6. Proposed vibrocore locations

3.2. TECHNICAL SPECIFICATIONS AND ON-BOARD METHODOLOGY

Survey

3.2.1. The vibrocore survey took place between the 10th and 13th May 2010 onboard the VOS *Baltic*. The survey was sub-contracted to Fugro Alluvial Offshore Limited as part of a joint coring program between WA and University of Southampton National Oceanographic Centre (NOC). The joint coring program was developed in order to cut the vessel costs for both parties.

3.2.2. The VOS *Baltic* is a 61m long offshore support vessel and operations were on a 24-hour basis. The vessel was suitable for the survey and could hold position on location.

3.2.3. The acquisition of the vibrocores was conducted by Fugro Alluvial Offshore Limited; the positioning and the recording of water depths at each location was conducted by Fugro Survey Limited. Theses operations were overseen by representatives of WA and NOC.

3.2.4. WA and NOC provided three personnel each to oversee operations and to aid in the onboard processing of the vibrocore samples.

3.2.5. The vessel was mobilised on the 10th May in Great Yarmouth. Personnel joined the vessel and mobilisation was completed by 19:00 hrs and the vessel departed Great Yarmouth for the Area 240 site. The vessel arrived on site at 21:30 hrs and after a safety briefing acquisition of the vibrocores commenced.

3.2.6. The strong tidal current in the area, amplified by the strong northerly winds in the week prior to survey, hindered operations. The currents were too strong for the vessel to stay at the sample location during acquisition and would also risk damaging the vibrocore equipment. As such, between 00:00 hrs and 09:30 hrs acquisition could only take place at slack tide; 5:15 hours were lost to weather downtime. However, from 09:30 hrs on the 11th May the tidal conditions improved and acquisition continued until 20:00 hrs when the acquisition of cores at Area 240 was complete and the vessel transited to the NOC Thames site. Out of the twenty proposed vibrocores 19 were acquired; one secondary (OSL) core was not acquired at location WA_VC8 due to the tidal current.

3.2.7. Acquisition of vibrocores at the Thames site commenced at 22:45 hrs and was completed by 04:40 hrs on the 13th May. The vessel then proceeded to Great Yarmouth for demobilisation at 09:30 hrs on the 13th May. The vibrocores were prepared for transit and WA personnel left the vessel at 14:00 hrs 13th May.

3.2.8. The vibrocores were delivered to WA office in Salisbury on the afternoon of 17th May.

Positioning

3.2.9. Positions for the proposed vibrocore locations were provided to Fugro Survey Limited surveyors prior to commencement of the survey. Online navigation was supplied by a navigation PC running the Starfix.SEIS navigation suite. Primary positioning for the vessel was provided by Fugro Starfix.HP DGPS navigation with secondary positioning provided by Fugro Starfix.XP DGPS. Anticipated dynamic positional and height accuracies of Starfix.HP DGPS are typically within ±0.5 metres. Vessel datum and offset positions were computed in Fugro's SEIS navigation software using antenna position data along with Meridian gyrocompass data.

3.2.10. During mobilisation a gyrocompass calibration and a DGPS gross error check were performed.

3.2.11. Provisional positions were provided to WA onboard for checking and confirmation. Finalised positions were provided to WA post-survey.

Echo sounder

3.2.12. An echo sounder was provided to ensure accurate depth measurements at each vibrocore location. Depth data were provided by Fugro Survey Limited using a Reson TC 2122 33/2110 khz dual frequency echosounder transducer interfaced with a Knudsen 320M topside unit.

3.2.13. Water depths were corrected for vessel draft and reduced relative to Lowest Astronomical Tide (LAT) using predicted tides extrapolated to Area 240 from the nearest Standard Port of Lowestoft.

Vibrocore

3.2.14. A High Performance Corer (HPC), developed by Fugro Alluvial Offshore Limited was used to acquire the vibrocores. The design utilises innovative electric motor and sample barrel design allowing successful acquisition of a range of sediments, including gravels and sands.

3.2.15. The samples were acquired with a 6m barrel. Recovery ranged between 2.81m and 6.22m. From the 19 vibrocores in excess of 97m sediment were acquired.

3.2.16. At each vibrocore location the core barrel was prepared with a plastic liner loaded into the barrel. It was planned that at each vibrocore location that two samples were acquired: one in a clear plastic liner (suffix C) and the other in an opaque liner (suffix B) to provide OSL dating samples.

3.2.17. Once the barrel was prepared it was loaded into the coring rig. The coring rig was deployed and recovered from the side of the vessel using a 12t deck crane (**Plate 1** and **2**, respectively).

3.2.18. Once recovered, the barrel was removed from the rig (**Plate 3**) and the plastic core liner removed (**Plate 4**). The vibrocore samples were cut into 1m sections, capped and taped, labelled and stored in an upright position on the vessel so as to keep the disturbance of the cores to a minimum. Any samples, such as from the shoe sample of the corer were bagged and labelled, the samples kept airtight and were stored with the vibrocores. A record was kept of the acquisition and sampling of the cores.

4. PROCESSING METHODOLOGY

4.1. POSITIONING DATA

4.1.1. The finalised positioning data were provided to WA from Fugro Survey Limited. These positions were imported into the project GIS. A list of the proposed and actual positions of the vibrocores is provided in **Appendix I** and the actual positions are illustrated in **Figure 5**.

4.2. VIBROCORE SEDIMENT DESCRIPTION

4.2.1. The vibrocores (acquired in clear liners) were split longitudinally using an angle grinder and carefully prised open with a knife in order to preserve sedimentary structure. One half of each core was cleaned where necessary, and photographed (**Figures 6** to **15**).

4.2.2. Each vibrocore was then geoarchaeologically recorded and the descriptions are given in full in **Figures 6** to **15.** The vibrocore descriptions provided details of the depth to each sediment horizon and the character of the sediment. Sedimentary characteristics were recorded including texture, colour, stoniness and depositional structure (*cf.* Hodgson 1976).

4.2.3. The sediments described within the vibrocores were then grouped into a number of sedimentary units (and sub-units) based on the observed sedimentary characteristics. This was conducted prior to the integration with the geophysics data.

4.3. INTEGRATION

4.3.1. Details from the vibrocore logs were compared to the geophysics data (2005 and 2009) in order to characterise the geophysical units identified at the core locations and to extrapolate the interpretation for Area 240. However, the geophysical data and the logs record different properties and, as such, care has to be taken when comparing the two datasets; they are not directly comparable.

4.3.2. The sub-bottom profiler data records changes in acoustic impedance of sub-surface sediments; layers recorded on the data reflect changes in the bulk properties of the sediment and not necessarily changes in sediment type. The geoarchaeology log, on the other hand, records actual, physical boundaries relating to detailed changes in sediment type and depositional structure.

4.3.3. Also, the geophysical horizons within the sub-bottom profiler data (in this case boomer, pinger and chirp) are displayed in terms of two way travel time. This is the time from the discharge of acoustic energy from the seismic source to the time (in milliseconds) that the hydrophone receives the reflected energy from the different seabed horizons. To calculate the depth of the geophysical horizons beneath the seabed a velocity of the seismic wave through the seabed geology has to be assumed. A velocity of 1600m/s was assumed throughout the processing of the data (Sheriff and Geldart 1983; Telford *et al*. 1990). The parametric sonar used in this project works on different principles to the systems mentioned above (Wessex Archaeology 2009). However, depth values are calculated in a similar way and are calculated based on a constant sound velocity. Work has been carried out on the comparison of geophysics layers and sediment types taking sediment densities into account (e.g. Plets *et al*. 2007), but this is complex and not used for a general comparison between the geophysics and geoarchaeological data.

4.3.4. Although the geophysics data and sediment descriptions can be compared and is very useful for broad-scale ground-truthing of the geophysics data, there may be differences in depths of horizons from each data type and subtle changes in density may be obvious in the geophysics data but not the sediment data. Equally subtle changes in the sediment type do not necessarily result in a significant enough density change for it to be recorded in the sub-bottom profiler data.

4.3.5. To account for the potential differences in seabed depths between 2005 and 2010, all sediment depths have been reduced to depths below OD (mbOD) and are provided along with depths sub-seabed. This allows comparison between horizons irrespective of changes in the seabed depth (either due to natural erosion, natural accretion or dredging activities). **Table 7** details the water depths at the vibrocore locations based on Stage 1 (2005), Stage 2 (2009) and Stage 4 (2010) echosounder data.

WA_VC	2005 water depth (mbOD)	2009 water depth (mbOD)	2010 water depth (mbOD)
1C	27.3	27.3	27.6
2C	27.3	27.2	27.8
3C	27.1	27.6	27.8
4C	31.8	32.4	32.9
5C	27.6	-	27.3
6C	28.1	-	28.2
7C	27.4	-	27.3
8C	30.7	-	30.7
9C	27.7	-	24.7
10C	31.1	-	31.4

Table 7. Water depth variation between 2005 and 2010 at vibrocore locations

4.3.6. The obvious anomaly between the water depths is in **WA_VC9C**. In 2005 the water depth was recorded at 27.7mbOD whereas **WA_VC10C** was recorded at 24.7mbOD. This indicated that there had been considerable accretion of sediments at this location. This could be due to a build up of recent sediment in the form of a sandwave. However, this was proved not to be the case (Section 5). The second core acquired at this location (**WA_VC10B**) was acquired less than 1m from **WA_VC10C** yet the water depth was recorded at 27.0mbOD. This is comparable to the 2005 water depth and considered a more accurate representation of the water depth at this location. As such, this depth has been used throughout this report.

5. RESULTS

5.1. VIBROCORES

5.1.1. The sediments described within the vibrocores have been grouped into seven major sedimentary units, **Units a** to **g**. Some of these units have been split into subunits.

5.1.2. Correlations have been made between deposits recorded within the vibrocores where apparent. The large size of the survey area and, as such, distances between some of the vibrocore locations plus the complexity of the Pleistocene sediments preclude linking sedimentary units with any certainty based solely upon sedimentary characteristics. Integration of the geoarchaeology with the geophysics interpretation allows geographic comparisons to be made with more certainty.

5.1.3. **WA_VC6C** penetrated the seabed to 1.24m and due to insufficient penetration another vibrocore, **WA_VC6C1** was taken. The sediment descriptions for **WA_VC6C** and **WA_VC6C1** have been combined (**WA_VC6C/C1**) to provide a more complete sequence at that location as it was noted that the top 1.35m of vibrocore **WA_VC6C1** was disturbed to a depth of 1.35m below seabed (**Figure 11**)**.** This disturbance was probably caused by the first vibrocore, **WA_VC6C** at that location. There is however a discrepancy of 0.4m between the levels of the top of the cores **WA_VC6C** (28.20m below OD) and **WA_VC6C2** (28.60m below OD) and **Figure 11** has been compiled assuming the levels recorded are correct using the undisturbed sections of the two cores: 0 to 1.24m below seabed of vibrocore

WA_VC6C and 1.35 to 5.24 of **WA_VC6C1**. In order to indicate continuity of depth below seabed of the sediments, and assuming the levels recorded for the two cores are correct, 0.4m has been added to the value of depth below seabed of **WA_VC6C1**.

5.1.4. The geoarchaeological units and subunits are summarised below in **Table 8** and detailed on **Figures 6** to **15**.

Unit	Sub-unit	Sediment type	Depth (mbOD)	Description	Figures
a		Sand and gravel	24.70 to 34.27	Observed in all ten vibrocores and ranged in thickness from 0.04m (**WA_VC5C**) to 1.37m (**WA_VC4C**) in thickness. The unit comprised sand, gravelly sand and sandy gravel and is interpreted as seabed sediment.	**6 - 15**
b	**bi**	Sandy gravel	31.07 to 31.39	Recorded in **WA_VC8C** and was 0.32m in thickness. The unit comprised sandy gravel and is interpreted as a shallow marine gravel lag deposit.	**13**
	bii	Sand	31.39 to 31.57	Recorded in **WA_VC8C** and was 0.18m in thickness. The unit comprised sand with occasional small pebbles and frequent marine molluscs. The unit is interpreted as shallow marine/outer estuarine sand.	**13**
	biii	Sandy clayey peaty silt	31.57 to 32.06	Recorded in **WA_VC8C** and was 0.49m in thickness. The unit comprised horizontally bedded layers/laminae of sand, silt, peat and clay. The peat layers were up to 3mm in thickness and appeared to comprise horizontally bedded plant remains. The unit is interpreted as intertidal mudflat/saltmarsh deposits.	**13**
c	**ci**	Sand	27.15 to 27.99	Recorded in **WA_VC5C** and was 0.84m in thickness. The unit contained horizontally bedded sand and clay indicative of tidal deposition. The unit was interpreted as estuarine alluvium.	**10**
	cii	Clayey sand	27.44 to 29.22	Recorded in **WA_VC5C** and **WA_VC7C** and ranged from 1.00m (**WA_VC7C**) to 1.23m (**WA_VC5C**) in thickness. The unit comprised clayey, silty sand and bivalve molluscs were present including *Ostrea edulis* and *Cerastoderma edule*. The unit was interpreted as having formed in a brackish/marine environment such as an outer estuarine location or a brackish lagoon.	**10** and **12**
d		Sand and sandy gravel	29.22 to 36.65	Recorded in **WA_VC5C** and **WA_VC8C** and ranged from 3.54m (**WA_VC5C**) to 4.54m (**WA_VC8C**) in thickness. The gravel was predominantly composed of flint with occasional quartz. Molluscs were present, mostly broken and included the bivalve molluscs Ostrea edulis and Cerastoderma edule. The unit is interpreted as shallow marine gravel with the upper part of the unit in **WA_VC8C** (from 32.08 to 32.7mbOD) containing finer grained sediments possibly being formed in an outer estuarine/shallow marine environment.	**10** and **13**
e	**ei**	sandy gravel	27.12 to 28.0	Recorded in vibrocore **WA_VC9C** and was 0.88m in thickness. The unit comprised sandy gravel. The gravel was predominantly flint although contained with a high percentage of quartz and no molluscan or other inclusions. The unit was interpreted as glaciofluvial alluvium.	**14**
	eii	Sand and sandy gravel	28.44 to 30.42	Recorded in **WA_VC7C** and was 1.98m in thickness. The unit comprised sand and sandy gravel. The gravel predominantly comprises flint	**12**

Unit	Sub-unit	Sediment type	Depth (mbOD)	Description	Figures
				with occasional quartz and some darker organic bands and clay lumps were also noted in the upper part of this unit from 28.44 to 28.89mbOD. The unit is interpreted as possible glaciofluvial alluvium.	
f	**fi**	Sand	27.7 to 37.82	Recorded in **WA_VC1C**, **WA_VC2C**, **WA_VC3C** and **WA_VC4C** and ranged from 3.08m (**WA_VC1C**) to 5.05m (**WA_VC3C**) in thickness. The unit comprised sand with horizontal bedding and occasional silt layers and clay inclusions. The unit was generally devoid of any identifiable molluscs and was interpreted as waterlain sand although it is likely to have formed in a shallow marine/outer estuarine environment.	**6 – 9**
	fii	Clay and sand	30.78 to 38.19m	Recorded in **WA_VC1C**, **WA_VC2C**, **WA_VC3C** and **WA_VC4C** and ranged from 0.33m (**WA_VC1C**) to 0.86m (**WA_VC3C**) in thickness. The unit comprised horizontally bedded layers of sand and clay which may have been caused by tidal rhythmitic deposition. The unit is interpreted as waterlain sand and clay although if the sedimentary structure is indeed tidally induced then it is probably estuarine alluvium.	**6 – 9**
	fiii	Sand	33.27 to 38.70	Recorded in **WA_VC2C** and **WA_VC4C** and ranged from 0.51 (**WA_VC4C**) to 0.64m (**WA_VC2C**) in thickness. The unit comprised sand with occasional clay inclusions and was interpreted as waterlain sand. It is possible that the unit has been deposited in a shallow marine/outer estuarine environment.	**7** and **9**
g	**gi**	Sand	28.99 to 32.38	Recorded in **WA_VC6C** and **WA_VC6C1** and assuming that the unit is continuous between the two cores it was 1.68m in thickness. The unit comprised sand with occasional flint and quartz pebbles and is interpreted as waterlain (probably shallow marine/outer estuarine) sand.	**11**
	gii	Sand	32.38 to 35.18	Recorded in **WA_VC6C1** and was 2.80m in thickness. The unit comprised yellowish brown sand with prominent orange horizontal oxidised layers of sand increasing with depth. The deposit is interpreted as a waterlain (probably shallow marine/outer estuarine) sand with subsequent evidence of sub-aerial exposure.	**11**
	giii	Sand and gravel	30.42 to 32.09	Recorded in vibrocore **WA_VC7C** and was 1.67m in thickness. The unit comprised gravel and sand with horizontal bedding noted. The unit is interpreted as waterlain (probably shallow marine/estuarine) sand.	**12**
	giv	Sand and gravel	28.0 to 31.8	Recorded in **WA_VC9C** and was 3.80m in thickness. The unit comprised sands and gravel with occasional silt layers and clay inclusions. The unit was interpreted as waterlain (probably shallow marine/estuarine) sand.	**14**

Unit	Sub-unit	Sediment type	Depth (mbOD)	Description	Figures
g	**gv**	Sand	31.8 to 31.83	Recorded in **WA_VC9C** and was 0.03m in thickness. The unit comprised horizontally bedded silty clay and fine sand. This structure may be tidally induced (tidal rhythmites). The major element of the unit comprised two clay bands of 15mm thickness which were oxidised with the upper band more heavily oxidised, indicative of sub aerial exposure subsequent to deposition. The unit is interpreted as waterlain (probably estuarine) sand/clay which has been oxidised.	**14**
	gvi	Sand	31.83 to 32.53	Recoded in **WA_VC9C** and was 0.7m in thickness. The unit comprised sand with horizontal bedding and silty sand layers with very occasional black organic inclusions. The unit is interpreted as waterlain (probably shallow marine/estuarine) sand.	**14**
	gvii	sandy gravel	31.58 to 35.86	Recorded in **WA_VC10C** and was 1.59m in thickness. The unit comprised sandy gravel. The gravel was predominantly flint with occasional quartz and broken molluscs. The unit is interpreted as waterlain (probably shallow marine) sand and gravel.	**15**
	gviii	sandy gravel	35.86 to 36.04	Recorded in **WA_VC10C** and was 0.18m in thickness. The unit comprised sandy gravel. The gravel was predominantly flint with occasional quartz. The unit is interpreted as waterlain sand and gravel.	**15**

Table 8. Descriptions of geoarchaeological units and subunits

5.2. INTEGRATION

5.2.1. In this section each vibrocore location is discussed comparing it to the geophysics data at the vibrocore location. The implications of these comparisons on the interpretation of the Area 240 area and the area from which the hand axes were dredged is discussed in **Section 6**. Depths are discussed referring to metres sub-seabed and metres below OD (mbOD).

WA_VC1C

5.2.2. **WA_VC1C** is situated in the central area of Area 240 within the area from which the hand axes were dredged. The location was selected to target the stratification observed in the clamshell grabs (T1_G3 and G7) as identified in *Stage 3: Seabed sampling* (Wessex Archaeology 2010).

5.2.3. The geophysics data from 2005 (Stage 1) indicates the vibrocore penetrates the fill of a small cut feature (**Unit 6**) cutting into **Unit 4**. The base of this unit is observed at 3.7m sub-seabed (31.0mbOD) overlying a unit with southerly dipping reflectors.

5.2.4. The 2009 parametric sonar data (**Figure 6**) indicates 0.5m thick unit interpreted as recent marine sediment overlying 3m of a relatively transparent unit marked at its base by a strong reflector at 3.5m sub-seabed (30.8mbOD). This unit was interpreted as **Unit 4a** overlying **Unit 2** separated by the strong reflector. The nearest boomer line (16m to the west) indicates the base of the transparent unit at 3.5m sub-seabed (30.8mbOD) overlying a seismic unit comprising southerly dipping reflectors. This unit unconformably overlies a unit (interpreted as **Unit 1**) comprising sub-parallel reflectors, marked by a strong reflector at 11.9m sub-seabed

(39.2mbOD). The cut feature observed in the 2005 data is not observed in the 2009 data.

5.2.5. The geoarchaeology (**Figure 6**) indicates 0.1m seabed sediment (**Unit a**) overlying waterlain sand to a depth of 3.18m (30.78mbOD) and then waterlain sand/clay to a depth of 3.51m (31.11mbOD) at the base of the vibrocore.

5.2.6. The strong basal reflector at around 31.0mbOD in the Stage 1 and Stage 2 geophysics coincides with the base of the vibrocore. It is possible that the sediment change at this depth curtailed the penetration of the vibrocore at this depth.

5.2.7. The stratification observed in the grab sample at this location may be comparable to the stratification observed at 0.61m in the vibrocore where there is a change in colour and inclusions.

WA_VC2C

5.2.8. **WA_VC2C** is situated in the central area of Area 240 within the area from which the hand axes were dredged, approximately 30m to the northeast of **WA_VC1C**. The location was selected to target the central region of T1, around G22 and 23 where the most promising flint artefacts were recovered from the clamshell grab in Stage 3 (Wessex Archaeology 2010).

5.2.9. The geophysics data from 2005 (Stage 1) indicates the vibrocore penetrates up to 1.0m seabed sediment overlying the fill of a small cut feature (**Unit 6**) cutting into **Unit 4a**. The base of this unit is observed at 3.8m sub-seabed (32.1mbOD) overlying a unit with southerly dipping reflectors.

5.2.10. The 2009 boomer data (**Figure 7**) indicates a veneer of recent seabed sediment overlying up to 5.1m sub-seabed (32.3mbOD) of **Unit 4a**, in turn overlying **Unit 2**. Within **Unit 4** a prominent reflector is observed at 1.9m sub-seabed (29.1mbOD). The cut feature observed in the 2005 data is not observed in the 2009 data.

5.2.11. The geoarchaeology (**Figure 7**) indicates 0.45m seabed sediment (**Unit a**) overlying waterlain sand to a depth of 5.10m (32.9mbOD) (**Unit fi**) and then waterlain sand/clay to a depth of 5.47m (33.27mbOD) (**Unit fii**) overlying waterlain sand to the base of the vibrocore at 6.11m (33.91mbOD) (**Unit fiii**).

5.2.12. The boundary observed on the geophysics between **Units 4a** and **2** at 32.3mbOD is considered comparable to the abrupt boundary between **Units fi** and **fii** in the vibrocore. The prominent reflector within **Unit 4a** at 29.1mbOD is probably comparable to the abrupt boundary observed in the vibrocore between medium sand to medium-coarse sand at 29.2mbOD.

WA_VC3C

5.2.13. **WA_VC3C** was also situated in the central area of Area 240 within the area from which the hand axes were dredged, approximately 215m and 185m to the northeast of **WA_VC1C** and **WA_VC2C**, respectively. The location was selected to target the eastern end of T1, around station G5 where the fossilised bone and flint artefacts were recovered from the clam shell grab (Wessex Archaeology 2010).

5.2.14. The geophysics data from 2005 (Stage 1) indicates two strong reflectors. The first is observed at 2.0m sub-seabed (29.1mbOD) and marks a subtle change in seismic response: stronger, brighter reflectors overlying weaker reflectors. This boundary is interpreted as an internal reflector of **Unit 4a** indicating a possible change in sediment type within the unit. The second prominent reflector is observed at 5.2m sub-seabed (32.3mbOD) and is interpreted as the boundary between **Units 4a** and **2**.

5.2.15. The 2009 (Stage 2) parametric sonar data (**Figure 8**) indicates an upper unit of approximately 0.6m of recent sediment (**Unit 8**) overlying a unit comprising strong reflectors (**Unit 4**) to a depth of 2.2m sub-seabed (29.8mbOD) overlying a more transparent unit (**Unit 2**). The 2009 (Stage 2) boomer dataset indicates a faint reflector at 2.2m sub-seabed, as observed in the parametric sonar data.

5.2.16. The geoarchaeological descriptions (**Figure 8**) indicate 0.25m of recent seabed sediment, to a depth of 28.05mbOD (**Unit a**) overlying waterlain sand (**Unit fi**) to 5.3m sub-seabed (33.1mbOD). From 5.3m sub-seabed (33.1mbOD) to the base of the core the sediments comprise waterlain sand and clay (**Unit fii**).

5.2.17. Comparing the sub-bottom profiler data with the vibrocore **Unit 8** is comparable with **Unit a**. The strong reflector observed at 29.8mbOD in the 2009 data possibly marks a change in density within **Unit fi**. In the vibrocore there is a slightly higher clay and organic content within **Unit fi** above 30.2mbOD. This may be reflected in the geophysics data.

5.2.18. The reflector observed in the 2005 sub-bottom profiler data at 5.2m sub-seabed (32.3mbOD) is likely to be comparable to the boundary between **Unit fi** and **fii** in the vibrocore at 33.1m OD. This is similar to the boundary observed in **WA_VC1** and **WA_VC2**.

WA_VC4

5.2.19. WA_VC4 was also situated in the central area of Area 240 to the north of the area from which the hand axes were dredged. The location was selected to target the silty sand observed in the sample at T3_G1 (during Stage 3) to establish if this is the same unit to the silty sand observed in T1_G3 and G7, or if this represents an older unit. This also targets the area in which FeO sheets were recovered during the grab sampling.

5.2.20. In the geophysics a diffuse boundary is observed at 3.7m sub-seabed (35.5mbOD) and 3.5m sub-seabed (35.9mbOD) in the 2005 and 2009 datasets, respectively. This diffuse boundary was interpreted as a possible boundary between **Units 4a** and **2**. In the 2009 dataset a partial reflector is observed at 5.25m sub-seabed (38.0mbOD) and is interpreted as another internal reflector within **Unit 2** (**Figure 9**).

5.2.21. A further prominent reflector is observed at 7.4m sub-seabed (39.2mbOD) and 7.8m sub-seabed (40.2 below OD) in the 2005 and 2009 datasets, respectively. This boundary is interpreted as the base of **Unit 2**.

5.2.22. The geoarchaeological descriptions indicate 1.37m recent seabed sediment (**Unit a**) overlying waterlain sand (**Unit fi**) to a depth of 4.92m (37.82mbOD), waterlain clay and sand (**Unit fii**) to a depth of 5.29m (38.19mbOD) and waterlain sand to the bottom of the vibrocore at 5.8m (38.7mbOD).

5.2.23. There is little correlation between the geophysics data and the vibrocore data. Based on the depth data, the boundary observed around 35.9mbOD may be comparable to the abrupt boundary observed in the vibrocore within **Unit fi** at 36.76mbOD. However, based on the seismic character of the unit it is likely that the reflector marks the boundary between **Unit fi** and **fii**, as observed in **WA_VC1**, **2** and **3**. In the vibrocore this boundary is observed at 4.92m (37.82mbOD); a disparity of 1m between the vibrocore and the geophysics data. The partial reflector observed in the 2009 data (at 38.0mbOD) possibly marks the boundary between **Units fii** and **fiii** observed in the vibrocore at 38.19mbOD.

WA_VC5C

5.2.24. WA_VC5C is situated towards the western edge of Channel A, the infilled channel observed in the 2005 (Stage 1) dataset (**Figure 4**). The aim was to target a small cut and fill feature identified within the channel feature.

5.2.25. The sub-bottom profiler data (**Figure 10**) indicates a veneer of recent seabed sediment forming a tail of a sandwave to the south. At a depth of 2.5m sub-seabed (30.1mbOD) a strong reflector marks the base of a cut and fill feature. The fill unit is observed as a semi-transparent unit and is interpreted as a fine-grained fill. The reflector marking the base of the fill unit also is interpreted as **Reflector A**, a strong reflector possibly marking a hiatus in the infilling of the channel. **Unit 4** comprises a series of strong reflectors interpreted as a coarse-grained sediment fill. The base of the channel cut is observed at 5.4m sub-seabed (33.0mbOD) and this cuts into a more transparent unit interpreted as **Unit 2**.

5.2.26. The geoarchaeological descriptions indicate three units. Recent seabed sediment is observed to a depth of 0.05m (27.15mbOD) which overlies a fine-grained unit of sandy clay (**Unit ci**) and clayey sand (**Unit cii**) interpreted as estuarine alluvium/lagoonal sediments to a depth of 2.12m (29.22mbOD). **Unit c** is comparable to **Unit 5** on the geophysics data.

5.2.27. **Unit d** is observed between 2.12m (29.22mbOD) and the base of the core at 5.66m (32.76mbOD) and is interpreted as a shallow marine gravel. This unit coincides with **Unit 4** in the geophysics data.

5.2.28. It appears that the vibrocore did not penetrate into the underlying **Unit 2**.

WA_VC6C/C1

5.2.29. **WA_VC6C** is situated in the northwest corner of Area 240. It was selected to target a bank structure comprising **Unit 5** identified in the 2005 geophysics dataset to assess whether this sediment unit is comparable to the **Unit 5** deposits observed further to the east associated with the channel and its edges. This site was also targeted to tie in with previous work in Area 254 (**Figure 1**) conducted as part of the Seabed Prehistory: Gauging the effects of Marine Aggregate Dredging (Wessex Archaeology 2008).

5.2.30. The geophysics data (**Figure 11**) indicates a veneer of seabed sediment overlying a small cut and fill feature interpreted as the fine-grained sediments of **Unit 5**. The base of **Unit 5** is observed at 3.1m sub-seabed (31.2mbOD). **Unit 5** overlies a unit of strong reflectors interpreted as **Unit 4** to a depth of 4.6m sub-seabed (32.7mbOD).

5.2.31. Underlying **Unit 4** is the semi-transparent **Unit 2** which in turn overlies **Unit 1** which is marked by a very strong reflector. This boundary is observed at 6.2nm sub-seabed (34.3mbOD).

5.2.32. There is little direct comparison between the geophysics data and the vibrocore, unlike at the other vibrocore locations. The geoarchaeology indicates 0.79m of recent sediment overlying **Unit g** (**gi** and **gii**) interpreted as waterlain (probably shallow marine/outer estuarine) sand.

5.2.33. There is no evidence in the vibrocore of a finer-grained unit (**Unit 5**) as observed in the geophysics and the boundary between **Units 4** and **2** in the geophysics at a depth of 32.7mbOD does not directly compare, but may mark the boundary between **Unit gi** and **gii**. Based on the vibrocore the strong reflector marking the boundary between **Units 2** and **1** was not penetrated.

WA_VC7C

5.2.34. **WA_VC7C** is situated on the northern edge of Channel A and targets the sediments that have infilled the channel and the channel edges, namely **Reflector A** and **Unit 5**.

5.2.35. The geophysics data (**Figure 12**) indicates a veneer of seabed sediments (**Unit 8**) overlying **Unit 5**, interpreted as a fine-grained unit to a depth of 2.1m sub-seabed (29.5mbOD).

5.2.36. Between 2.1m sub-seabed (29.5mbOD) and 6.0m sub-seabed (33.4mbOD) a unit of strong chaotic reflectors interpreted as **Unit 4c** is observed. Within this unit a very strong reflector (**Reflector A**) is observed at 3.5m sub-seabed (30.9mbOD) marking the boundary between **Units 4c** and **4b**.

5.2.37. Underlying **Unit 4b** is a seismic transparent unit interpreted as **Unit 2**.

5.2.38. Four sediment units are observed in the vibrocore. The upper 0.14m is seabed sediment which is equivalent to the veneer of **Unit 8** observed on the geophysics data. **Unit cii** interpreted as fine-grained estuarine alluvium deposits is observed between 27.44mbOD and 28.89mbOD equate to **Unit 5**, the base of which is observed in the geophysics at 29.5mbOD.

5.2.39. **Reflector A** observed in the geophysics at 30.9mbOD at a similar depth (30.42mbOD) to the boundary between **Unit e** and **g** in the vibrocore. As such **Unit 4c** is considered comparable to **Unit eii**.

5.2.40. The unit of chaotic reflectors (**Unit 4**) observed to a depth of 33.4mbOD in the geophysics is equivalent to **Unit g** recorded in the vibrocore. The vibrocore does not appear to have penetrated the underlying **Unit 2**.

WA_VC8C1

5.2.41. **WA_VC8C1** is also situated in the northwest corner of Area 240, approximately 1.3km south of **WA_VC6C/C1**. It was selected to target the infill deposits (**Unit 7**) of a very shallow Channel (Channel B, **Figure 5**) which was observed in the sub-bottom profiler data and as a trace on the bathymetry data. Based on vibrocore data from 2005 **Unit 7** was interpreted as a unit comprising fine-grained sediments and organic matter including peat.

5.2.42. The geophysics data (**Figure 13**) indicates 0.8m recent sediment (to a depth of 31.5mbOD) overlying **Unit 7** to a depth of 2.74m sub-seabed (33.4mbOD). The reflectors in **Unit 7** are very bright indicating possible organic content.

5.2.43. The unit underlying **Unit 7** was interpreted as **Unit 2** to a depth of 6.21m sub-seabed (36.2mbOD). However the seismic signature of this unit (stronger more chaotic reflectors) is different to elsewhere in Area 240 (semi-transparent unit with occasional reflectors). One of the aims of this core was to establish the nature of this unit.

5.2.44. The geoarchaeological descriptions indicate 0.37m of seabed sediment (to a depth of 31.07mbOD) which is comparable to **Unit 8** in the geophysics data.

5.2.45. Between 0.37 and 1.36m (31.07 and 32.06mbOD) the vibrocore indicates **Unit b** which comprises intertidal mudflat/saltmarsh deposits overlain by shallow marine/outer estuarine sand and a shallow marine lag gravel. **Unit b** is comparable to **Unit 7** in the geophysics. Peat layers observed in **Unit biii** are the cause of the bright reflectors observed in **Unit 7**.

5.2.46. **Unit 2** is comparable with **Unit d** (shallow marine gravels), in terms of depth but not necessarily sediment content. Based on the vibrocore data it is considered that **Unit 2** interpreted in the geophysics is in fact **Unit 4b** and **Unit 4** identified to the south of the vibrocore location (**Figure 13**) possibly represents **Reflector A** and marks the boundary between **Units 4b** and **4c**. The geophysics data will need to be revisited to confirm this.

WA_VC9C

5.2.47. **WA_VC9C** is situated to the south of where the hand axes were dredged. This location was selected to target a thin layer of **Unit 5** and **Reflector A** observed in the 2005 geophysics dataset. The aim was to compare the sediment units observed here to those in the north to establish similarities or disparities in sediment type.

5.2.48. There is a large discrepancy between the water depths at this vibrocore location. In 2005, based on the multibeam echosounder data, the water depth is recorded at 27.1mbOD; in 2005 at 24.7mbOD. This is a difference of 3.0m. Given the presence of strong tidal currents in the area and a number of large sandwaves formed by these processes, it was considered possible that between 2005 and 2010 recent sediment had accumulated accounting for the difference in water depth. However, once examined, the vibrocore indicates only a thin layer of seabed sediments. It is deemed likely that there is a problem with the depth recorded in 2010. Furthermore, the second core taken (**WA_VC9B**) within a metre of **WA_VC9C** records a depth of 27mbOD. It may be that this is a more accurate water depth for this location and as such is used here to compare depths (mbOD).

5.2.49. The geophysics data (**Figure 14**) indicates a veneer of recent seabed sediment (**Unit 8**) overlying a thin unit of fine-grained sediment interpreted as **Unit 5** to a depth of 1.6m (29.3mbOD). This overlies strong sub-parallel reflectors (**Unit 4c**) to a depth of 2.5m sub-seabed (30.2mbOD), the base of which is marked by a strong reflector (**Reflector A**). Below **Reflector A** is a unit containing strong reflectors to a depth of 4.1m sub-seabed (31.8mbOD). This is interpreted as **Unit 4b**. **Unit 2** underlies **Unit 4b.** To the north and south of the vibrocore there is no distinctive boundary between **Units 4b** and **4c**.

5.2.50. The geoarchaeology indicates 0.12m of recent seabed sediment (**Unit a**) and is directly comparable to **Unit 8** in the geophysics. This overlies **Unit e** between 0.12 and 1.0m (27.12 and 28.0mbOD) and is likely to be comparable to the interpreted **Unit 4c**). This overlies **Unit g** to the base of the vibrocore, comparable to **Unit 4b.** There was no evidence of the fine-grained sediments of **Unit 5** in the vibrocore. Based on the depths it is possible that the boundary between **Unit 4b** and **Unit 2** in the geophysics marks the boundary between **Unit giv** and **gv** marking the point at which there was a hiatus in deposition between and was marked by a lowering of the sea-level and subsequent oxidisation of **Unit gv**.

WA_VC10C

5.2.51. **WA_VC10C** is situated to the east of Area 240 and targets deposits with Channel A, as a comparison to sediments found in **WA_VC5C** and **WA_VC7C**.

5.2.52. The geophysics (**Figure 15**) indicates a veneer of seabed sediments, possibly up to 1m thick overlying a unit interpreted as containing finer grained sediments (**Unit 5**) to a depth of 2.8m sub-seabed (33.9m OD). The base of this fill unit is marked by a strong reflector.

5.2.53. Underlying **Unit 5** is **Unit 4** to the base of Channel A at 6.8m sub-seabed (37.9mbOD).

5.2.54. The geoarchaeological descriptions indicate a veneer (0.18m) of seabed sediment (**Unit a**) overlying a series of waterlain sand and gravels to a depth of 4.64m (36.04mbOD) at the base of the vibrocore.

5.2.55. The boundary observed in the geophysics at 33.9mOD marking the boundary between **Unit 5** and **Unit 4** is possibly comparable to the boundary marking the boundary between waterlain sand/gravel and the overlying waterlain sand in the vibrocore at 34.27mbOD.

5.2.56. This indicates that the geophysics interpretation of Unit 5 in this instance needs to be re-addressed.

6. DISCUSSION

6.1. SEDIMENTARY UNITS

6.1.1. The following section discusses the depositional environment of each unit in relation to Area 240 as a whole and discusses the comparisons between the geoarchaeological units and the geophysical units.

Geoarchaeological Units f and g

6.1.2. The sediments within vibrocores **WA_VC1C**, **WA_VC2C**, **WA_VC3C** and **WA_VC4C** are directly comparable (**Figures 6**, **7**, **8** and **9**), with a similar sequence noted for each of these cores. These cores are proximal as can be seen in **Figure 5**. This sequence comprised sand (**Unit fiii**) overlain by clay and sand (**Unit fii**) and sand (**Unit fi**). The sand (**Units fi** and **fiii**) was generally well sorted and horizontally bedded with occasional small flint and clay inclusions. These sands are waterlain and it is considered likely they were deposited in the outer reaches of an estuary/shallow marine environment. The alternating clay and sand bands may have been deposited as a result of tidal deposition (i.e flood couplets/tidal rhythmites).

6.1.3. Although not proximal to vibrocores **WA_VC1C**, **WA_VC2C**, **WA_VC3C** and **WAVC4C** the base of **WA_VC9C** (**Figure 14**) contained similar sands and clays (**Units gvi**, **gv** and **giv**) which appear to have formed under similar conditions to **Units fiii**, **fii** and **fi**. The subsequent oxidisation of the sands and clays noted in **Unit gv** is an indication of relative lowered sea level subsequent to deposition. The base of vibrocore **WA_VC6C1** (**Figure 10**) also contained waterlain sand (**Unit gi**) and sand which had been oxidised subsequent to deposition (**Unit gii**).

6.1.4. Waterlain sands (**Units giii**, **gvii** and **gviii**) were also noted within vibrocores **WA_VC7C** and **WA_VC10C** (**Figures 12** and **15**) although notably gravellier than those within vibrocores **WA_VC1C**, **WA_VC2C**, **WA_VC3C**, **WA_VC4C** and **WA_VC9C**.

6.1.5. The basal subunits of **Unit f (subunits fi and fii)** are equivalent to geophysical **Unit 2**. Whereas the overlying **Unit fi** is equivalent to geophysical **Unit 4a**. **Unit 4a** is generally observed in the central region of Area 240 and is marked by a diffuse basal reflector as oppose to the strong basal reflector of **Unit 4b** to the north and south of Area 240. The **Unit gv** may also mark the boundary between the underlying **Unit 2** and **Unit 4b**.

6.1.6. With the exception of **Units gv** and **gvi**, **Unit g** is equivalent to **Unit 4b** in the geophysics. **Unit 4b** is observed with a strong basal reflector (between **Unit 2** and **4b**) and strong top reflector (**Reflector A**) and is predominantly associated with the oldest infill sediments of Channel A.

6.1.7. The boundary observed in the geophysics between **Units 4** and **2** may not represent a change in sediment deposition but a subtle change in sediment type within one depositional unit. This could have implications on the interpretation of the geophysics throughout the area. Based on the geophysics data **Unit 2** was interpreted as the Yarmouth Roads Formation and **Unit 4** as a younger unit deposited after the Anglian Glaciation. Based on work carried out in Area 254 (Wessex Archaeology 2009) **Unit 4** was given a possible Wolstonian date. However if the subunits of **Unit f** were deposited subsequent to each other in the same environment then this calls into question the relative ages of **Units 2** and **4.** Further palaeo-environmental work and dating may solve this issue.

Geoarchaeological Unit e

6.1.8. **Unit e** comprises **Units eii** in **WA_VC 7C** (**Figure 11**) and **ei** in **WA_VC9C** (**Figure 13**). These sandy gravels are devoid of marine molluscan inclusions and contain notably high proportions of quartz. These have been tentatively interpreted as glaciofluvial alluvium.

6.1.9. The geophysics data indicates that **Unit e** is equivalent to geophysical **Unit 4c**. This geophysical unit has a strong seismic response and the base of this unit is marked by a strong reflector (interpreted in Stage 1 as **Reflector A**). **Reflector A** is primarily observed in the central northern section of Area 240 associated with the infilling of Channel A. **Reflector A** is also observed in small localised areas to the south of the area in the vicinity of **WA_VC9C**.

6.1.10. In the initial interpretation (Stage 1) **Reflector A** was interpreted as marking a hiatus in the infilling of the channel cut. Based on seismic data alone it was not possible to distinguish between the unit below the reflector (**Unit 4b**) and the unit above (**Unit 4c**), i.e. the seismic response is similar. In both vibrocores **WA_VC7C** and **WA_VC9C Unit e** is observed overlying **Unit g**. The deposition environment of these two units is interpreted as considerably different indicating that **Reflector A** represents not only a hiatus in deposition but also a significant change in depositional environment.

6.1.11. **Unit e** may be equivalent to the early part of the Brown Bank Formation (Cameron *et al.* 1992).

Geoarchaeological Unit d

6.1.12. **Unit d**, a shallow marine sandy gravel was recorded in the base of vibrocores **WA_VC5C** (**Figure 10**) and **WA_VC8C** (**Figure 13**).

6.1.13. This unit is possibly equivalent to geophysical **Unit 4b** and is the basal deposit in the infilled Channel A.

6.1.14. **Unit d** may be analogous to the shelly gravelly sands at the base of the Brown Bank Formation as described by the British Geological Survey (Cameron *et al.* 1992).

Geoarchaeological Unit c

6.1.15. This unit was recorded in vibrocores **WA_VC5C** and **WA_VC7C** (**Figures 10** and **12**). The unit was interpreted as estuarine/ lagoonal sediments. Subtle changes in the sediments within this geoarchaeological unit (**Unit ci** and **cii**) indicate subtle changes in depositional environment.

6.1.16. Geoarchaeological **Unit c** is equivalent to geophysical **Unit 5**.

6.1.17. **Unit 5** has a distinct seismic character and is observed primarily in the north of Area 240 associated with the infilled channel and its floodplain. Small localised thin patches of the unit were also interpreted to the south of the area. Although, it should be noted that in **WA_VC9C** there was no evidence of **Unit c** even though the geophysics suggested there might be up to 1m present. In the north of the area the unit is more distinct and is observed infilling a series of cut features or forming small bank structures on the edge of the infilled channel.

6.1.18. Within the aggregate dredging Area 254, to the north of Area 240 (**Figure 2)** similar estuarine and lagoonal deposits were investigated (Wessex Archaeology 2008) and were thought to be potentially Ipswichian date. This would suggest that **Unit c** is analogous to the brackish silty clays of the early Brown Bank Formation as described by the British Geological Survey (Cameron *et al.* 1992).

Geoarchaeological Unit b

6.1.19. This unit, recorded in **WA_VC8C** (**Figure 13**), comprised a sequence of interbedded peat/silt, clay and sand indicative of intertidal/saltmarsh deposition (**Unit biii**), overlain by shallow marine/ outer estuarine sands (**Unit bii**) and a shallow marine lag gravel (**subunit bi**). This sequence is indicative of a terrestrial environment which has been inundated and covered by shallow marine sediments.

6.1.20. Recent dating of peat within a core to the east of this vibrocore suggests the peats (**Unit biii**) may be early Holocene in date (Hazell in preparation). Given their probable early Holocene date it is likely that the sequence of deposition is associated with the last marine transgression.

6.1.21. No deposits of this type and age have been recorded in the area by the British Geological Survey (Cameron *et al.* 1992) and it is likely that they have been previously ascribed to the Brown Bank Formation.

6.1.22. This geoarchaeological unit is equivalent to **Unit 7** identified in the geophysics data. Based on the seismic response of the unit and the similarities between **WA_VC8C** and those acquired previously as part of aggregate assessment, it is considered that **Unit 7** will contain similar sediments where it has been interpreted. **Unit 7** is associated with a shallow channel feature in the northwest of Area 240. The development of this feature is discussed further in **Section 6.2**.

Geoarchaeological Unit a

6.1.23. This unit, of sandy gravel and gravelly sand was recorded in all of the vibrocores and is interpreted a as a recent seabed sediment. This unit is also likely to have been, in part, related to recent dredging history within Area 240, the history of which is detailed within the Stage 1 report (Wessex Archaeology 2009). **Unit a** is the equivalent to **Unit 8** in the geophysics data.

Summary

6.1.24. **Table 9** provides a table of equivalence between the geophysical and geoarchaeological units, as described above.

Geoarchaeological Unit	Geophysical Unit	Description
Unit a	Unit 8	Recent seabed sediment
Unit b	Unit 7	Intertidal/saltmarsh deposition overlain by shallow marine/ outer estuarine sands associated with Channel B
Unit c	Unit 5	Brackish estuarine/ lagoonal fine-grained sediments primarily associated with the infill of Channel A
Unit d	Unit 4b	Shallow marine sands and gravels primarily associated with the infill of Channel A
Unit e	Unit 4c	Glaciofluvial alluvium sands and gravels primarily associated with the infill of Channel A
Unit f	Unit 4a/Unit 2	Waterlain - outer reaches of an estuary/shallow marine environment situated in the central region of area 240, associated with the area from which the hand axes were dredged.
Unit g	Unit 4b/Unit 2	Waterlain - outer reaches of an estuary/shallow marine environment associated with the older deposits of Channel A

Table 9. Equivalence between geoarchaeological and geophysical units

6.2. FEATURES

6.2.1. The following section discusses the relationship between the sedimentary units in terms of their broader context within Area 240. Three features are discussed: the area from which the hand axes were dredged, Channel A and Channel B.

Hand axe area

6.2.2. The dominant unit in the area from which the hand axes were dredged is **Unit 4a** (**Unit fi**) and comprises sands with occasional gravel. If the hand axes were dredged *in situ* then it is likely they were recovered from this unit, unless the entire sediment unit from which the hand axes were recovered has been removed by the dredging process.

6.2.3. Based on the water depths recorded at **WA_VC1**, **WA_VC2** and **WA_VC3** between 2005 and 2009, during which time the hand axes were dredged, there is only a slight deepening of the seabed indicating the removal of approximately 0.5m. Although it is difficult to assess if this was caused by natural erosion of seabed sediments or the dredging of underlying sediment, it is not a significant removal and, based on the available geophysical and geotechnical data, it is considered that any dredging will not have dredged out a complete unit of sediment from which the hand axes were dredged.

6.2.4. If dredged from **Unit 4a** (**Unit fi**), then the hand axes were recovered from sediments deposited in an outer estuarine environment. The condition of the hand axes implies that they were recovered in three different environments: mint (from a primary context), fresh (from an eroding surface) and weathered (from secondary contexts, mainly from the seafloor).If the hand axes were all dredged from **Unit 4**

(**Unit fi**) then this may indicate that the hand axe conditions may be related to depositional histories within one unit, rather than different units.

6.2.5. The stratigraphic and chronological relationship between **Unit 4a**, **Unit 4b** and **Unit 4c** across the area remain unknown at this time. The similarities between geoarchaeological **Units f** and **g** may indicate a lateral change in sediment type rather than a chronological change in deposition. Palaeo-environmental work and assessment of these sediments is required to establish this relationship between the infilling of Channel A and the deposition of the sediments from which the hand axes were dredged.

Channel A

6.2.6. In the geophysics data the base of channel A is marked by a boundary between **Unit 2** which has been cut into and the overlying infill sediments of **Units 4b**, **4c** and **5**. Geoarchaeologically **WA_VC 5**, **7** and **10** indicates **Units g**, **d**, **e** and **c**.

6.2.7. **WA_VC7C** is situated on the shoulder of the channel and exhibits a more complex sequence than within the channel (**WA_VC5C** and **10C**).

6.2.8. The geoarchaeology indicates an initial filling sequence of sand and sandy gravels (**Unit d**) and sands and gravels, with flint and clay inclusions (**Unit g**) deposited. Both **Units d** and **g** (equating to geophysical **Unit 4b**) were deposited in outer estuarine or shallow marine environment. At this time it is unsure if the differences in sediment type represent deposition at different times or contemporaneous deposition but within different parts of the estuary.

6.2.9. **Units d** and **g** are observed to the west of the channel in **WA_VC 6** and in the base of WA_VC8. **Unit g** is also observed to the south of the area (**WA_VC9**) indicating that deposition of these sediments was extensive in Area 240, extending beyond the edges of the channel itself. The relationship between **Unit g** in the north and south, and the **Unit f** deposits in the centre of the area is difficult to assess without further palaeo-environmental assessment and dating.

6.2.10. In **WA_VC6 Unit g** exhibits evidence of oxidisation indicating a lowering of sea-level and exposure prior to subsequent deposition. Within the aggregate dredging Area 254, to the north of Area 240 (**Figure 2**) similar sands and gravelly sands were observed as oxidised. These sands were OSL dated and interpreted as primarily Wolstonian in age (Wessex Archaeology 2008). However, further dating would be required to confirm this.

6.2.11. Within the channel there then appears to be a change in depositional environment, certainly within parts of the channel. Geophysical **Unit 4c** is marked at its base by **Reflector A** and comprises sands and gravels possibly deposited in a glaciofluvial environment (**Unit e**).

6.2.12. Fine–grained deposits of **Unit 5 (Unit e)** were then deposited forming small cut and fill features or small bank structures within and on the edge of channel. The numerous small channels indicate deposition in a restrictive environment within an estuarine system, as the channel continued to develop both temporally and spatially.

6.2.13. Interestingly, **WA_VC9** to the south of the area contains sediment units similar to those infilling the channel (**Unit e**).

6.2.14. Within the aggregate dredging Area 254, to the north of Area 240 (**Figure 2**) similar fine-grained sediments were observed and given an Ipswichian date based on the palaeo-environmental assessment (Wessex Archaeology 2008).

6.2.15. Dating of these sediment units is required to establish the chronostratigraphy of the channel infill sediments.

6.2.16. If **Unit 4a** (**Unit fi**) associated with the channel was deposited contemporaneously with the later filling of the channel (**Unit 4c**) then it is likely the channel may have been completely infilled by the time of hand axe deposition. However, if **Unit 4a** (**Unit fi**) proves to be older then it is possible that the channel was in flow when the hand axes were deposited.

Channel B

6.2.17. The base of Channel B cuts into deposits that are observed in Channel A (**Unit d**). This indicates that deposits associated with Channel A extend to the west and have then been cut by water action forming the base of Channel B. Based on the geoarchaeology the infill of Channel B is indicative of a transgressive sequence. Based on previous work indicating these sediments to be Early Holocene (Hazell in preparation), it is likely that these deposits are associated with the last marine transgression.

6.3. WIDER REGIONAL IMPLICATIONS

6.3.1. Channel features are documented in the southern North Sea to the east of Area 240 (Cameron et al. 1992). These are documented as flowing north and northeast to a lagoonal area and the infill is interpreted as Brown Bank Formation (Late Ipswichian/Early Devensian). It is possible that the features observed in Area 240 form part of the same system of channels.

6.3.2. The Palaeo-Yare valley sediment formations occupy the floor of a buried valley system underlying the marshland and river valleys of the present day River Yare, onshore. There are two notable formations: the Yare Valley Formation and the Breydon Formation.

6.3.3. Onshore, possible Devensian sediments are ascribed to the Yare Valley Formation and are only recognised from boreholes. The Formation comprises fine to coarse gravel, with variable amounts of fine to coarse grained sand. The gravel fraction is predominantly flint. Some silty gravel is recorded, as well as shell fragments and chalk cobbles. The type-borehole for this formation comprises grey, silty, fine to coarse gravel passing in the top-most metre to grey-brown gravelly, medium grained sand (Arthurton *et al.* 1994). The Yare Valley Formation is tentatively recognised in offshore seismic profiles (Arthurton *et al.* 1994) close to the shore.

6.3.4. There is no direct evidence for the age of the formation. Coxon (1979) suggests Devensian; Cox *et al.* (1989) suggest Late Devensian. Arthurton *et al.* (1994) supposes at least some of the deposits to be Late Devensian/early Holocene age, deposited by rivers flowing within the now buried valley system and draining central parts of East Anglia to the contemporary southern North Sea Basin. However, Funnell (1990) has argued that the general characteristics of the deposits imply a late Anglian age. The formation postdates the Anglian succession (Lowestoft and Corton tills) but it is possible that it includes the glaciofluvial deposits of Late Anglian age.

6.3.5. The gravel deposits identified by Bellamy (1998) within dredging Area 254, directly adjacent to the north of Area 240 were tentatively identified as analogous to the terrestrial Yare Valley Formation. These sands and gravels identified during the Seabed Prehistory: Great Yarmouth project (Wessex Archaeology 2008) were interpreted as fluvial sediments with OSL dates suggesting deposition during the Wolstonian period.

6.3.6. Onshore, the confluence of the Rivers Bure and Tare at Great Yarmouth has resulted in a large complex of alluvium, peat and Fen silts adjacent to the coast (Geological Survey of Great Britain, Sheet 12). Peat of freshwater and brackish origins is a major component in the valleys of the River Yare and overlies the Yare Valley Formation gravels (Arthurton *et al.* 1994:72).

6.3.7. These post-glacial peats are identified as the Breydon Formation, a fill of the buried valley system underlying present-day marshland. The formation is dominated by silt and clay. Associated with the formation are three peat layers: the basal, middle and upper peat. Of these peat layers the basal peat is the one of interest with regards to Area 240; the middle and upper peat were deposited onshore after the inundation of Area 240 (Boomer and Godwin 1993; Arthurton *et al.*1994).

6.3.8. The basal peat is recorded to have formed *c.* 7580+/- 90 BP (6598 – 6244 cal. BC) at a depth of around 23m below OD and is up to 2m thick (Arthurton *et al.* 1994:77). Based on seismic data of the near coastal area, the Breydon Formation is thought to be preserved offshore in two distinct areas off Great Yarmouth to the limit of the Cross Sand area, approximately 6km offshore, to the northwest of Area 240.

6.3.9. It has been suggested that these sediments continue offshore to Area 254 and then south into Area 240 (Bellamy 1998).

6.3.10. With the exception of sediments deposited in a glaciofluvial environment (**Unit e**) the majority of the channel infill deposits in Area 240 are associated with deposition in an outer estuarine environment. The sediments recorded in **Unit e** are similar to those documented from the type-borehole and the more generalised description of the formation. It is possible that Channel A forms part of the offshore extension of the palaeo-Yare and the outer estuarine sediments possibly represents a later rise in sea-level. However, at this time, there is no conclusive evidence (geophysical or geoarchaeological) that the channel and associated deposits in Area 240 form an extension of the Palaeo-Yare valley deposits, although it cannot be ruled out.

6.3.11. In Area 240 radiocarbon dating of the top and bottom of a peat unit recording in a vibrocore acquired in 2005 dates the peat between 10,470+/-35 BP (10,710 – 10,280 cal. BC, SUERC-11978) and 8370+/-25 (7530 – 7350 cal. BC, SUERC 11975) (Hazell in preparation) at depths of 30.80mbOD and 30.05mbOD, respectively. These dates are slightly older and deeper than those documented by Arthurton *et* al. (1994:77). It is likely that the peats identified in Area 240 were formed in similar conditions and within the same timeframe as those observed onshore but there is no evidence that Channel B in Area 240 is a continuation of the onshore basal peat of the Breydon Formation.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. CONCLUSIONS

7.1.1. Seven geoarchaeological units (**Units a – g**) were identified in the vibrocores. The sediments identified in these units were deposited in a range of environments: shallow marine, outer estuarine, estuarine/lagoonal (restricted environment), glaciofluvial and intertidal mudflat/saltmarsh.

7.1.2. Integration with the geophysics data from Stages 1 and 2 (**Units 1 – 8**) resulted in considerable correlation between the geophysical and geoarchaeological units.

7.1.3. Geoarchaeological **Units a**, **b**, **c** and **e** were directly comparable with geophysical **Units 8**, **7**, **5** and **4c**, respectively. However, questions remain over geoarchaeological **Units d** and **g** (geophysical **Unit 4b**), **Unit f** (geophysical **Unit 4a/2**) and **Unit g** (geophysical **Unit 4b/Unit 2**). Further work including palaeo-environmental assessment and dating, and re-visiting the geophysics data from Stages 1 and 2 is required in order to solve these issues.

7.1.4. Discrepancies between the geophysics and geoarchaeoloigcal interpretations are noted in **WA_VC8C** and **WA_VC10C**. The geophysics data from 2005 would need to be reassessed. However, it is recommended that this is only carried out once palaeo-environmental assessment and dating is complete.

7.1.5. The dominant unit in the area from which the hand axes were dredged is a unit comprising sands with occasional gravel deposited in an outer estuarine/shallow marine environment (**Unit 4a/ Unit fi**). If the hand axes were dredged *in situ* then it is likely they were recovered from this unit.

7.1.6. Two channels are observed in the area, to the north of where the hand axes were dredged. Channel A exhibits a complex infill sequence that differs in various parts of the channel. The most comprehensive infill sequence was observed in **WA_VC7C** which is situated on the shoulder of the channel cut. Here, the fill sequence includes outer estuarine/shallow marine sands and gravels overlain by glaciofluvial gravel, which is, in turn, overlain by estuarine alluvium/lagoonal clayey sand deposits (restricted environment). **WA_VC5C** situated within the channel indicates shallow marine gravels overlain by estuarine alluvium/lagoonal clayey sand deposits.

7.1.7. Based on both the geophysics and the geoarchaeological units there is evidence of similar sediments observed to the south of Area 240 that are similar to those associated with Channel A. Further investigation is required to confirm this and ascertain any relationship between the two areas.

7.1.8. Channel B cuts into infill sediments associated with Channel A and is infilled by a transgressive sequence of sediments which comprises intertidal/saltmarsh clayey peaty silt overlain by outer estuarine sand and then shallow marine lag gravel. Based on previous radiocarbon dating, it is likely that the peats were deposited during the Early Holocene and that the overlying sediments were deposited during the last transgression.

7.1.9. The work carried out under Stage 4 of the project has improved our understanding of Area 240, particularly with the intergration of the geoarchaeological and geophysical data. However, further work is required in order to fully understand the area. This work would include palaeo-environmental assessment and analysis of selected units to establish their depositional environments and also dating to provide a chronostratigraphic framework for the area.

7.2. RECOMMENDATIONS

7.2.1. This section provides recommendations for follow-on palaeo-environmental assessment and dating work (Stage 5).

7.2.2. Based on the integration of the geoarchaeological and geophysical data a number of specific research aims have been developed which will guide the palaeo-environmental assessment and dating (Stage 5).

7.2.3. These research aims have also been applied to the main objectives of the project. The objectives relating to Stage 5 are as follows:

1. characterise the area in which the hand axes were dredged. This characterisation involves the date, extent, depositional environment of the material and significance;

2. establish the relationship between the sediments from which the hand axes were dredged with sediment units and features identified within Area 140;

3. improve the understanding of the character of the historic environment in the East Coast region.

7.2.4. **Table 10** details the research tasks, the objective to which it relates and the relevant recommended action. As it is not possible to assess and date every core, a minimum number of vibrocores has been selected in order to satisfy all the research aims. The number of samples for assessment and dating is constrained both by costs and time remaining in the project.

No.	Research task	Objective	Action
1	Assess each of the main geoarchaeological sediment units to establish depositional environment	1, 2 and 3	Sample relevant units from **WA_VC2**, **7**, **9** and **8**
2	Assess and date sediment unit from which hand axes were most likely dredged	1, 2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC2C** and OSL dating of **WA_VC2B**
3	Establish any difference between geoarchaeological **Units fi** and **fii** (geophysical **Unit 4** and **2**), particularly the relative dates.	1, 2 and 3	Palaeo-environmental assessment of **Units fi** and **fii** in **WA_VC2C** and OSL dating of **WA_VC2B**
4	Establish the relationship between the northern, central and southern areas of Area 240	1, 2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC2C**, **7C** and **9C** and OSL dating of **WA_VC2B**, **7B** and **9B**
5	Establish the similarities between geoarchaeological **Units f** and **g**, if any	1, 2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC2C**, **7C** and **9C** and OSL dating of **WA_VC2B**, **7B** and **9B**
6	Assess the sequence of channel infill sediments to establish changes of deposition and further knowledge on the chronostratigraphy of the sequence	2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC7C** and OSL dating of **WA_VC7B**
7	Establish the relationship between geoarchaeological **Units g** and **d** (geophysical **Unit 4b**)	1, 2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC7C**, **9C** and **8C**

No.	Research task	Objective	Action
8	Establish the relationship between **Units e** and **g** in the north associated with the channel, and similar units to the south of the site	2 and 3	Palaeo-environmental assessment of relevant units in **WA_VC7C** and **9C** and OSL dating of **WA_VC7B** and **9B**
9	Establish the nature and timing of the lowering of sea-level and subsequent exposure of sediments as indicating by an oxidation layer	2 and 3	Palaeo-environmental assessment of relevant units in **WA_ 9C** and OSL dating of **WA_VC9B**
10	Confirm expected date on **Unit biii** as Early Holocene	2 and 3	Radiocarbon date suitable peat material from **Unit biii** of **WA_VC8C**
11	Assessment of the transgressive sequence of sediments (**Unit bi**, **bii** and **biii**)	2 and 3	Palaeo-environmental assessment of **Units bi**, **bii** and **biii** of **WA_VC8C**
12	Assess the relationship between the cutting of Channel B into the underlying sediments associated with Channel A	2 and 3	Palaeo-environmental assessment of b and the underlying **Unit d** of **WA_VC8C**
13	Establish any similarities between channel infill sediments in Area 240 and the onshore Yare Valley Formation	3	Palaeo-environmental assessment of relevant units in **WA_VC7C** and OSL dating of **WA_VC7B**
14	Establish any similarities between channel infill sediments in Area 240 and the onshore Breydon Formation	3	Palaeo-environmental assessment of **Units biii** of **WA_VC8C**

Table 10. Palaeo-environmental assessment and dating research tasks

7.2.5. The palaeo-environmental assessment will include assessments of the following:

- Microfaunal assessment: foraminifera and ostracods
- Microfloral assessment: pollen, diatoms and microcharcoal
- Macrofaunal assessment: molluscs and insects
- Macrofloral assessment: plant material, wood and charcoal

7.2.6. These microfaunal and microfloral samples will be concentrated within the finer grained sediments as these remains are usually better preserved and more numerous.

7.2.7. The samples will be concentrated at depths within the cores where these remains were visible during the sub-sampling of the cores within the relevant geoarchaeological units.

7.2.8. Details of the level of palaeo-environmental assessment and dating for each of the relevant vibrocores are described in more detail below. However, slight alterations to these recommendations may occur during the preparation of the sub-samples to ensure that the correct sediments are targeted for successful assessment.

WA_VC2

7.2.9. The palaeo-environmental assessment and dating of **WA_VC2** will satisfy research task numbers 1 – 5. It is recommended that nine microfaunal and microfloral samples are assessed. These would include two samples from each of the subunits of **Unit fi** (between 0.45 and 5.10m); two samples from **Unit fii** (between 5.10 and 5.47m) and one sample from **Unit fiii** at the base of the vibrocore (between 5.47m and 6.11m).

7.2.10. Five macrofaunal and macrofloral assessments are proposed: one sample from each of the three subunits of **Unit fi** and one each from **Unit fii** and **fiii**.

7.2.11. Three OSL samples are recommended: two from **Unit fi** and one from **fii**.

WA_VC7

7.2.12. The palaeo-environmental assessment and dating of **WA_VC7** will satisfy research task numbers 1, 4 – 8 and 12. It is recommended that seven microfaunal and microfloral samples are assessed. These would include two samples from **Unit c** (between 0.14 and 1.14m); two samples from **Unit e** (between 1.14 and 3.12m) and one sample from each subunit of **Unit giii** at the base of the vibrocore (between 3.12m and 4.79m).

7.2.13. Five macrofaunal and macrofloral assessments are proposed: one sample from **Unit c**, two from **Unit e** and two from **Unit g**.

7.2.14. Three OSL samples are recommended: one from each of **Units c**, **e** and **g**. the exact depths of these samples will be dependent on the presence of quartz rich sands suitable for dating.

WA_VC9

7.2.15. The palaeo-environmental assessment and dating of **WA_VC9** will satisfy research task numbers 1, 4, 5, 7, 8 and 9. It is recommended that seven microfaunal and microfloral samples are assessed. These would include two samples from **Unit e** (between 0.12 and 1.00m); two samples from **Unit giv** (between 1.00 and 4.50m), one sample from **Unit gv** (between 4.50 and 4.80m), one at the oxidation layer (between 4.80 and 4.83m) and one from **Unit gvi** at the base of the vibrocore (between 4.83m and 5.53m).

7.2.16. Five macrofaunal and macrofloral assessments are proposed: one sample from **Unit e**, two from **Unit giv**, one across the oxidation layer and one from **Unit gvi**.

7.2.17. Three OSL samples are recommended: two from **Unit g** and one from **Unit e**. the exact depths of these samples will be dependent on the presence of quartz rich sands suitable for dating.

WA_VC8

7.2.18. The palaeo-environmental assessment and dating of **WA_VC8** will satisfy research task numbers 1, 7, 10, 11, 12 and 14. It is recommended that six microfaunal and microfloral samples are assessed. These would include two samples from **Unit biii** at the top and the bottom of the subunit containing peat (between 0.37 and 1.36m) and four samples throughout **Unit d** (between 1.38 and 5.95m).

7.2.19. Four macrofaunal and macrofloral assessments are proposed: one sample from **Unit biii**, and three from **Unit d**.

7.2.20. Two sample for radiocarbon dating are recommended: one from the top and bottom of the unit containing peat (**Unit biii**). For the radiocarbon dating, the presence of suitable stratigraphically secure material for example plant remains such as *Phragmites* reeds stratified within peat deposits will be selected.

Summary

7.2.21. Based on the results of Stage 4 recommendations have been made for a total of 29 samples for microfaunal and microfloral assessment and 19 samples for macrofaunal and macrofloral assessment across four vibrocres.

7.2.22. Nine OSL dates are proposed in order to establish dates of pertinent units within three vibrocores, namely for establishing the date of the unit from which the hand axes were likely dredged (**WA_VC2B**), establish chronostratigraphy of the Channel A infill sediments (**WA_VC7**) and compare the age of the sediments to the south of Area 240 (**WA_VC9**).

7.2.23. At this stage no assessment has been proposed for full sampling of the transgressive sequence (**Units bi** and **bii**). It is recommended that further work on these sediments can be done at a future date depending on the results of the assessment and dating of **Unit biii**.

7.2.24. WA personnel will attend the OSL laboratory in order to ensure the selection of suitable samples of quartz rich sand.

7.2.25. Two samples for radiocarbon dating are recommended from the top and base of **Unit biii** (**WA_VC8C**).

7.2.26. It is recommended that further dating (OSL and amino acid racemisation) and analysis of vibrocores (macro- and micro-) are considered as follow-on work based on the outcome of the assessment.

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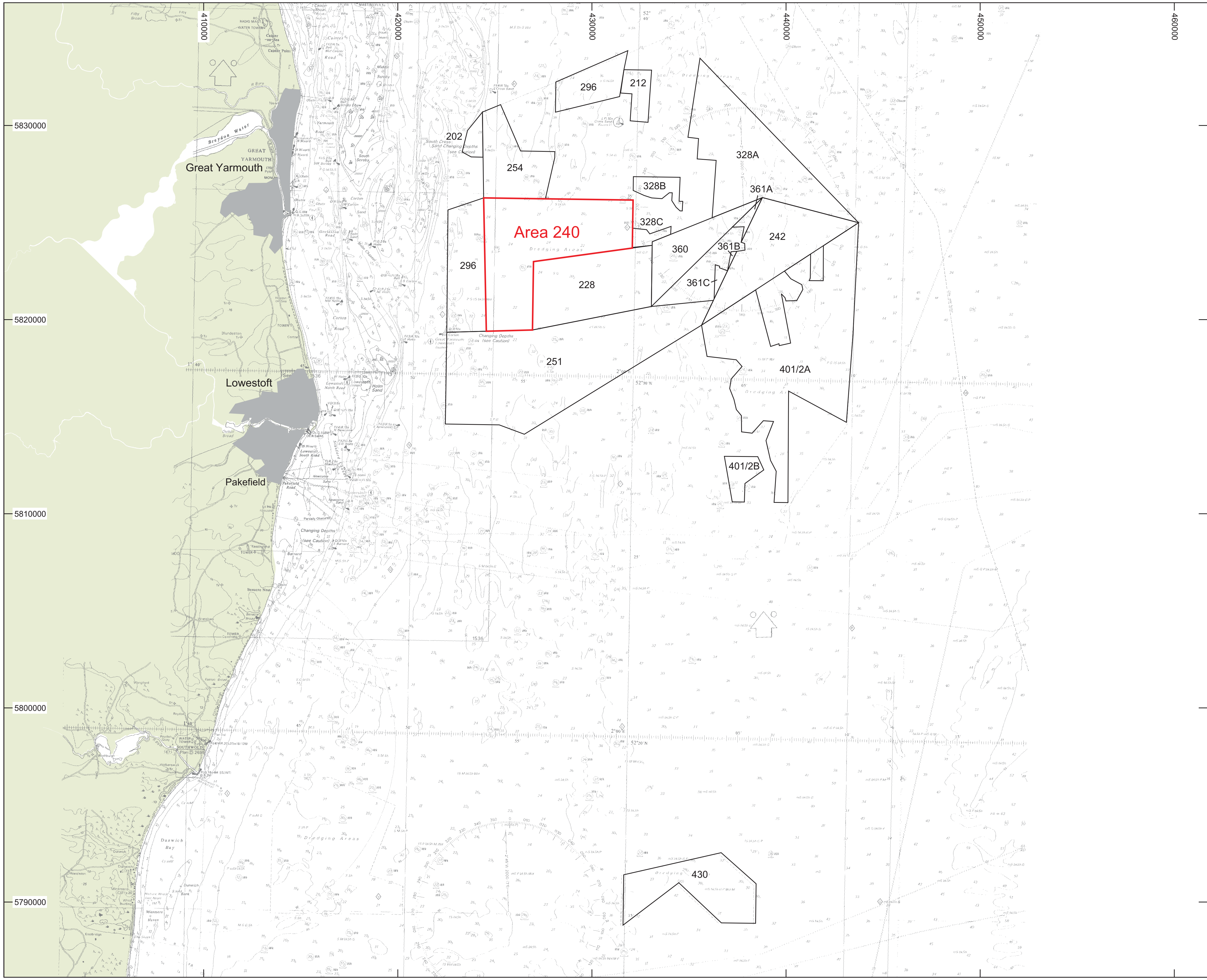
APPENDIX I VIBROCORE SAMPLE STATION LOG

Vibrocore	Date	Time (UTC +1)	Proposed position		Actual position		Distance from intended (m)	Penetration (m)	Water depth (m)
			Easting	Northing	Easting	Northing			
WA_VC1B	11/05/2010	10:44	426296	5821835	426296	5821832	2.8	5.31	25.9
WA_VC1C	11/05/2010	09:49	426296	5821835	426296	5821835	0.5	3.49	26.1
WA_VC2B	11/05/2010	17:56	426321	5821851	426319	5821849	2.9	3.36	26.4
WA_VC2C	11/05/2010	17:22	426321	5821851	426320	5821850	1.2	6.12	26.3
WA_VC3B	11/05/2010	12:02	426501	5821895	426500	5821897	2.4	5.9	26.6
WA_VC3C	11/05/2010	11:18	426501	5821895	426501	5821895	0.5	6.22	26.3
WA_VC4B	11/05/2010	16:33	426918	5824016	426917	5824015	1.5	5.94	31.6
WA_VC4C	11/05/2010	15:59	426918	5824016	426914	5824017	4.1	5.81	31.4
WA_VC5B	11/05/2010	05:08	426430	5825807	426439	5825806	1.4	4.06	20.1
WA_VC5C	11/05/2010	04:36	426430	5825807	426430	5825809	1.8	5.66	25.8
WA_VC6B	10/05/2010	22:29	424922	5826205	424924	5826211	6.1	5.24	25.7
WA_VC6C	10/05/2010	21:36	424922	5826205	424920	5826205	1.6	1.24	26.7
WA_VC6C1	11/05/2010	03:06	424922	5826205	424923	5826206	1.4	5.27	27.1
WA_VC7B	11/05/2010	13:37	429834	5825585	429833	5825588	3.4	2.81	26
WA_VC7C	11/05/2010	13:03	429834	5825585	429831	5825586	3.1	4.8	25.8
WA_VC8C	11/05/2010	08:51	424948	5824882	424948	5824880	1.7	0	29.2
WA_VC8C1	11/05/2010	09:31	424948	5824882	424948	5824880	1.7	5.95	27.8
WA_VC9B	11/05/2010	19:21	426553	5819779	426551	5819778	2.3	4.63	25.5
WA_VC9C	11/05/2010	18:52	426553	5819779	426552	5819778	1.4	5.53	23.2
WA_VC10B	11/05/2010	14:52	431156	5824543	431156	5824545	1.7	5.82	29.6
WA_VC10C	11/05/2010	14:22	431156	5824543	431154	5824544	2.0	4.64	29.9

1) Vibrocore naming convention is as follows: C = clear liner; B = opaque liner; suffix number indicates repeat acquisition at the same location.

2) Water depths are tidally reduced to LAT.



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Area 240

Other Licence Areas

0 10km

Drawing Projection: UTM WGS84 z31N.
Admiralty Chart 1543 (dated 2000).

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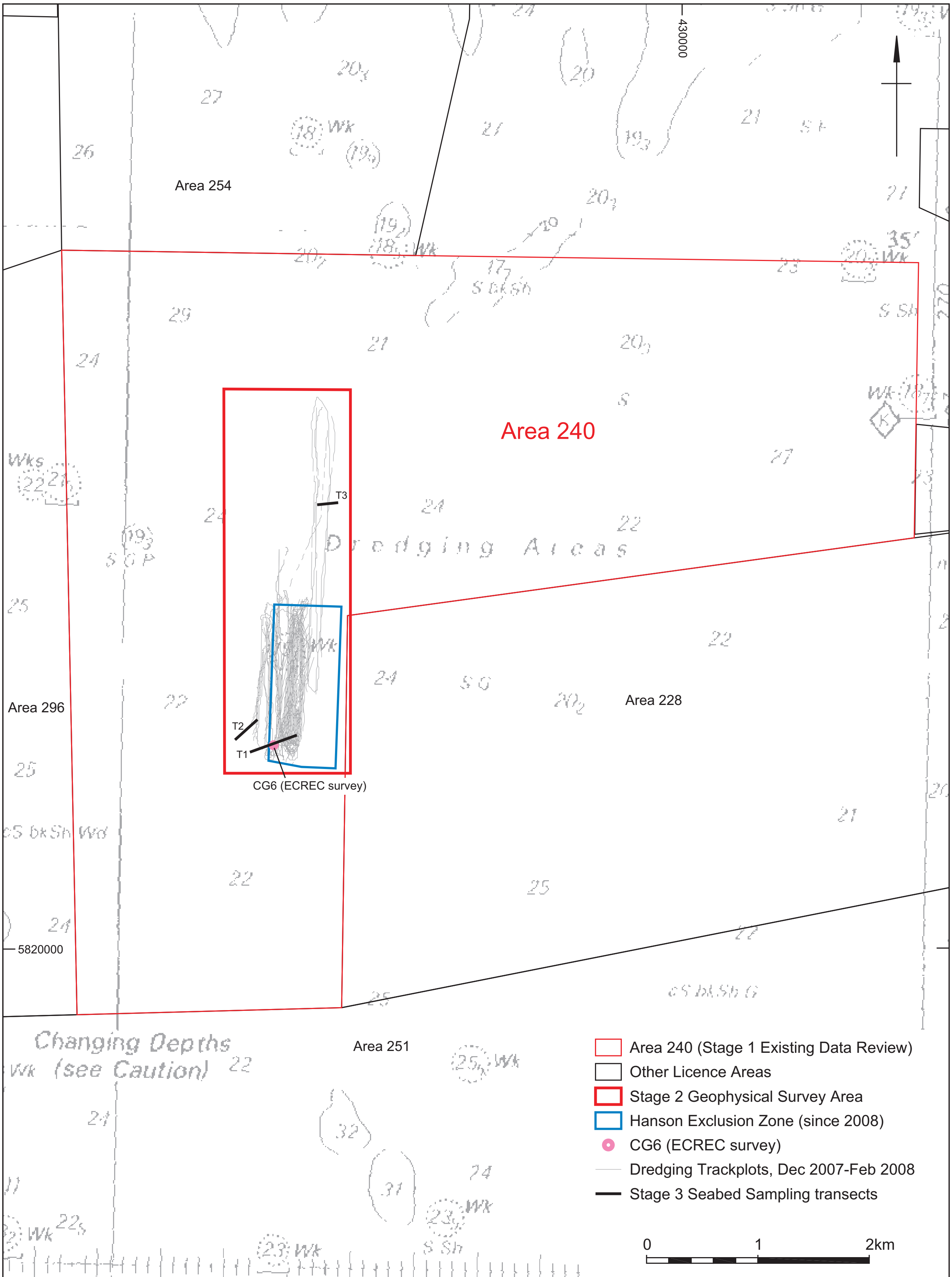
Report Figs\Enviro sampling\10-06-24

Area 240 location

Figure 1



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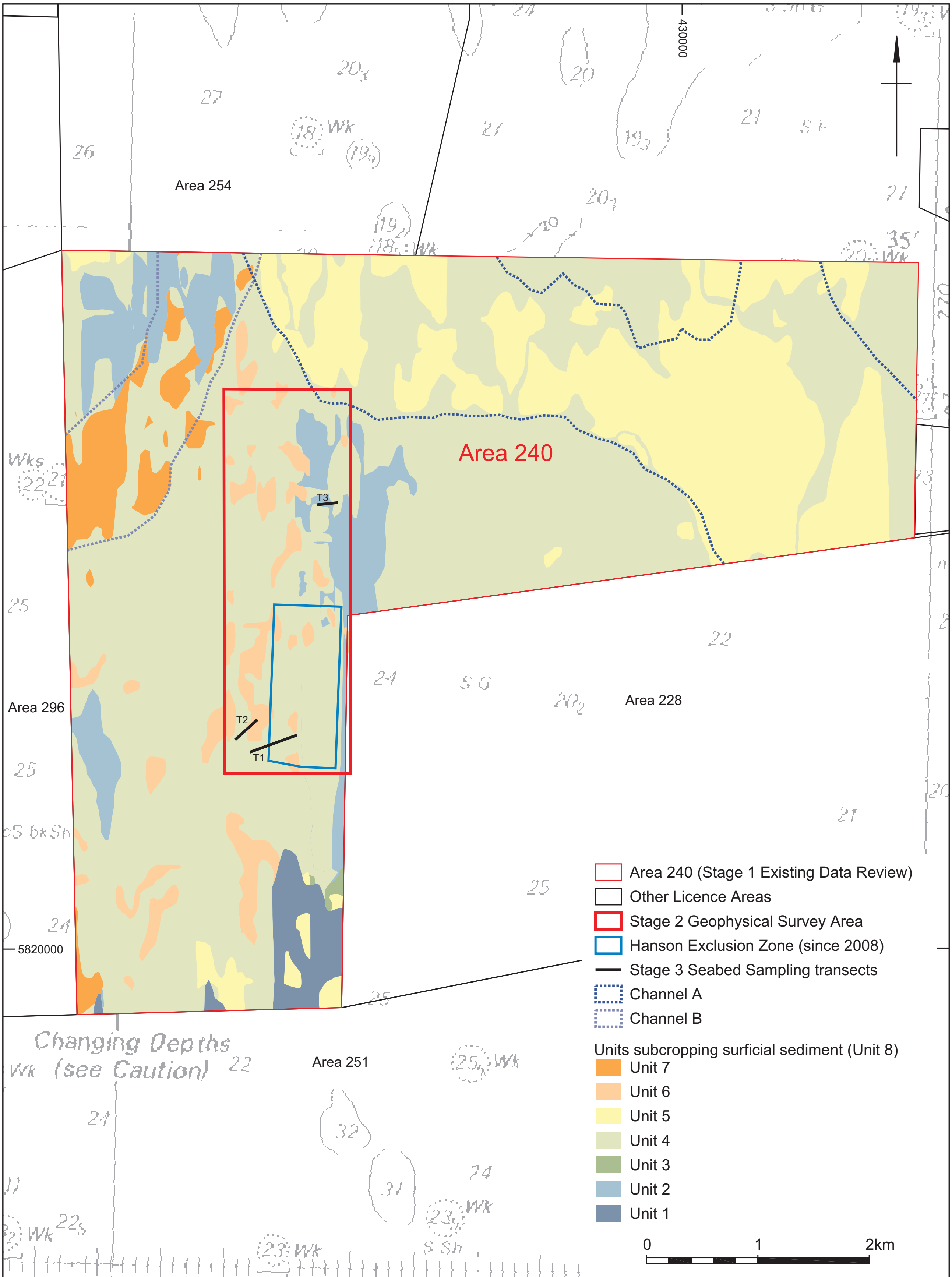
Previous work in Area 240 (Stages 1, 2 and 3)

Figure 2



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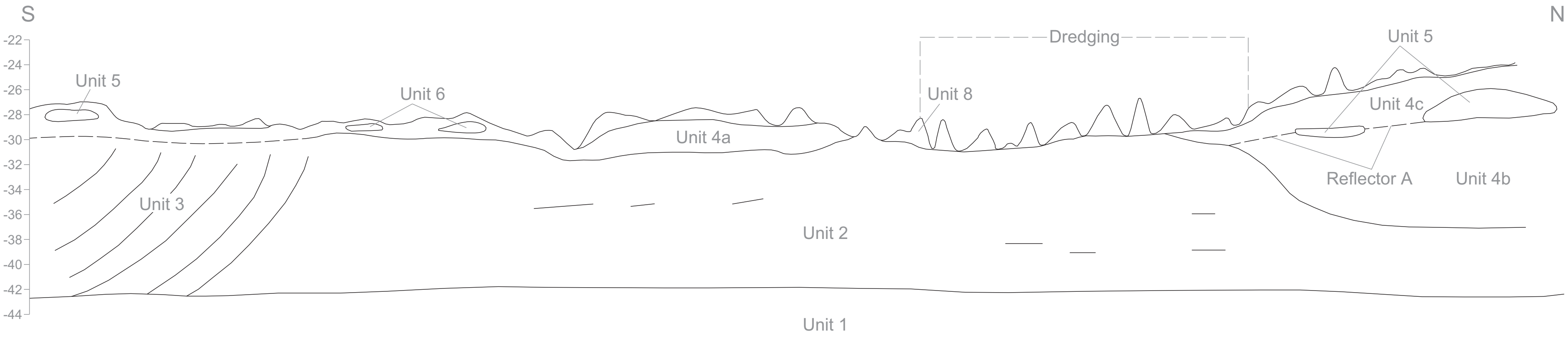
Wessex Archaeology

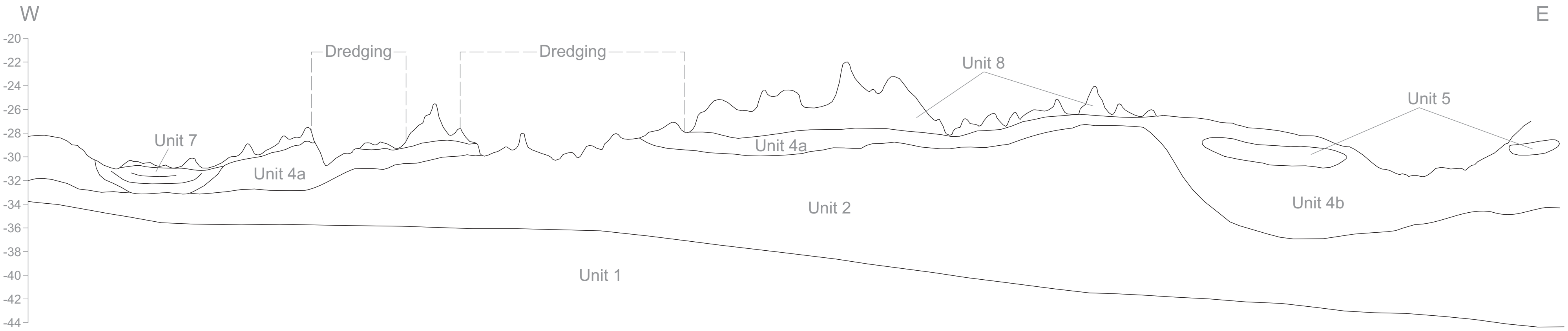
Overview of geophysical interpretation (Stages 1 and 2)

Figure 3

A. South to north



B. West to east



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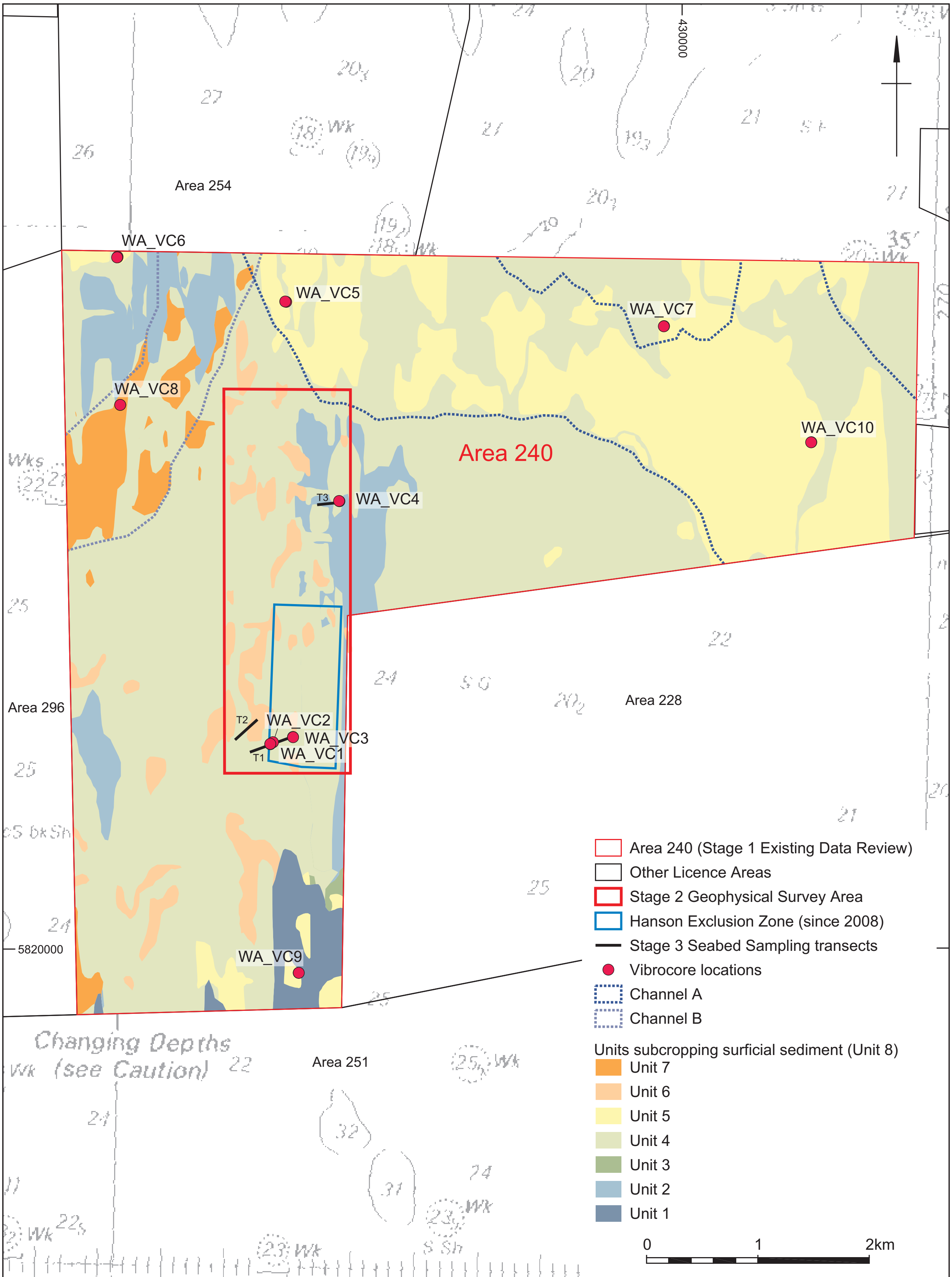
Schematics of seismic units identified in Area 240 (Stages 1 and 2)

Figure 4



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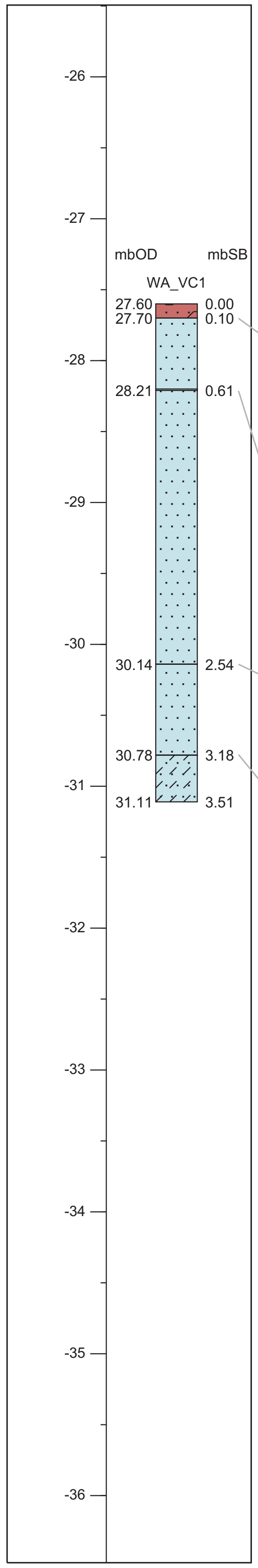
Vibrocore locations with overview of geophysical interpretation (Stages 1 and 2)

Figure 5



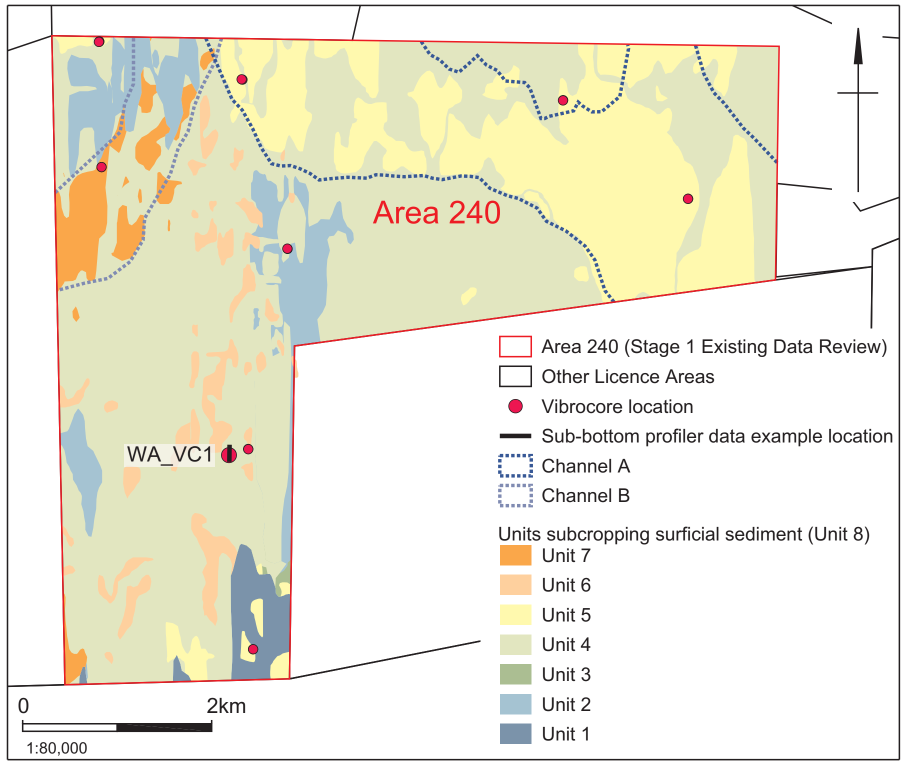
2.5Y5/2 Greyish brown gravelly sand. Loose/disturbed. Sand is medium to coarse (predominantly medium) grained. Gravel is subrounded to subangular flint up to 10mm diameter. Angled sharp boundary. **Seabed sediment** (Unit a)

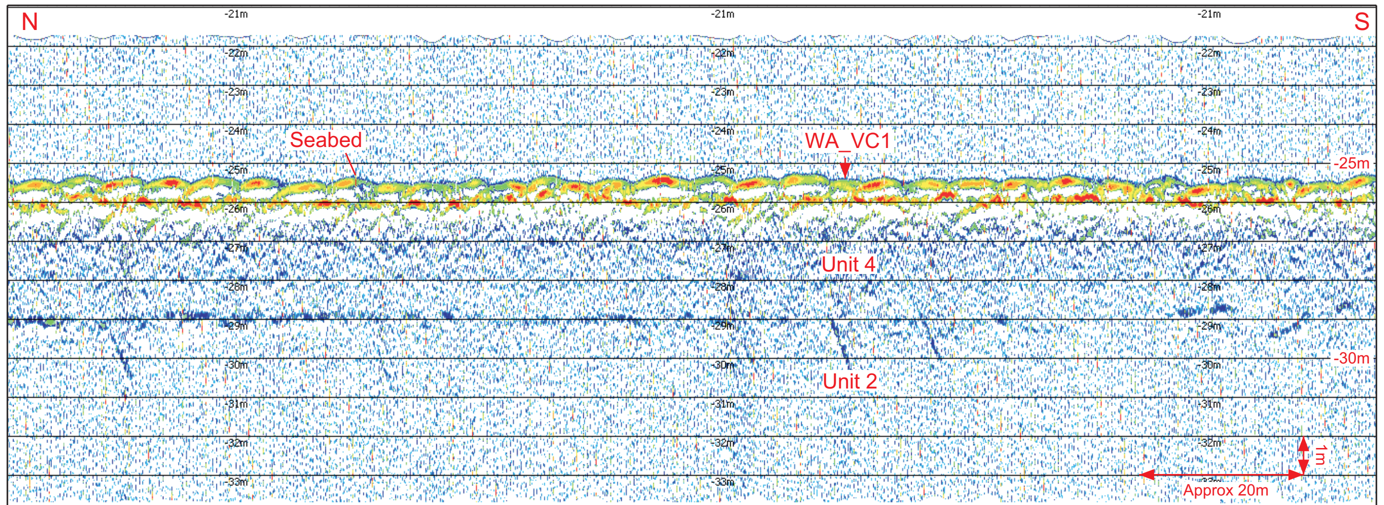
2.5Y 5/2 Greyish brown sand. Sand is medium grained. Occasional horizontally bedded pebble layers (at 0.23 to 0.24m) and pebble inclusions comprising subrounded to subangular flint up to 4mm diameter. From 0.25 to 0.39 and 0.51 to 0.61m there are 2.5Y 3/1 very dark grey organic silty fine sand layers displaying smooth laminar horizontal stratification which has been dragged at the edges of the core. The laminations are up to 10mm in thickness and include darker (possibly with a higher organic content) lighter siltier and sandier laminations. **Waterlain sand** (Subunit fi)

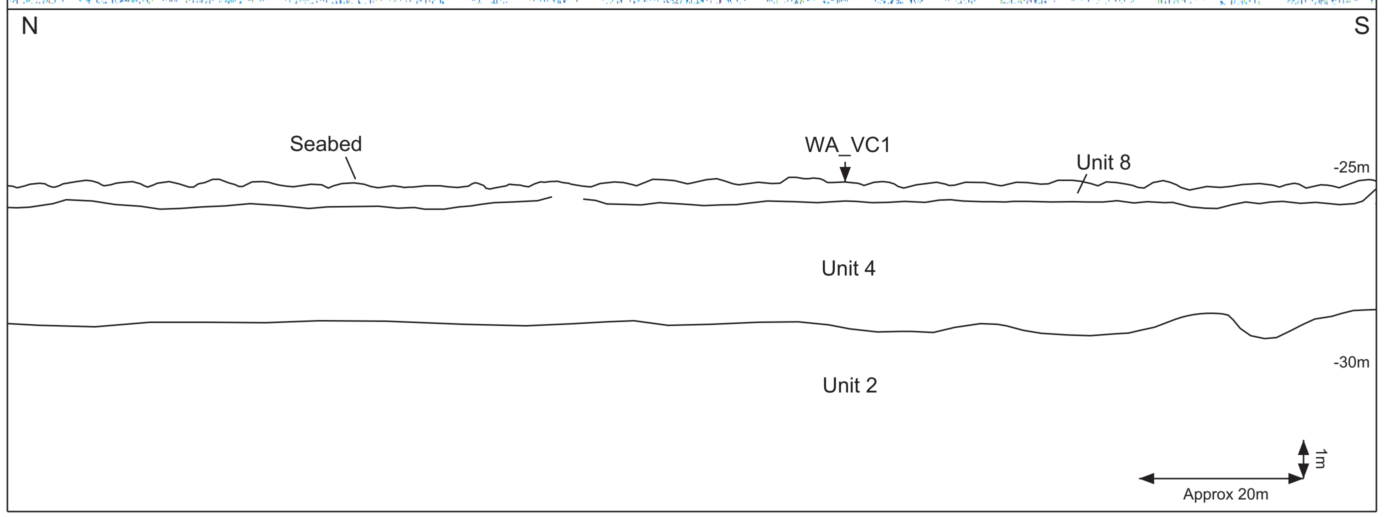
2.5Y 5/1 Grey sand. Sand is medium grained. Well sorted. Occasional subangular to subrounded flint (at 1.49, 2.26 and 2.33m). Some orange streaking from 1.00 to 1.75m possibly caused by drying subsequent to coring. Occasional (at 1.71, 1.77 and 2.00m) grey subrounded clay/mudstone inclusions up to 12mm diameter with an orangey brown oxidised coating noted on the inclusion at 2.00m. Feint horizontal bedding visible. Sorted. Metal core catcher stuck between 1.90 and 1.98m. A gap between 2.00 and 2.04 and some disturbed/loose sediment was noted from 2.10 to 2.18m. Angled, gradual boundary. **Waterlain sand** (Subunit fi)

2.5Y 3/1 Very dark grey sand alternating with areas of lighter (2.5Y 6/1 grey) drier sand. Sand is medium to coarse (predominantly medium) grained. Sorted. Occasional lenticular olive grey clay inclusions up to 35mm diameter (at 2.71, 2.72, 2.82, 2.88 and 2.98m) softer than those in the overlying sediment. Very occasional black flint at 2.58 and 2.67m up to 15mm diameter. Clear boundary. **Waterlain sand** (Subunit fi)

2.5Y 3/1 Very dark grey alternating grey fine silty sand (medium grained), silt and clay of up to 5mm in thickness from 3.28 to 3.27 and 3.45 to 3.51m. Laminar horizontal bedding Darker organic band at 3.46m. Occasional lenticular olive grey clay inclusions more numerous from 3.18 to 3.23m and in a convoluted arrangement. **Waterlain sand/clay** (Subunit fii)

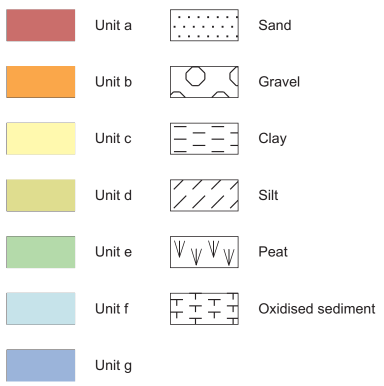






Sub-bottom profiler (parametric sonar) data example at WA_VC1 (Stage 2 survey dataset)

Key



Drawing Projection: UTM WGS84 z31N.

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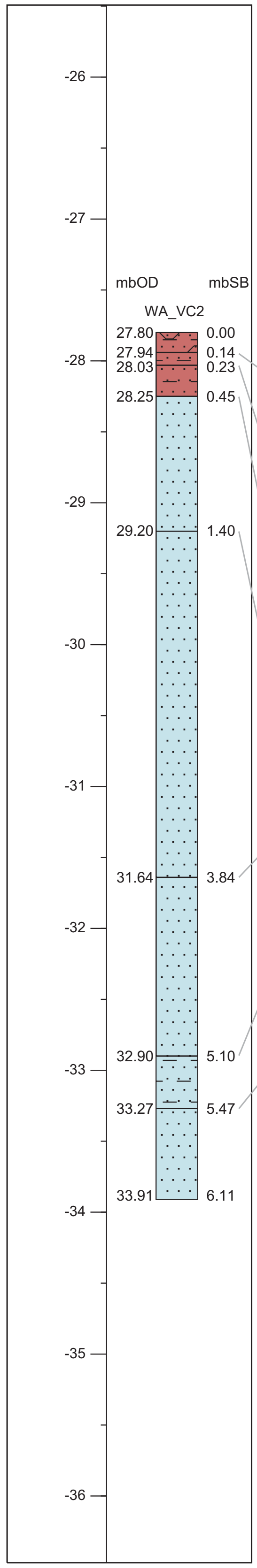
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC1c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 6



10YR 6/3 Pale brown gravelly sand. Sand is medium to coarse grained. Gravel is flint, rounded to angular (predominantly subrounded) up to 10mm diameter with occasional small subrounded quartz up to 4mm diameter. Poorly sorted. Abrupt boundary. Disturbed. **Seabed sediment** (Unit a)

2.5Y 7/2 Light grey sand. Sand is fine to medium grained. Very occasional subangular flint up to 40mm diameter. One angular piece of reworked sediment comprising laminated sand and organic black peaty silty sand, 40x65mm diameter. Disturbed. Abrupt boundary. **Seabed sediment** (Unit a)

2.5Y 6/2 Light brownish grey sand. Sand is fine, medium and coarse grained (predominantly medium). Fining upwards. Well sorted. Occasional angular flint up to 5mm diameter. Well sorted. Abrupt boundary. **Seabed sediment** (Unit a)

2.5Y 6/2 Light brownish grey (becoming 2.5Y 6/4 Light yellowish brown from 1.00m onwards) sand. Sand is medium grained. Well sorted. Occasional angular flint up to 25mm diameter. Contains some near vertical oxidised banding, probably due to post coring drying of sediment. Abrupt boundary. **Waterlain sand** (Subunit fi)

2.5Y 5/1 Grey sand. Sand is medium and coarse grained. Well sorted. Occasional rounded flint up to 12mm diameter. Fining upwards. Some feint convoluted bedding structure apparent between 3.10 and 3.15m and diagonally bedded laminae of lighter/darker sand 3.30 to 3.36m. At 3.53 to 3.60 the metal core catcher is embedded and the sediment is disturbed. Diffuse boundary. **Waterlain sand** (Subunit fi)

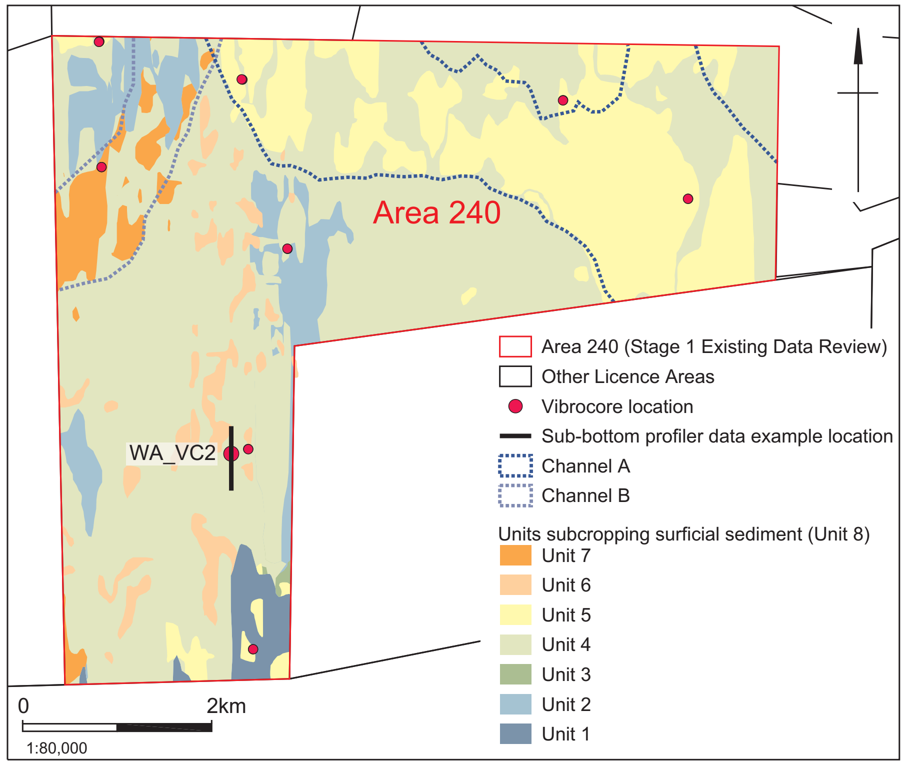
2.5Y 5/1 Grey sand. Sand is medium to coarse grained. Sorted. Occasional subangular to rounded flint up to 20mm diameter. Occasional grey clay lumps up to 35mm diameter at 3.76 and 4.17m. Some laminar horizontal bedding noted between 4.15 and 4.22m. From 4.50 to 4.95m some ?mollusc burrows are noted containing grey silty clay. Abrupt boundary. **Waterlain sand** (Subunit fi)

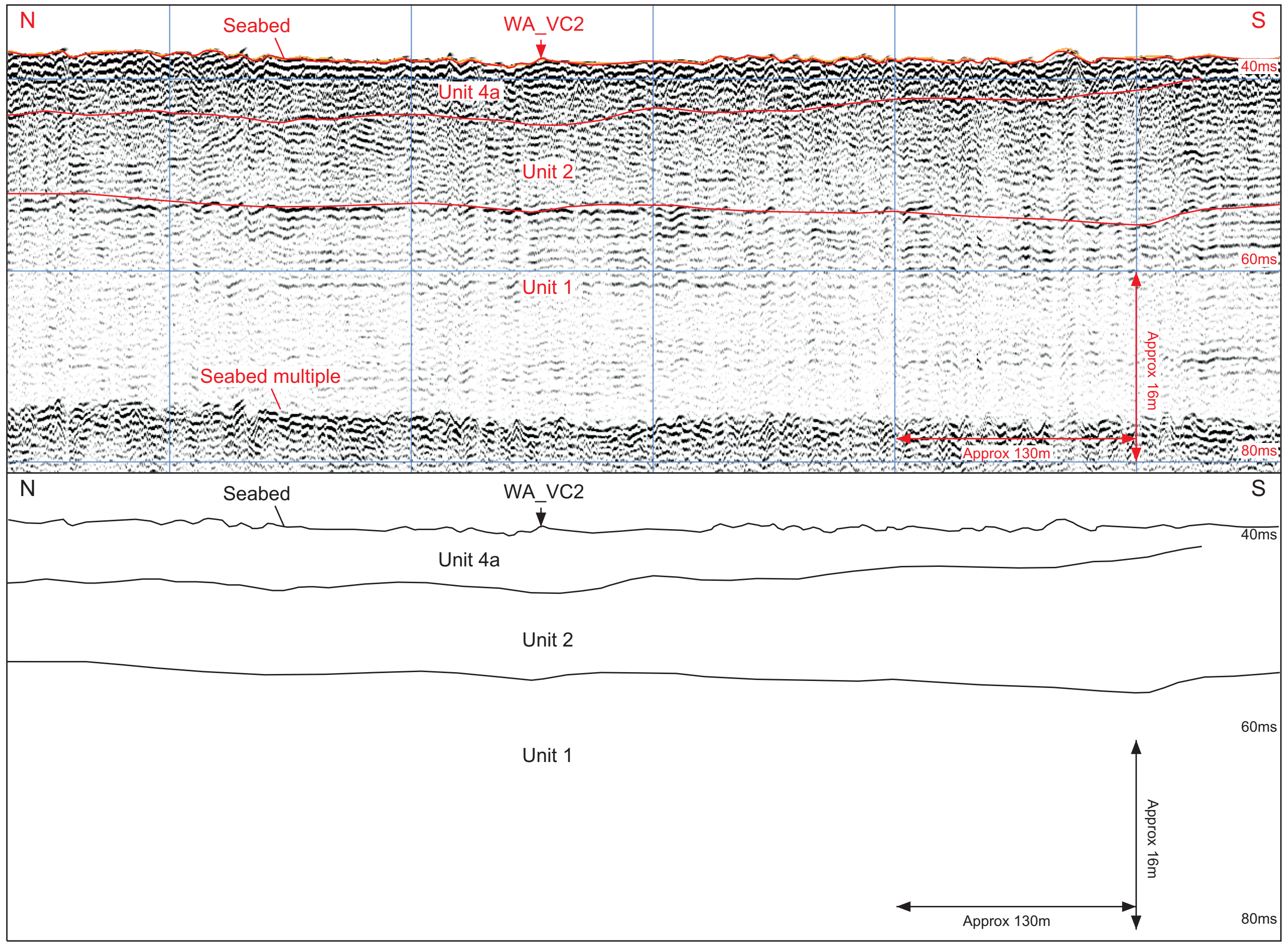
2.5Y 5/2 Brown clay with interbedded 2.5Y 5/1 grey sorted medium grained sand in predominantly horizontal laminar beds (flood couplets). Some slightly wavy and convoluted bedding is also noted. The clay beds are up to 30mm in thickness. Fining upwards. Abrupt boundary. **Waterlain clay/sand** (Subunit fii)

2.5Y 5/1 Grey sand. Sand is medium to coarse (predominantly medium) grained. Very well sorted. No inclusions. **Waterlain sand** (Subunit fiii)

Key

	Unit a		Sand
	Unit b		Gravel
	Unit c		Clay
	Unit d		Silt
	Unit e		Peat
	Unit f		Oxidised sediment
	Unit g		





Sub-bottom profiler (boomer) data example at WA_VC2 (Stage 2 survey dataset)

Drawing Projection: UTM WGS84 z31N.

Wessex Archaeology

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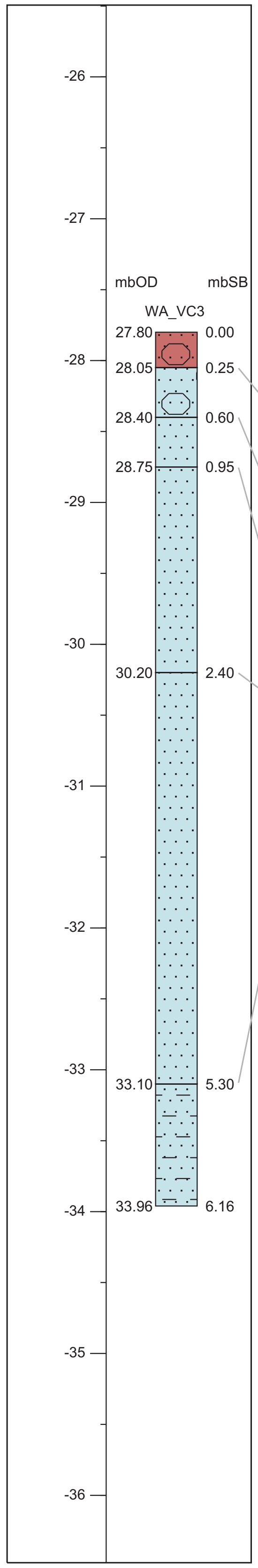
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC2c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 7



2.5Y 6/3 Light yellowish brown sandy gravel. Sand is medium to coarse grained. Gravel is subrounded to subangular flint up to 30mm diameter. Poorly sorted. Gap in one half of the core. Disturbed. Occasional broken molluscs up to 5mm diameter. **Seabed sediment** (Unit a)

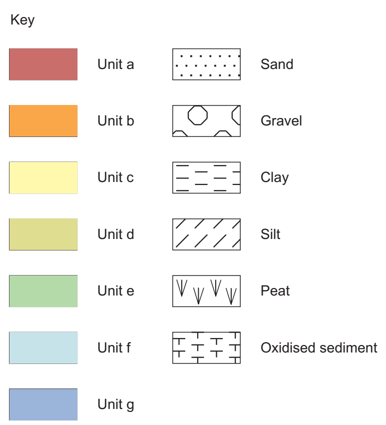
2.5Y 5/1 Grey gravelly sand. Coarsening upwards with highest gravel content between 0.25 and 0.36m. Gravel is predominantly subrounded to subangular flint up to 30mm diameter. Occasional subrounded quartz up to 18mm diameter. Poorly sorted. **Waterlain sand** (Subunit fi)

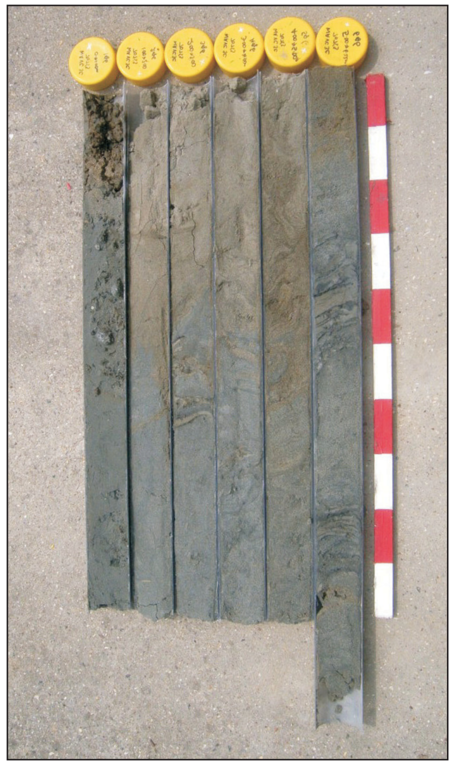
2.5Y 5/1 Grey sand. Sand is medium grained. Occasional grey clay streak (at 0.65m). Moderate small up to 20mm diameter predominantly black subrounded to subangular flint. Very occasional small grey mudstone lump (at 0.65m). **Waterlain sand** (Subunit fi)

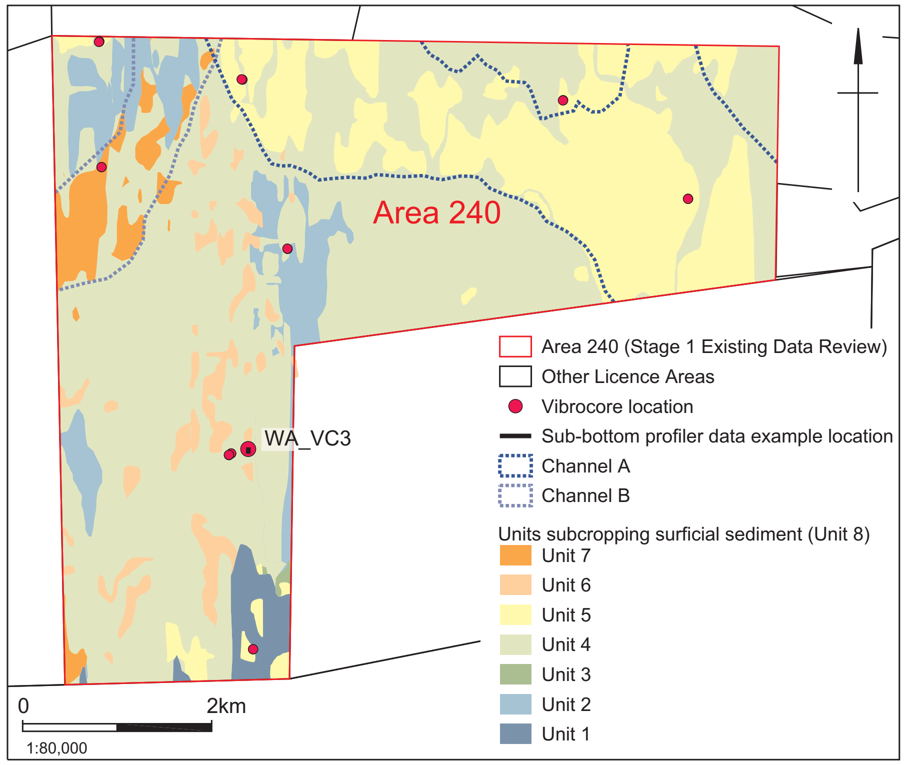
2.5Y 5/1 Grey sand. Sand is fine to medium (predominantly medium) grained. Massive. At 1.30m a 1mm thick and 15mm wide horizontal streak of organic silt. At 1.95m grey clay lump 2 x 5mm. Sand dries to a beige colour. Angled 5cm boundary. **Waterlain sand** (Subunit fi)

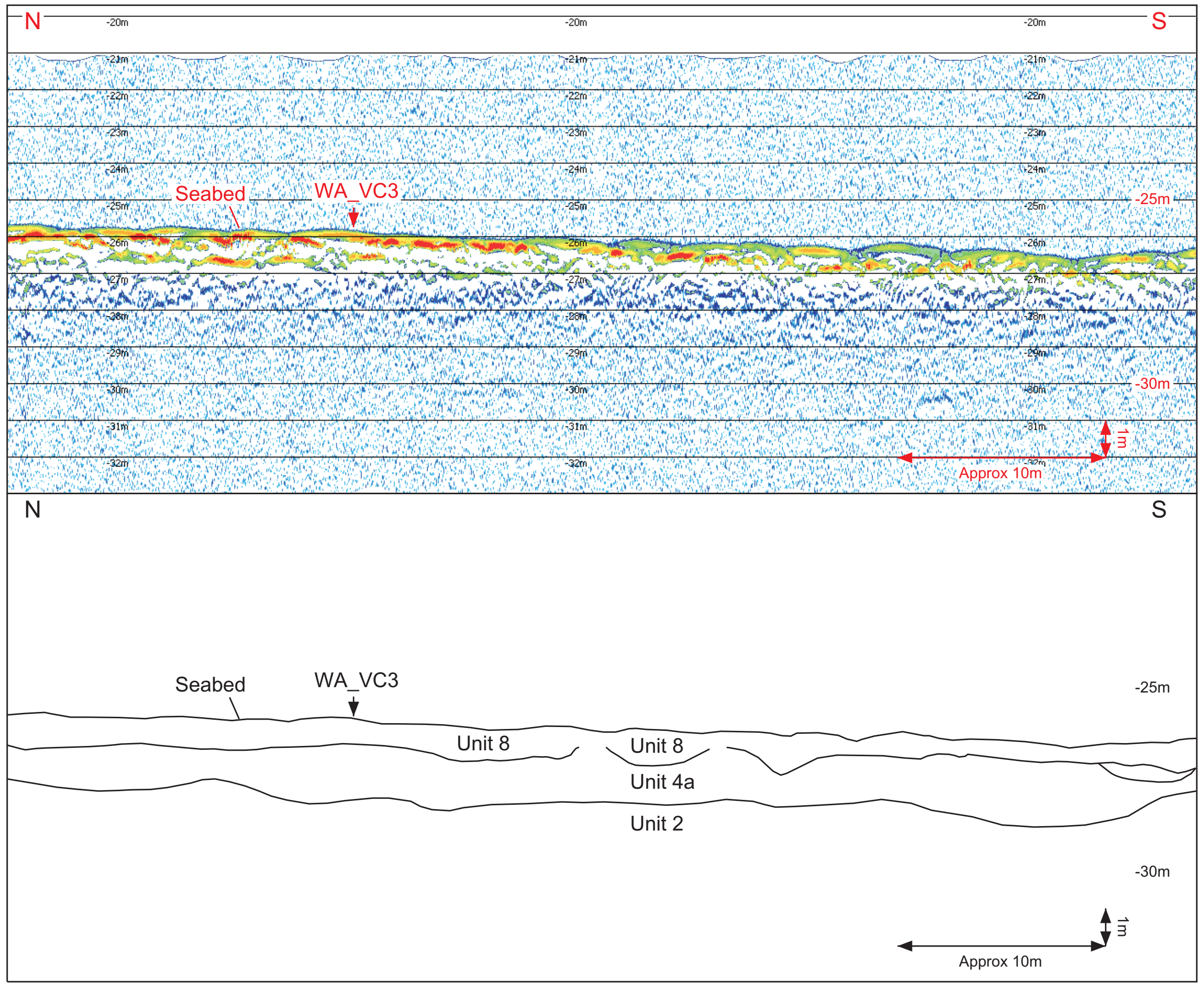
2.5Y 5/1 Grey sand. Sand is fine to medium (predominantly) medium grained. From 2.58 to 2.65 grey clay in horizontal beds up to 10mm in thickness. Feint horizontal bedding noted from 3.35 to 3.42m. A grey clay streak at 3.55m and lumps of grey clay up to 2mm thick at 3.70m. Occasional small subangular flint up to 10mm diameter (at 4.16 and 4.83m). From 4.10 to 4.60m convoluted and wavy horizontal to vertical bedding delineated by darker an lighter bands of sand up to 3mm in thickness. This may be a result of post coring drying. At 4.75 and 4.77m small grey clay lumps, up to 10mm diameter. From 5.00 to 5.15m some orange streaks of oxidised sand. Abrupt boundary. **Waterlain sand** (Subunit fi)

2.5Y 5/1 Grey sand . Sand is medium to coarse grained including from 5.30 to 5.52 and 5.78 to 5.86m. 2.5Y 5/2 clay bands (up to 35mm in thickness) with interbedded fine to medium sand with evidence of burrowing. Some evidence of burrowing. Small rounded black flint at 5.61m. Small 30mm diameter clay inclusion at 5.94m. **Waterlain sand** (Subunit fii)









Sub-bottom profiler (parametric sonar) data example at WA_VC3 (Stage 2 survey dataset)

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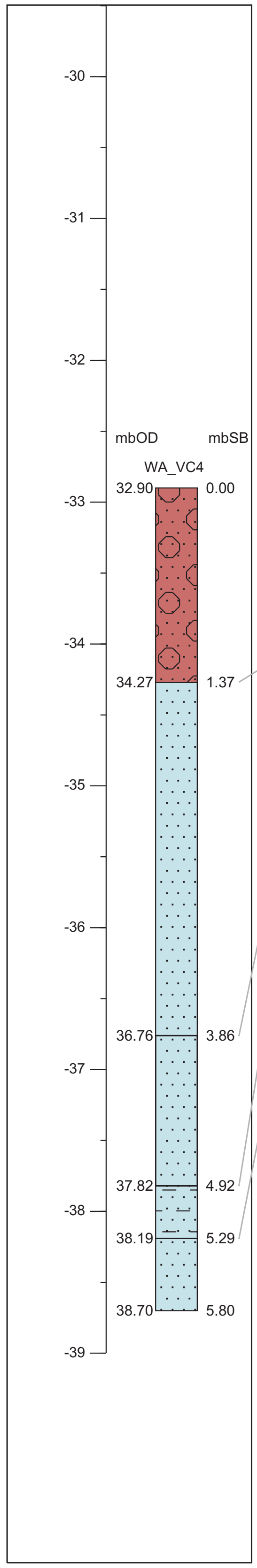
WA_VC3c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 8



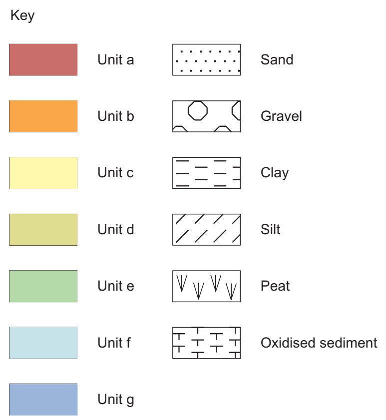
10YR 7/4 Mid greyish brown sand. Sand is fine to medium grained. Poorly sorted. Loose at top of core. Moderate small oxidised mudstone inclusions up to 20mm diameter. Possible burrow at 0.83m containing slightly coarser sand. Diffuse boundary. **Seabed sediment** (Unit a)

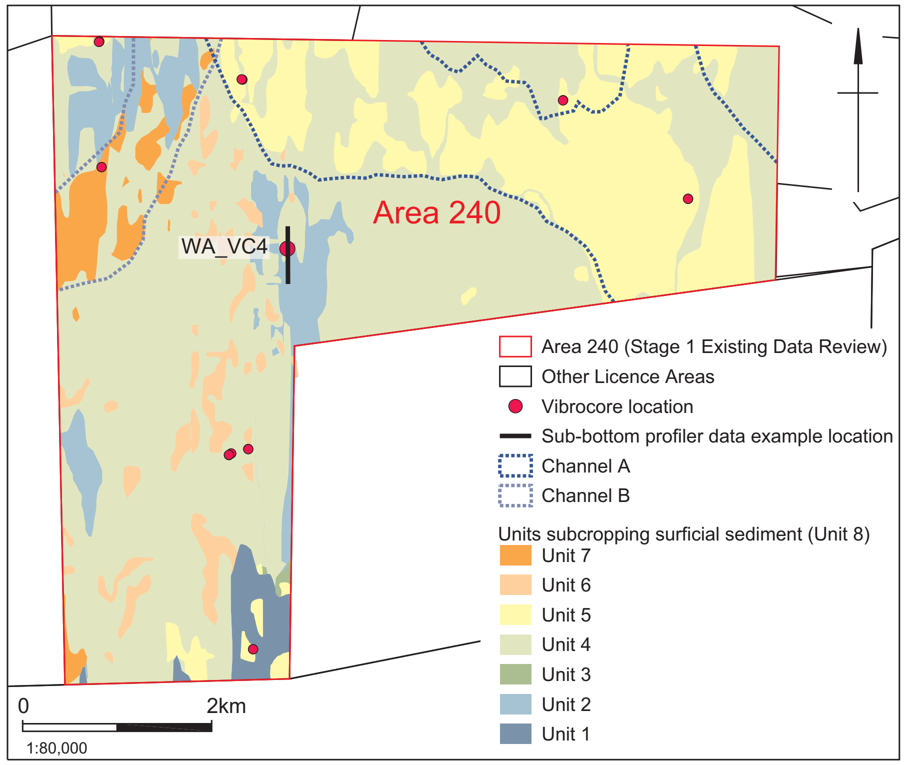
2.5Y 6/1 Mid grey sand. Sand is fine to medium grained. Well sorted. Some colour changes noted probably due to water content from 2.00 to 2.59m 2.5Y 6/2 mid brownish grey; 2.59 to 3.00m mid grey; 3.00 to 3.47m 2.5y 6/2 mid brownish grey; 3.47 to 3.86m 2.5Y 6/1 mid grey. Occasional lenticular grey mudstone inclusions less than 30mm diameter. Laminar horizontal bedding noted from 2.11 to 2.22 and 3.14 to 3.75m including up to 2mm thick silty sand bands. Disturbance at 3.18m, between 3.52 to 3.62m including parts of metal core catcher. Small flecks of dark (possibly contaminant) organic material from 3.52 to 3.62m. Abrupt boundary. **Waterlain sand** (Subunit fi)

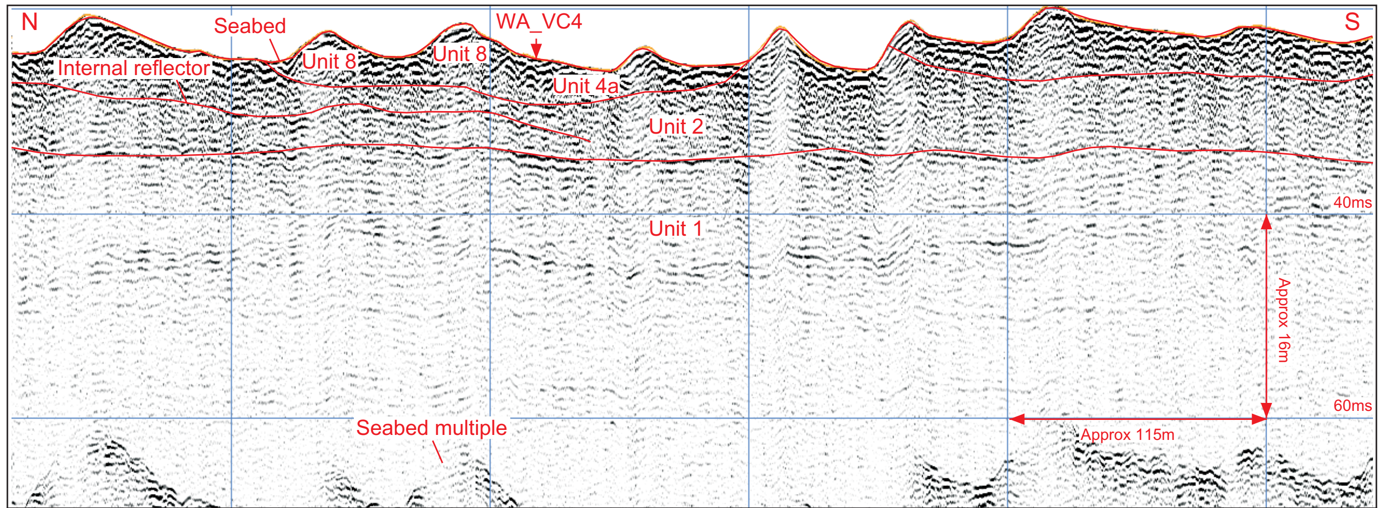
2.5Y 6/1 Mid grey sand. Sand is fine to medium grained. Well sorted. Becomes greyer with depth (from 4.52m onwards). Fining upwards. Lenticular grey clay lumps at 4.52, 4.61 and 4.77m up to 50mm diameter. Sand becomes slightly coarser from 4.62 to 4.92m. Abrupt boundary. **Waterlain sand** (Subunit fi)

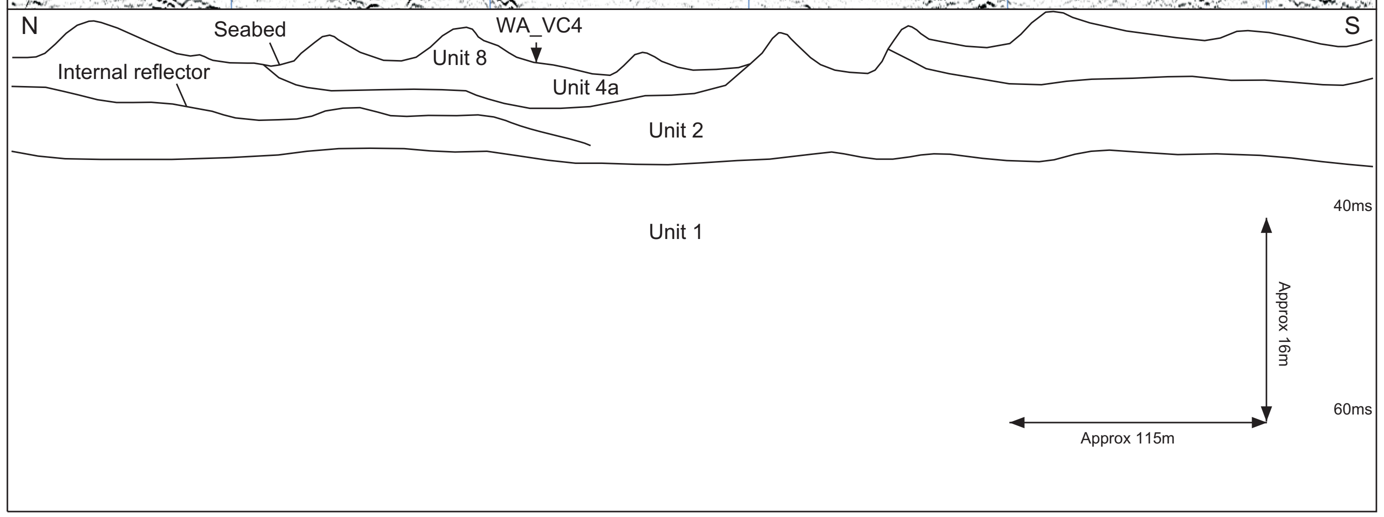
2.5Y 4/2 Dark grey clay. Interbedded with grey sand (fine to medium grained) - flood couplets. Horizontally bedded. Clay layers are up to 20mm in thickness. Fining upwards. Clay is wet,soft and more frequent between 4.92 and 5.02m. Abrupt boundary. **Waterlain sand/clay** (Subunit fii)

2.5Y 5/1 Grey sand. Sand is fine to medium grained. Occasional small wet grey clay lumps up to 12mm diameter at 5.49, 5.59, 5.70 and 5.74m. Massive. Well sorted. **Waterlain sand (Subunit fii)**









Sub-bottom profiler (boomer) data example at WA_VC4 (Stage 2 survey dataset)

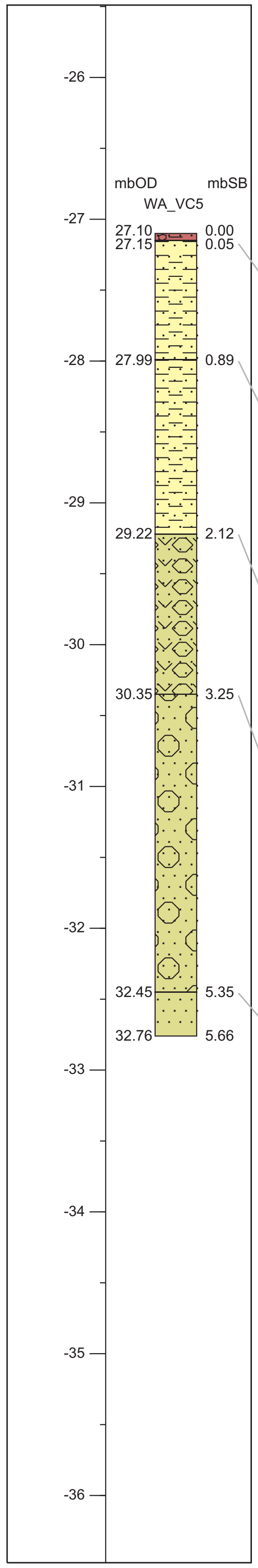
Drawing Projection: UTM WGS84 z31N.

Wessex Archaeology

Date:	29/06/10	Revision Number:	0
Scale:	SBP 1:600 vertical	Illustrator:	KJB/KMN
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC4c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 9



2.5Y 4/1 Dark grey sandy clayey gravel. Gravel is subrounded to subangular flint up to 25mm diameter. The grey fine sandy clay matrix incorporates sediment from the underlying layer. Clear boundary. **Seabed sediment** (Unit a)

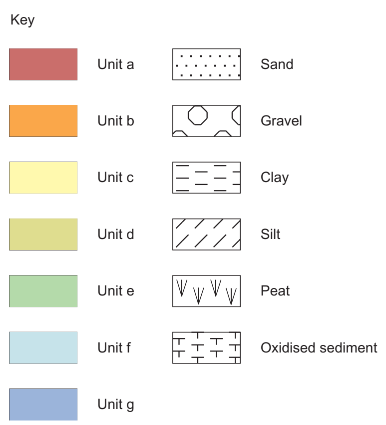
2.5Y 4/1 Dark grey sandy clay. Sand is fine grained. Alternate horizontal beds of sand and clay 1 to 10mm in thickness - tidal rhythmites. Occasional broken mollusc at 0.4, 0.51, 0.55 and 0.70m. Wet. Plastic. Part of broken metal core catcher at 0.37m. Intrusive brownish yellow coarse sand 0.04 to 0.24m around edges of the core. Small (3x1mm) charcoal at 0.6m. Slightly darker organic streaks from 0.45 to 0.53m. Angled clear boundary. **Estuarine alluvium/ lagoon** (Subunit ci)

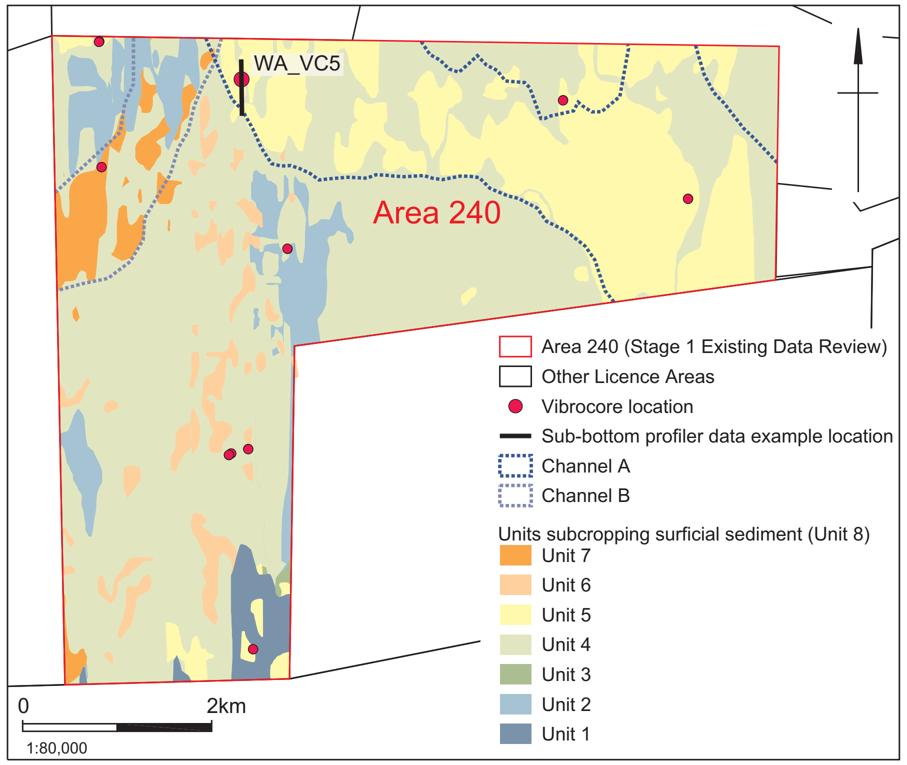
2.5Y 4/1 Dark grey clayey sand. Sand is fine. Very frequent bivalve molluscs predominantly *Ostrea edulis* some of which (at 1.94m) have both valves still joined . White fragile broken part fossilised? molluscan remains frequent from 1.50 to 1.69m. Occasional to moderate pebbles (most frequent between 1.80 and 2.12m) predominantly subrounded to subangular flint up to 10mm diameter, mostly 4-5mm diameter. Very occasional rounded quartz up to 7mm diameter. Fining upwards. 2.00 to 2.08m gap. From 1.98 to to 2.25m there appears to be much mixing of the layers. 2.00 to 2.12m increase in sand grain size to fine, medium and coarse (predominantly medium and coarse) grained. Diffuse boundary. **Estuarine alluvium/ lagoon** (Subunit cii)

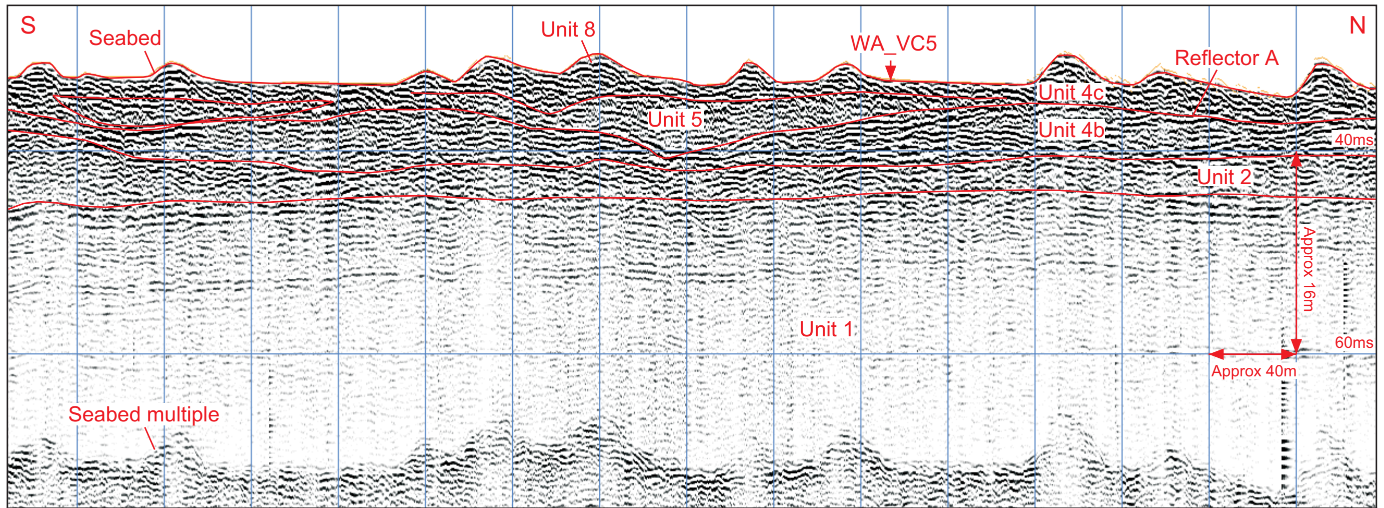
2.5Y 4/4 Olive brown silty sandy gravel. Sand is medium, coarse and very coarse (predominantly coarse) grained. Gravel is subangular to very rounded flint up to 55mm diameter. Occasional quartz subrounded to very rounded up to 18mm diameter. Silt content decreases from 2.70 to 3.25m. Frequent broken and abraded mollusc fragments up to 5mm diameter including at 2.73m *Cerastoderma edule*. Slightly sorted. Broken metal core catcher at 2.97m. From 3.00 to 3.25m a colour change is noted (10YR 5/6 Yellowish brown) and less broken molluscs are noted. Clear boundary. **Shallow marine gravel** (Unit d)

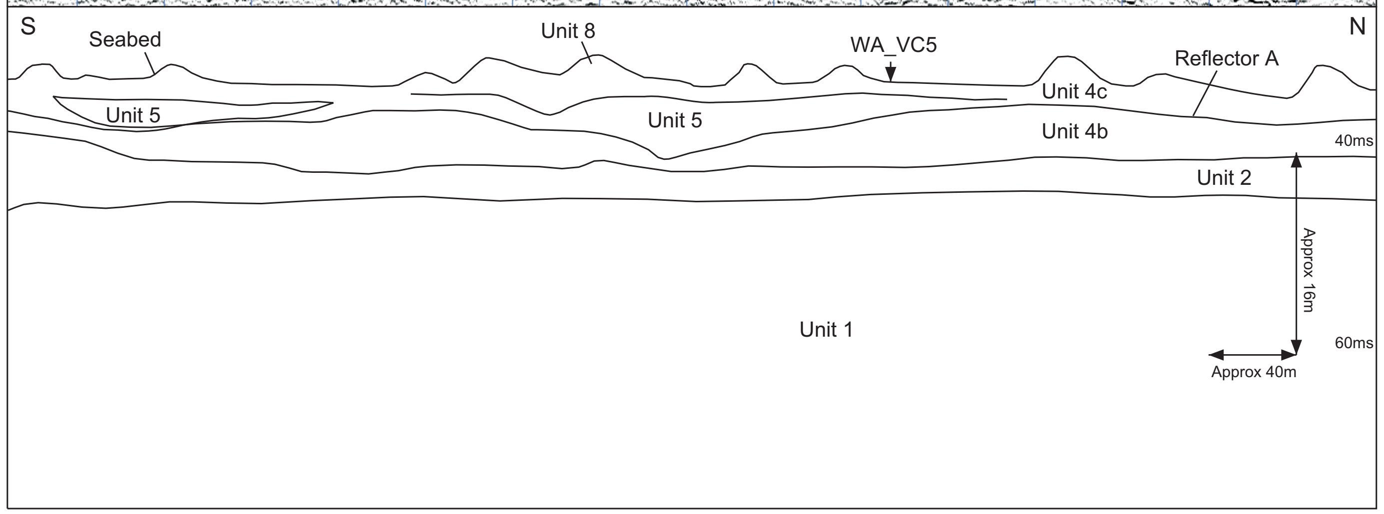
2.5Y 7/4 Pale yellow sandy gravel. Gravel is predominantly rounded to angular flint up to 45mm diameter and occasional subrounded to rounded quartz up to 45mm diameter. A singular subrounded granite pebble was recorded at 3.27m, 50mm diameter. Moderate molluscs, mostly broken up to 12mm diameter most frequent from 3.65 to 3.84m (including whole *Ostrea edulis* from 3.70 to 3.73m). Horizontally bedded. Sand is medium to coarse grained predominantly medium grained. Very sandy between 3.94 and 4.00m. Some hoizontal bedding of 100mm thick sandier and gravellier layers noted between 3.90 to 4.80m. At 4.82m one large flint (60mm diameter) and quartz pebble. From 4.92 to 5.35m less gravel is noted although an increase in sand grain size to medium coarse and very coarse (predominantly coarse) grained is noted. Abrupt boundary. **Shallow marine gravel** (Unit d)

2.5Y 6/2 Light brownish grey sand. Sand is medium, coarse and very coarse (predominantly coarse) grained. Moderate subrounded to subangular flint to 7mm diameter and very occasional subrounded quartz to 5mm diameter. Gravellier towards base . Fining upwards. Slightly sorted. Occasional small broken molluscs up to 3mm diameter. **Shallow marine gravel** (Unit d)









Sub-bottom profiler (boomer) data example at WA_VC5 (Stage 1 survey dataset)

Drawing Projection: UTM WGS84 z31N.

Wessex Archaeology

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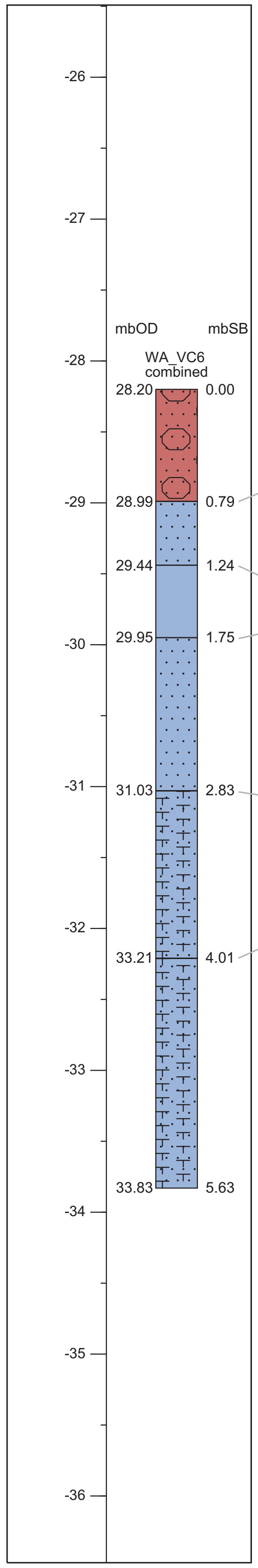
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC5c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 10



10YR 7.8 Yellow sandy gravel. Sand is medium and coarse grained. Gravel is predominantly rounded to angular flint, up to 60mm diameter. Very occasional subrounded to subangular quartz up to 5mm diameter. Coarsening upwards. Slightly sorted. Very occasional (at 0.01m) iron oxide coated sand sheet, 8mm diameter. Very occasional broken bivalve molluscs (at 0.3m). Clear boundary. **Seabed sediment** (Unit a)

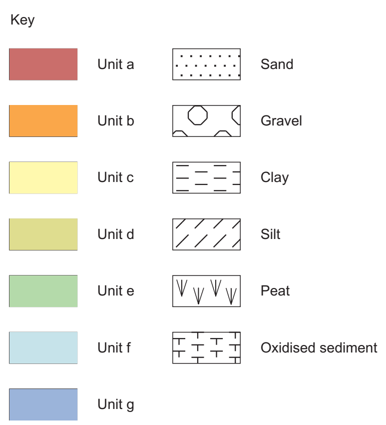
5Y 6/3 Pale olive sand (2.5Y 6/4 Light yellowish brown at top from 0.79 to 0.89m). Sand is fine and medium grained. Occasional subangular flint (most common between 1.01 and 1.08m) up to 10mm diameter. Well sorted. **Waterlain sand** (Subunit gi)

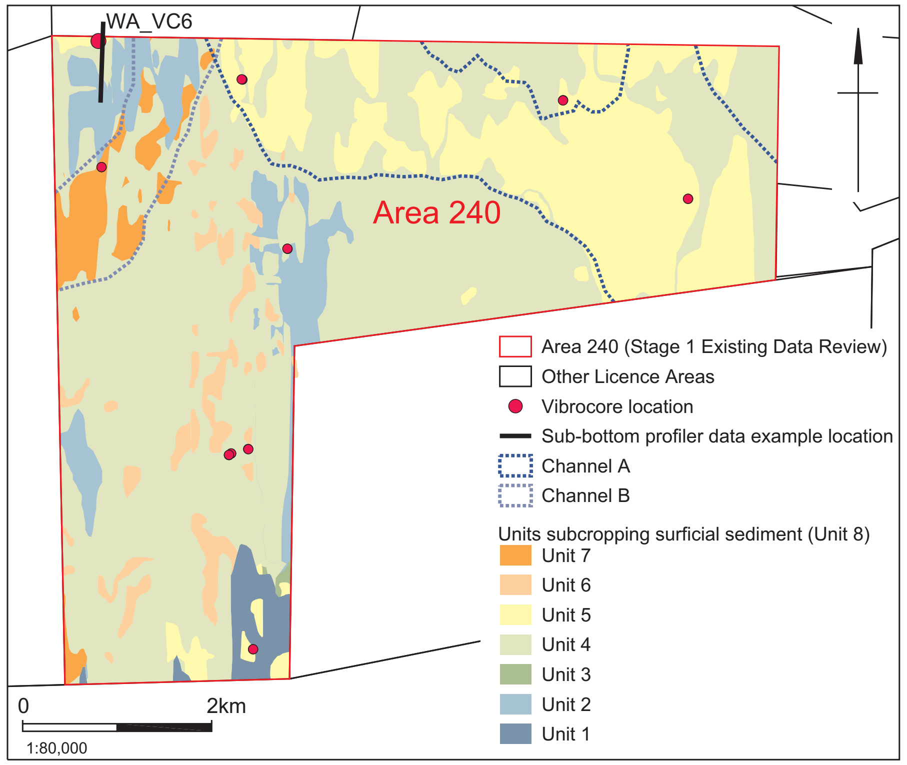
Gap

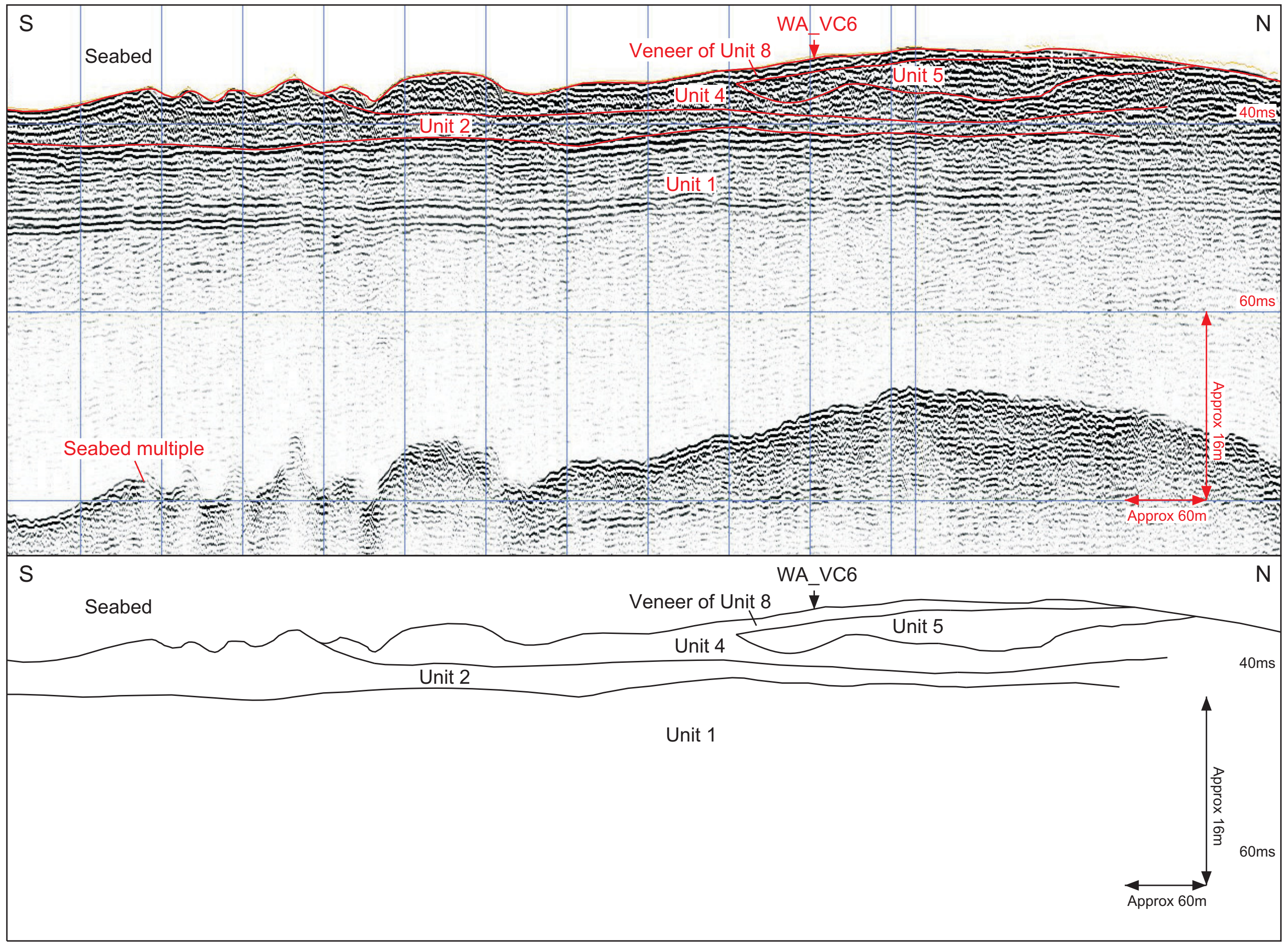
2.5Y 4/3 Olive brown sand. Sand is fine, medium and coarse (predominantly fine and medium) grained. Occasional to moderate pebble inclusions, predominantly rounded to angular flint up to 61mm diameter. Very occasional subrounded to rounded quartz up to 8mm diameter. Sorted. From 1.9 to 1.98m very gravelly. Lighter in colour (due to water loss?) from 2.00 to 2.35m. Metal core catcher plugged at 2.16 to 2.27m. Feint striping of orangey oxidised/ grey sand from 2.03 to 2.43m (?due to post coring water loss?). Angled clear boundary. **Waterlain sand** (Subunit gi)

2.5Y 6/3 Light yellowish brown sand. Sand is fine and medium grained. Feint horizontally bedded layers of oxidised (2.5Y 5/6 light olive brown) sand up to 5mm in thickness. Occasional diagonal to vertical streaking of oxidised sand is also visible. 2.70 to 2.76m part of metal core catcher. From 3.00 to 3.46m a colour change to a more grey/beige colour (10YR 5/8 Yellowish brown) is noted with the oxidised orange layers becoming more visible and prominent. Clear boundary. **Oxidised waterlain sand** (Subunit gii)

10YR 4/6 Yellowish brown/2.5Y 6/2 Light brownish grey sand. Sand in fine to medium (predominantly medium) grained. Oxidised horizontally bedded orange layers up to 20mm in thickness comprise *c.* 60% of the sediment. The layers have been dragged by coring. From 4.90 to 5.00m there is a gap. At 5.09m the oxidised sand has formed around a 15x2mm inclusion of grey silt. From 5.11 to 5.23m the sediment is predominantly grey sand with little oxidisation. **Oxidised waterlain sand** (Subunit gii)







Sub-bottom profiler (boomer) data example at WA_VC6 (Stage 1 survey dataset)

Drawing Projection: UTM WGS84 z31N.

Wessex Archaeology

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Scale:	SBP 1:600 vertical	Illustrator:	KJB/KMN
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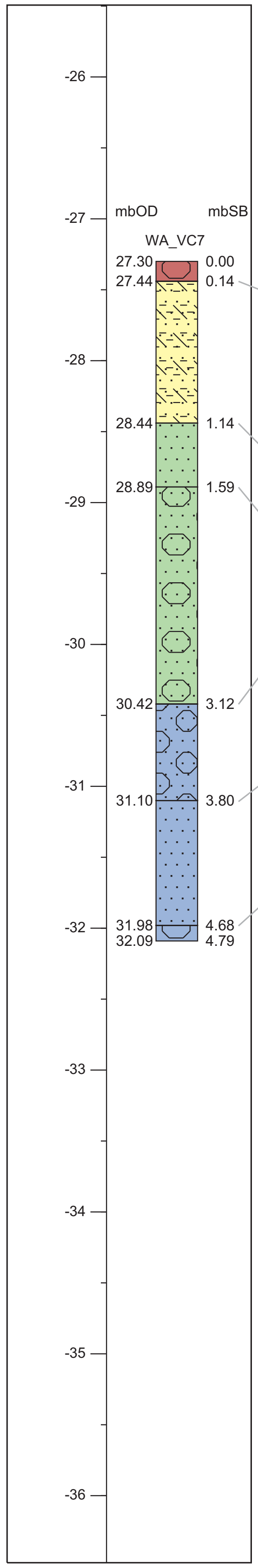
WA_VC6c/c1: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 11



2.5Y 6/4 Light yellowish brown sandy gravel. Sand is medium and coarse grained. Gravel is subrounded to rounded flint up to 20mm diameter. Clear boundary. **Seabed sediment** (Unit a)

2.5Y 3/1 Very dark grey silty clayey sand. Sand is fine to medium grained. Frequent mollusc inclusions and worm tubes. *Ostrea edulis* at 0.23, 0.43 and 0.63 to 0.68m. *Cerastoderma edule* at 0.38, 0.51, 0.73, 0.78 and 0.93m. Worm tubes at 0.27, to 0.36, 0.60 to 0.72m. Very occasional scallop. Twigwood at 0.62m. Plant ?root at 0.72m wood (10x50mm) at 1.00m. 20mm diameter burrows infilled with lighter medium grained sand from 0.38 to 0.42 and 0.74 to 0.87m. From 1.00 to 1.14m no molluscan inclusions. Clear boundary. **Estuarine alluvium/lagoon** (Subunit cii)

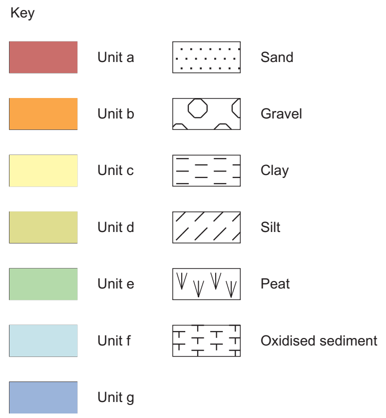
2.5Y 6/1 Grey sand. Sand is medium to coarse grained. Well sorted. Occasional dark organic streaks and clay lumps up to 5mm diameter. Clear boundary. **Waterlain ?glaciofluvial sand** (Subunit eii)

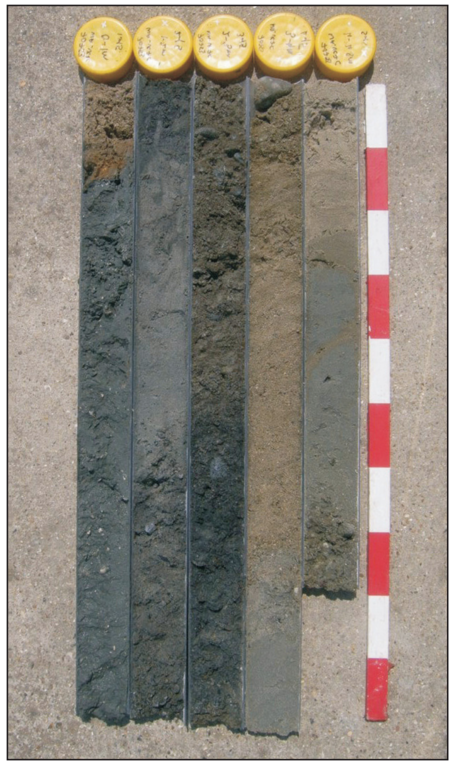
2.5Y 5/1 Dark grey sandy gravel. Sand is medium and coarse grained. Gravel is predominantly rounded to angular flint up to 45mm diameter. Occasional subrounded to rounded quartz up to 10mm diameter. Lighter colour from 2.00 to 2.60m (due to water loss). Slightly sorted. Abrupt boundary. **Waterlain ?glaciofluvial gravel** (Subunit eii)

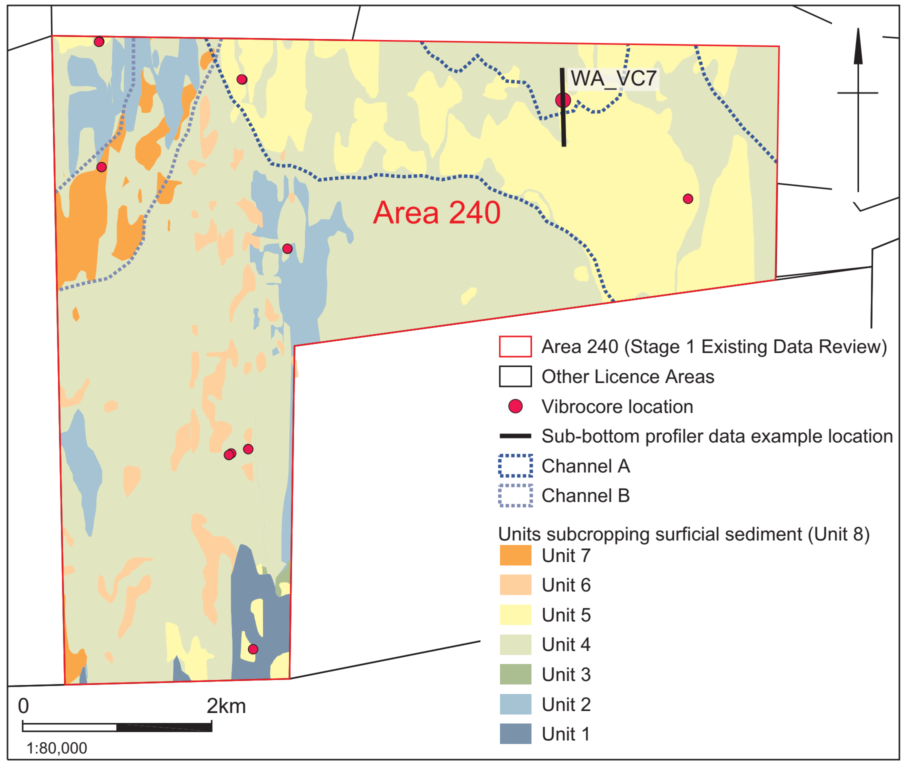
2.5Y 6/2 Light brownish grey gravelly sand. Sand is medium to coarse (predominantly medium) grained. Gravel is rounded to subangular flint up to 30mm diameter concentrated in horizontally bedded bands at 3.35 to 3.38 and 3.70 to 3.80m. Horizontal banding of lighter and darker sand visible from 3.12 to 3.42m. Clear boundary. **Waterlain sand** (Subunit giii)

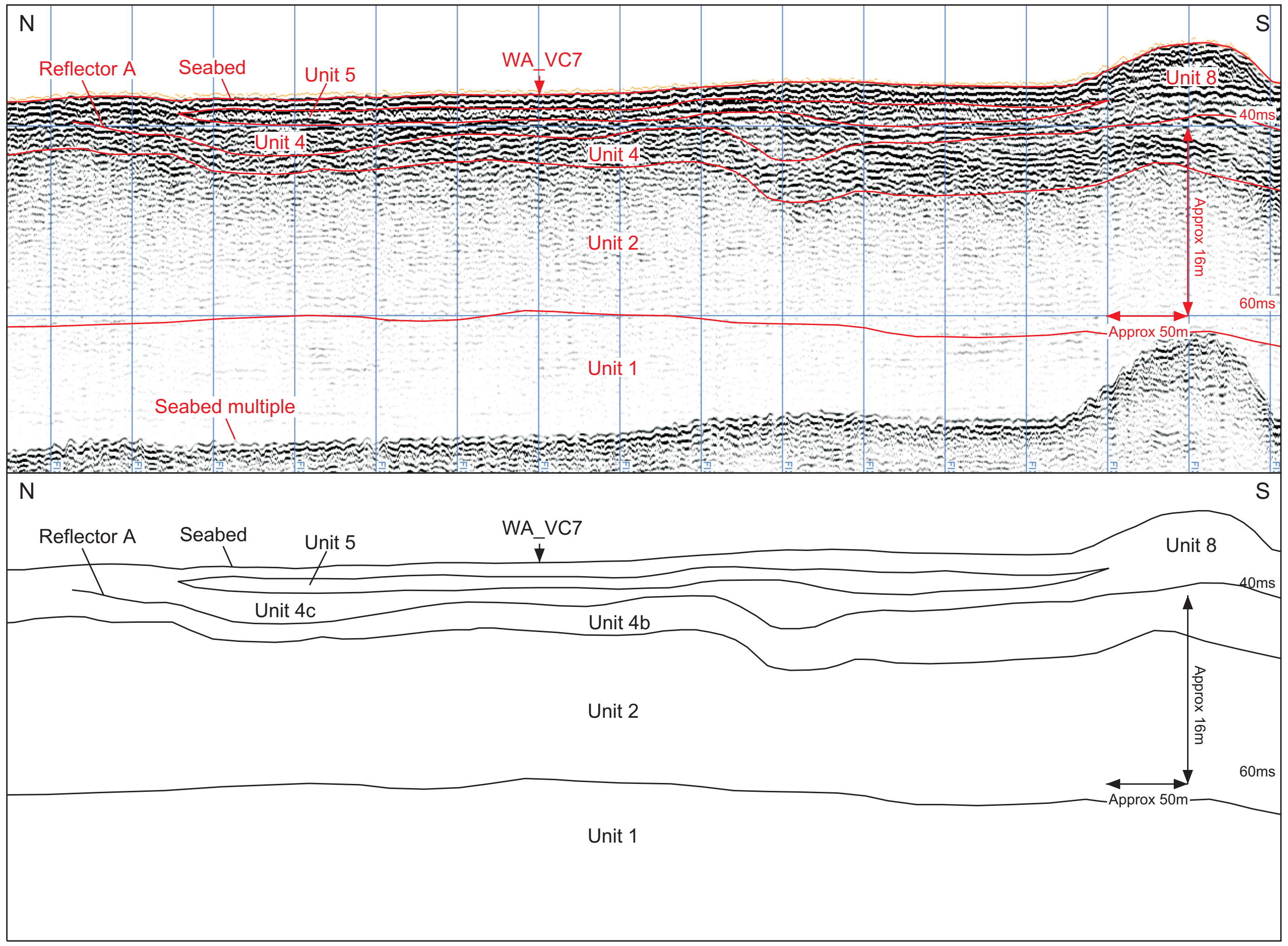
2.5Y 6/1 Light grey sand. Sand is medium to coarse (predominantly medium) grained. Well sorted. Metal core catcher plugged from 4.00 to 4.10m. From 4.00 to 4.27m the sediment is slightly lighter in colour due to water loss. Occasional rounded flint up to 15mm diameter (at 4.06, 4.22 and 4.60m), Clear boundary. **Waterlain sand** (Subunit giii)

2.5Y 6/2 Light brownish grey sandy gravel. Sand is medium, coarse and very coarse grained. Gravel is predominantly subrounded to subangular flint and *c*.15% subrounded quartz up to 8mm diameter. Slightly sorted. **Waterlain sand** (Subunit giii)









Sub-bottom profiler (boomer) data example at WA_VC7 (Stage 1 survey dataset)

Drawing Projection: UTM WGS84 z31N.

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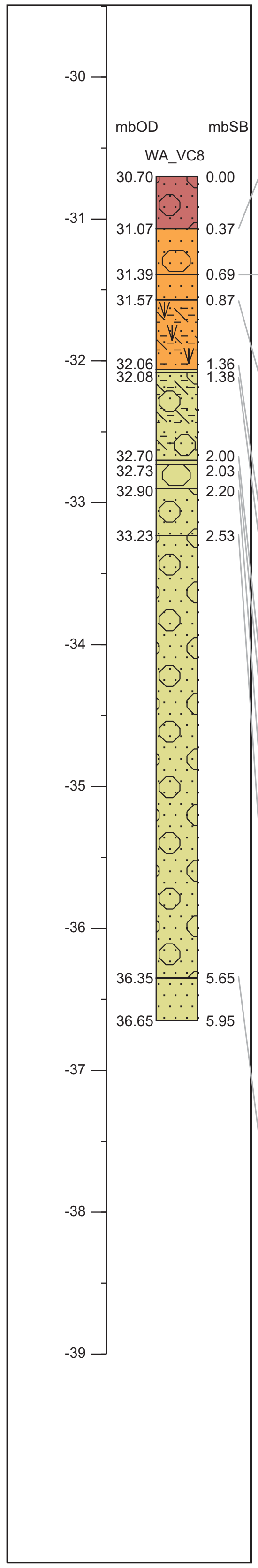
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC7c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 12



10YR 6/4 Light yellowish brown gravelly sand. Sand is medium, coarse and very coarse (predominantly coarse) grained. Very frequent small subrounded to subangular flint up to 12mm diameter. Occasional subrounded quartz up to 8mm diameter. Frequent broken and abraded mollusc fragments up to 3mm diameter. Sorted. Abrupt boundary. **Seabed sediment** (Unit a)

10YR 5/4 Yellowish brown sandy gravel. Sand is medium, coarse and very coarse (predominantly coarse) grained. Gravel is predominantly subrounded to subangular flint up to 25mm diameter. Occasional subrounded to rounded quartz up to 4mm diameter. Frequent broken molluscs including bivalves up to 10mm diameter. Poorly sorted. Clear boundary (dragged downwards at edges of core). **Shallow marine lag gravel** (Subunit bi)

2.5Y 4/1 Dark grey sand. Sand is fine, medium and coarse (predominantly medium) grained. Moderate small subangular flint to 6mm diameter, mostly between 0.69 and 0.77m. Very occasional subrounded quartz up to 5mm diameter. Frequent broken and whole molluscs including gastropods at 0.71 and 0.75m and Veneridae type bivalve at 0.76m. There is some evidence of horizontal bedding delineated by the molluscs. Twigwood at 0.79m. Frequent echinoid spines especially at 0.79m. Becoming slightly silty from 0.84 to 0.87m. Sorted. **Shallow marine/outer estuarine** (Subunit bii)

2.5Y 4/1 Dark grey sandy clayey peaty silt. Horizontally bedded and finely laminar. Sand is lighter grey (2.5Y 6/1 grey) fine grained and in 1 to 2mm thick laminae interspersed with grey clayey silt and (10YR 4/4 brown) fine organic peat layers up to 3mm in thickness, mostly *c.* 2mm in thickness with thicker bands at 1.05 and 1.30m. These thicker beds are also interspersed with mollusc fragments and what appear to be echinoid spines. The peat layers appear to comprise identifiable leaf and stem remains - possibly of reeds. Grey clayey silt beds are up to 20mm thick and display microlamination. At 1.30m one singular small subangular black flint 7mm diameter. Tidal rhythmic deposition. **Intertidal mudflat/saltmarsh** (Subunit biii)

Gap

2.5Y 4/1 Dark grey clayey silty gravelly sand/ Sand is fine, medium, coarse and very coarse (predominantly medium) grained. Gravel is predominantly rounded to angular flint up to 6mm. Occasional subangular to rounded quartz up to 4mm diameter. Frequent broken and whole molluscs including *Cerastoderma edule* (at 1.38, 1.49 1.64, 1.96 and 2.00m) and other bivalves. Poorly sorted. Very wet. Boundary lost at 2.00m. **Shallow marine/outer estuarine** (Unit d)

Gap

2.5Y 4/3 Olive brown gravelly sand. Sand is medium, coarse and very coarse (predominantly coarse) grained. Some darker grey patches, similar to overlying sediment. Broken and whole molluscs frequent especially from 2.04 to 2.15m including *Ostrea edulis* and other bivalves. Gravel is subangular to rounded flint up to 10mm diameter. Poorly sorted. Clear boundary. **Shallow marine** (Unit d)

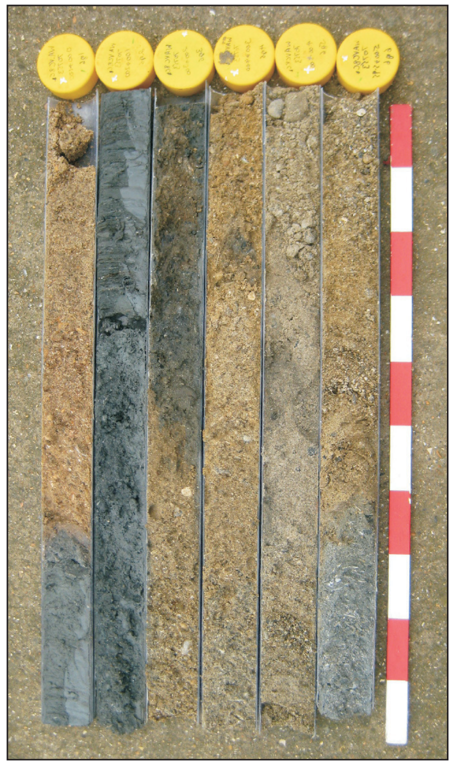
2.5Y 4/1 Dark grey sandy gravel. Sand is medium, coarse and very coarse (predominantly coarse). Gravel is subangular to rounded flint up to 41mm diameter, mostly *c.* 8mm diameter. No other inclusions. Clear boundary. **?Shallow marine** (Unit d)

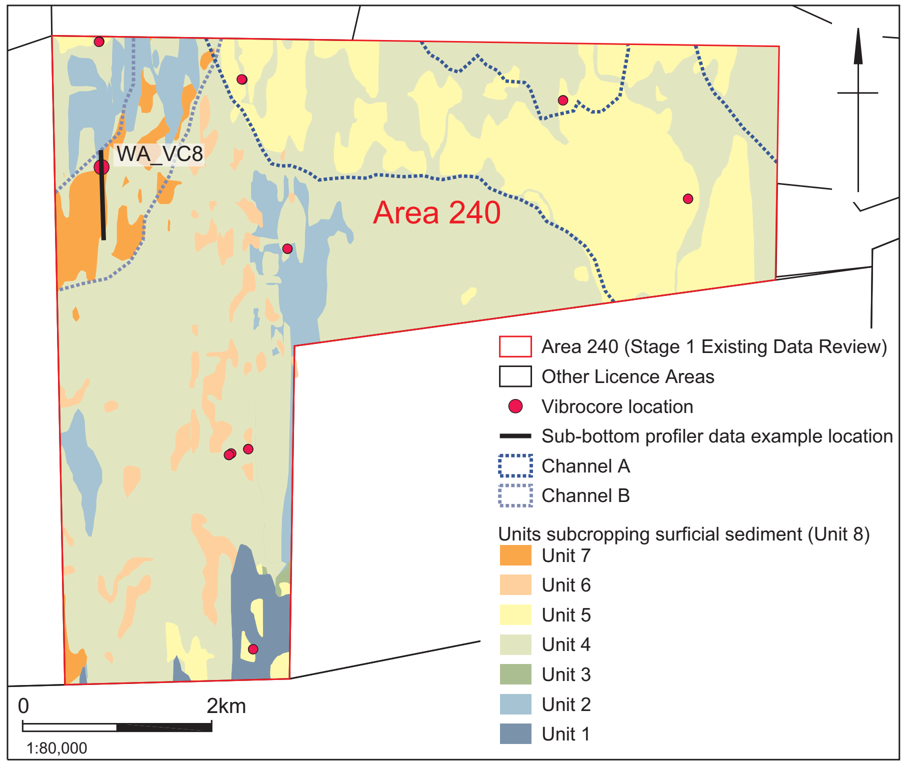
2.5Y 7/3 Pale yellow gravelly sand/sandy gravel . Sand is medium, coarse and very coarse (predominantly coarse) grained. Gravel is predominantly rounded to angular (mostly subrounded to subangular) flint up to 30mm diameter. Occasional rounded to subangular quartz up to 15mm diameter and very occasional subrounded quartzite up to 60mm diameter. Occasional broken molluscs, very abraded up to 15mm diameter at 4.58m, mostly *c.* 1-2mm and more frequent from 4.40 to 4.65m. Intermittent bands of gravellier (2.70 to 3.20, 4.98 5.21 and 5.48 to 5.65m) and sandier (4.30 to 4.80, 4.90 to 4.98 and 5.21 to 5.40m) sediment. Slightly sorted. Clear boundary. **Shallow marine** (Unit d)

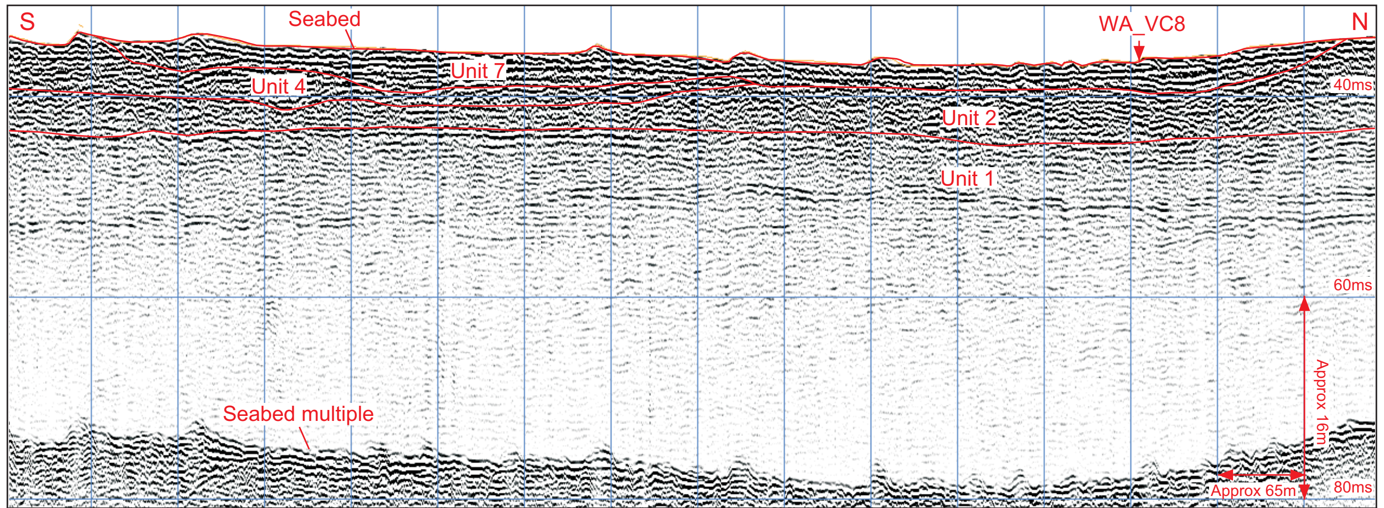
2.5Y 5/1 Grey sand. Sand is medium to coarse (predominanly medium) grained. Fining upwards. Occasional to moderate subangular to subrounded flint up to 6mm diameter. Between 5.65 to 5.69m frequent black angular?quartzite up to 25mm diameter. Very frequent molluscs broken and whole, and horizontally bedded (dragged downwards by coring). **Shallow marine** (Unit d)

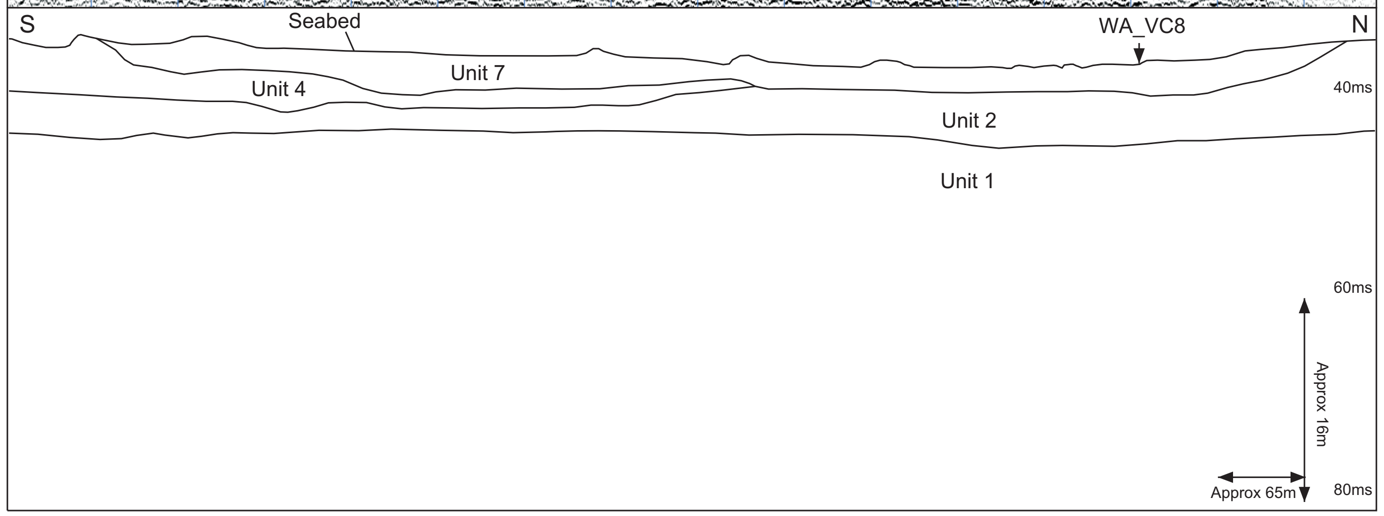
Key

Unit a · Unit b · Unit c · Unit d · Unit e · Unit f · Unit g · Sand · Gravel · Clay · Silt · Peat · Oxidised sediment









Sub-bottom profiler (boomer) data example at WA_VC8

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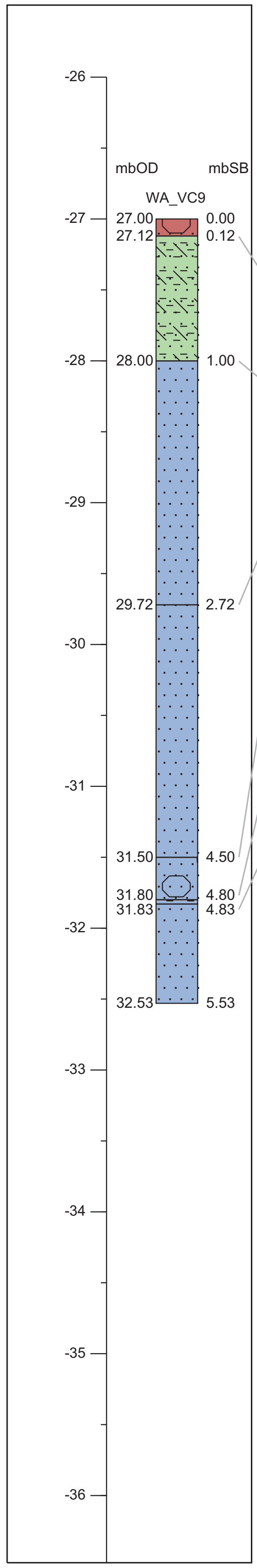
Scale:	SBP 1:600 vertical	Illustrator:	KJB/KMN
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC8c1: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation



2.5Y 6/3 Light yellowish brown sandy gravel. Sand is fine to medium grained. Gravel is rounded to angular flint up to 15mm diameter. Occasional broken mollusc. **Shallow marine seabed sediment** (Unit a)

2.5Y 5/2 Greyish brown sandy gravel. Sand is medium coarse and very coarse (predominantly coarse) grained. Gravel is predominantly rounded to subangular flint, up to 60mm diameter and 20% rounded to subangular quartz up to 45mm diameter. Slightly sorted. **?Glaciofluvial alluvium** (Subunit eii)

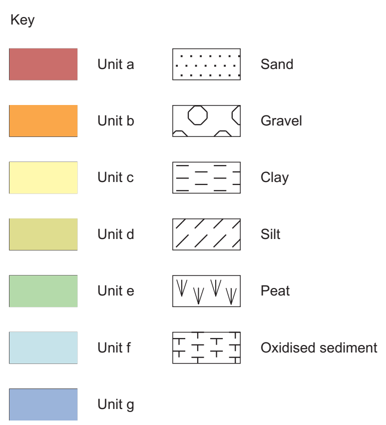
2.5Y 5/1 Grey sand. Sand is medium grained. Well sorted. Horizontal layering at 1.22 and 1.60 to 1.70m of alternate lighter (up to 10mm thick) and darker siltier (up to 2mm thick) bands. Dries out to a light beige colour. Occasional small (up to 2mm diameter) flecks of black organic material. Diffuse boundary. **Outer estuarine/ alluvial** (Subunit giv)

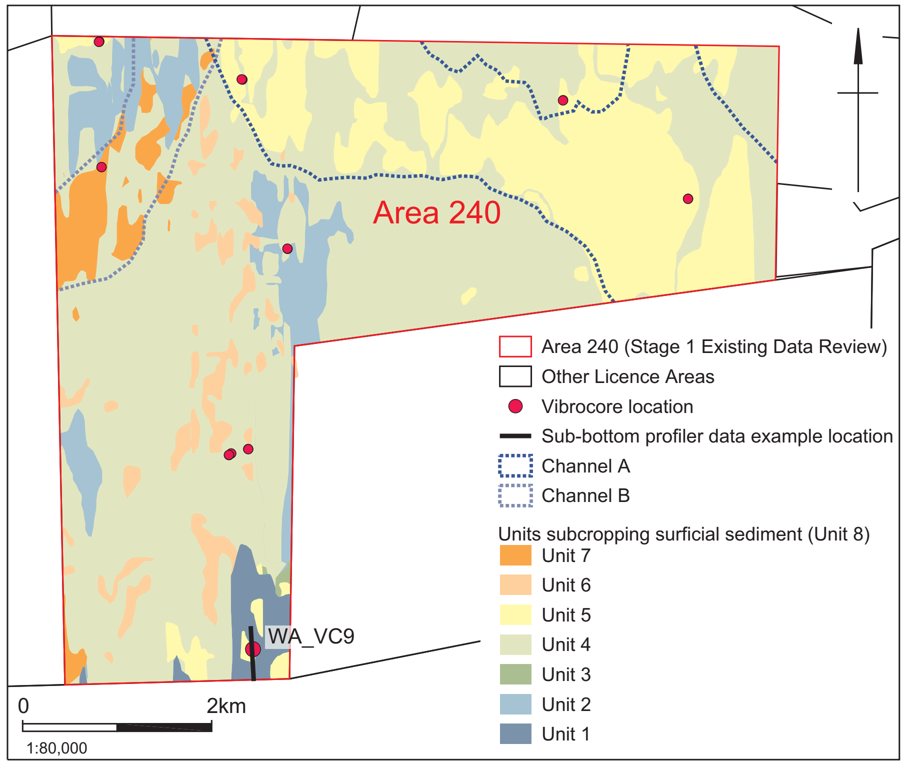
2.5Y 6/1 Grey sand. Sand is medium to coarse grained. Sorted. Contains occasional to moderate rounded to angular flint up to 12mm diameter most common between 3.00 and 3.40m. Occasional grey clay lumps up to 25mm diameter at 3.80m. Clear boundary. **Waterlain sand** (Subunit giv)

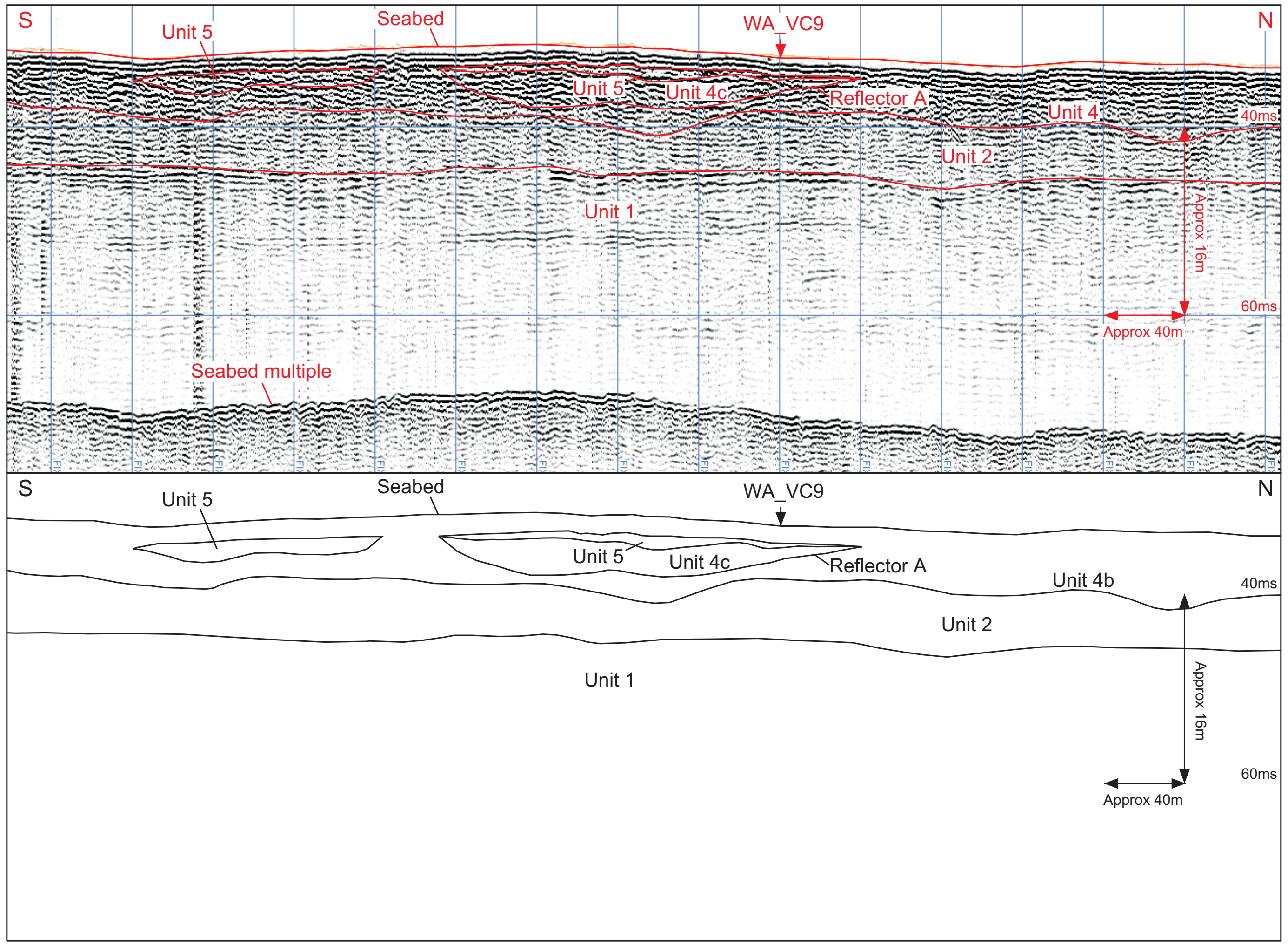
2.5Y 6/3 Light yellowish brown sandy gravel. Sand is medium, coarse and very coarse (predominantly coarse) grained. Gravel is predominantly subrounded to subangular flint up to 25mm diameter. 10% subrounded quartz up to 10mm diameter. Poorly sorted. Occasional grey clay lumps up to 25mm diameter (at 4.55m). Angled clear boundary. **Waterlain sand** (Subunit giv)

2.5Y 3/3 Dark olive brown silty clay. Interbedded with fine to medium grained sand.Two clay bands *c*.15mm in width. The upper band is heavily oxidised, the lower band only slightly. Abrupt boundary. **Waterlain sand subsequently subaerially exposed** (Subunit gv)

2.5Y 6/1 Grey sand. Sand is fine and medium grained. Well sorted. Horizontally bedded lenticular fine sand from 5.03 to 5.08m. Lenses and layers of horizontally bedded silty/sand 5.24, 5.34, 5.42 and 5.53m. Organic diagonal streak at 5.24m. **Waterlain sand** (Subunit gvi)







Sub-bottom profiler (boomer) data example at WA_VC9

Date:	29/06/10	Revision Number:	0
Scale:	SBP 1:600 vertical	Illustrator:	KJB/KMN
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

Drawing Projection: UTM WGS84 z31N.

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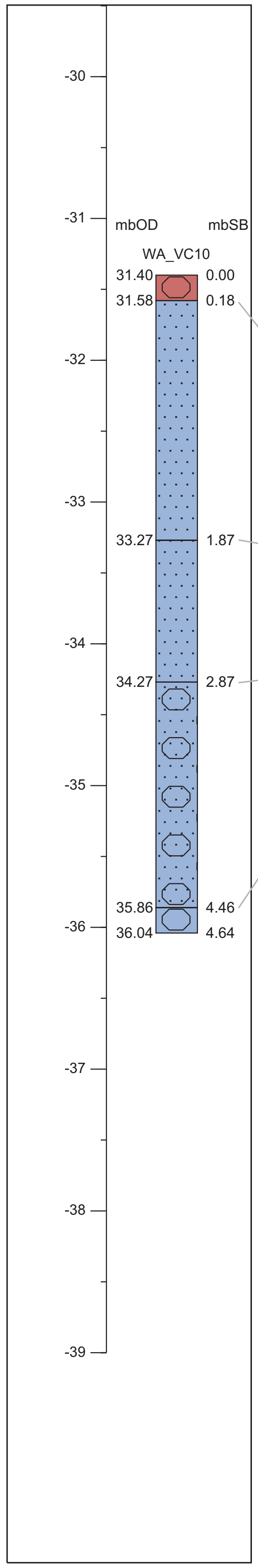
WA_VC9c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Figure 14



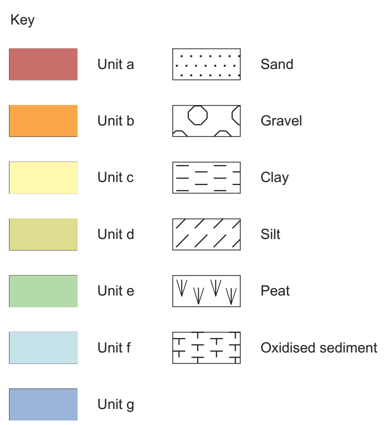
10YR 7/4 Very pale brown sandy gravel. Sand matrix is fine, medium and coarse (predominantly medium) grained. Gravel is predominantly rounded to subangular flint up to 35mm diameter. 10% subrounded to rounded quartz up to 10mm diameter. Occasional broken molluscs up to 5mm diameter. Slightly sorted. Clear boundary. **Seabed sediment** (Unit a)

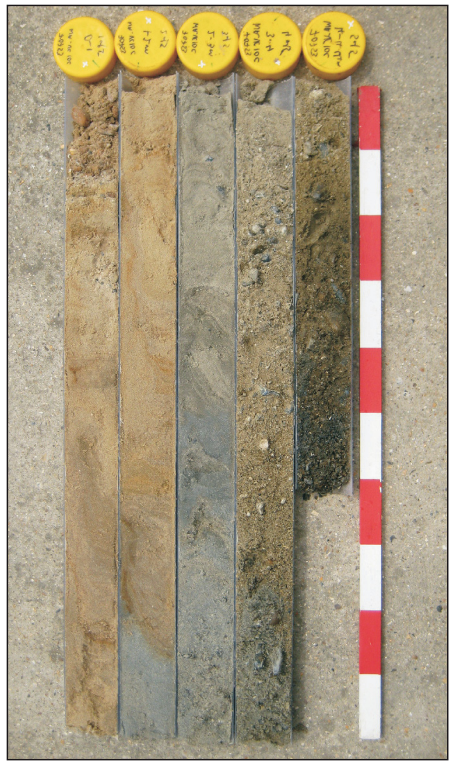
2.5Y 6/4 Light yellowish brown sand. Sand is fine to medium (predominantly medium) grained. Occasional small pebbles comprising subrounded to subangular flint up to 12mm diameter. Pockets of small gravel from 0.28 to 0.32 and 0.99 to 1.00 and at 1.12m. Occasional small broken molluscs 2-3mm especially filling a burrow from 0.72 to 0.84m. Small 8mm diameter orangey brown inclusion of oxidised sandy clay at 0.46m. Some indication of horizontal bedding from 0.45 to 0.80m and 1.58 to 1.67m. Fining upwards. Well sorted. 1.00 to 1.87m streaks of near vertical darker orange sand probably due to drying out. Abrupt angled boundary (mainly colour change). **Waterlain sand** (Subunit gvii)

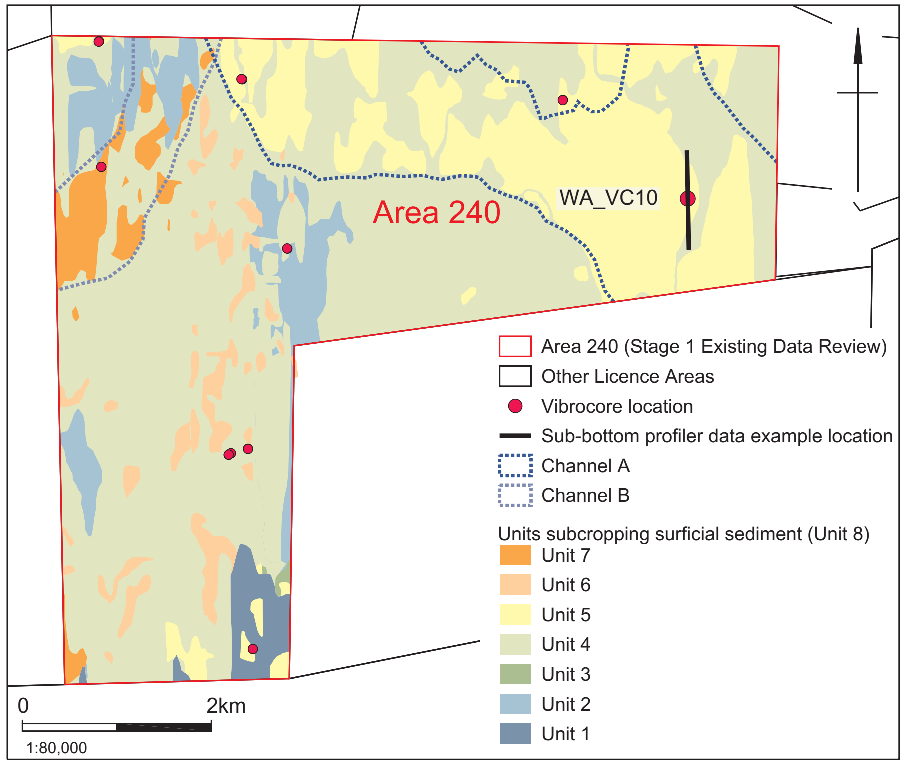
2.5Y 6/1 Grey sand. Sand is fine, medium and coarse (predominantly medium) grained. Occasional small pebbles comprising subangular flint up to 15mm diameter (at 2.14, 2.19, 2.66 and 2.70m). From 2.50 to 2.87m the sediment becomes slightly darker grey - probably due to a higher water content. Clear boundary. **Waterlain sand** (Subunit gvii)

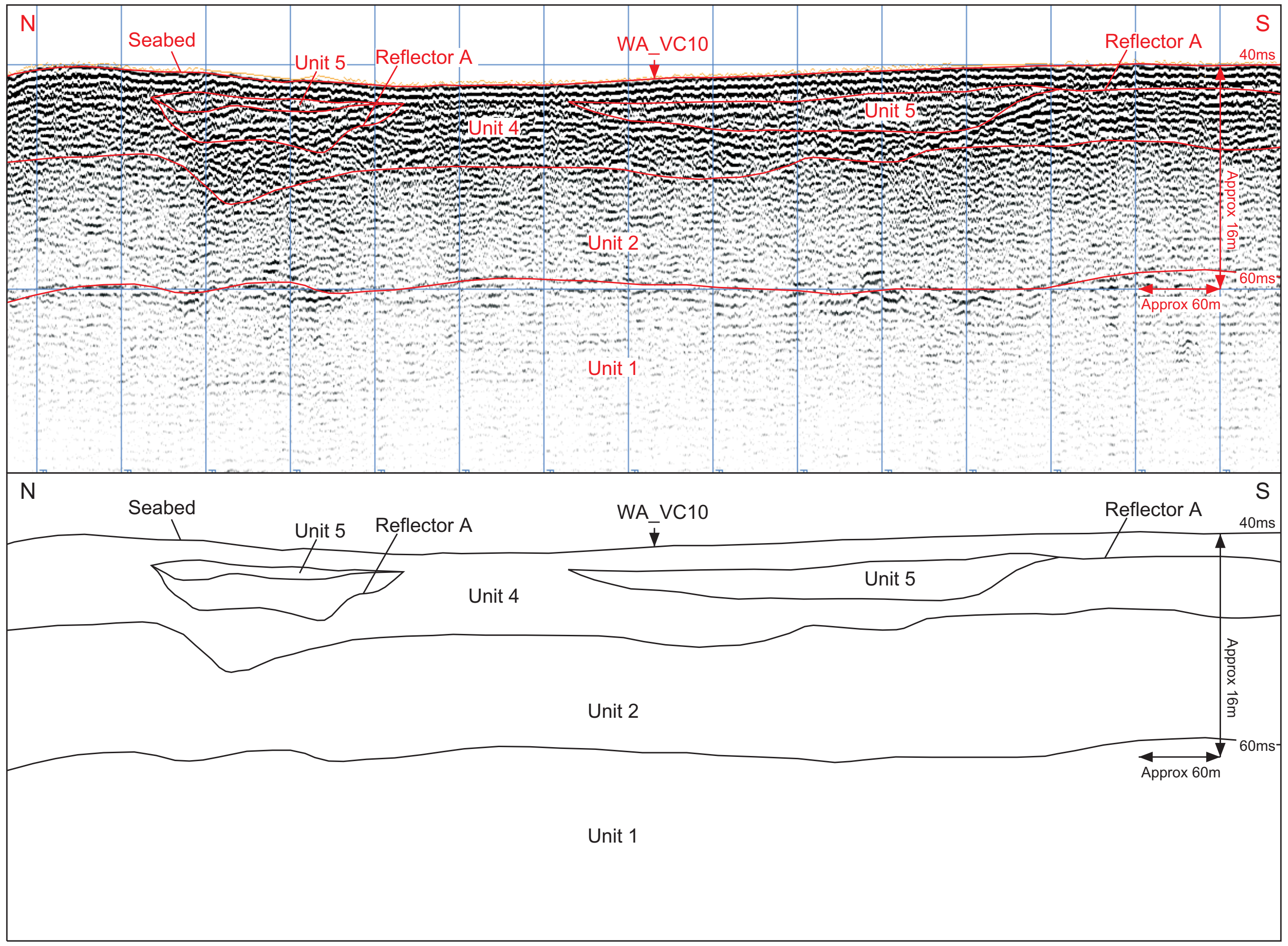
2.5Y 6/1 Grey sandy gravel. Sand is medium, coarse and very coarse (predominantly medium) grained. Gravel is rounded to angular flint up to 65mm diameter and very occasional subrounded to subangular quartz up to 23mm diameter quartz. Occasional broken molluscs up to 5mm diameter (at 2.95, 3.20 and 4.38m). Very gravelly between 3.08 to 3.40m, 3.70 to 3.96m and 4.20 to 4.40m. From 3.00 to 3.70m a beige colour is noted due to water loss. Sand becomes very coarse between 3.40 and 4.10m. Poorly sorted. Gradual boundary. **Waterlain sand/gravel** (Subunit gvii)

2.5Y 3/2 Very dark greyish brown sandy gravel. Sand is medium coarse and very coarse (predominantly coarse and very coarse) grained. Slightly sorted.Gravel is predominantly subrounded to subangular flint up to 25mm diameter (mostly c. 5mm diameter). Occasional subrounded quartz up to 7mm diameter.**?Glaciofluvial alluvium** (Subunit gviii)









Sub-bottom profiler (boomer) data example at WA_VC10 (Stage 1 survey dataset)

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Scale:	SBP 1:500 vertical	Illustrator:	KJB/KMN
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

WA_VC10c: Vibrocore log, sediment description, photograph, location, geophysical data example and interpretation

Plate 1: Deploying the vibrocore

Plate 2: Recovering the vibrocore

Date:	25/06/10	Revision Number:	0
Scale:	N/A	Illustrator:	KJB
Path:	W:\Projects\70753\Drawing Office\Report Figs\Enviro sampling\10-06-24		

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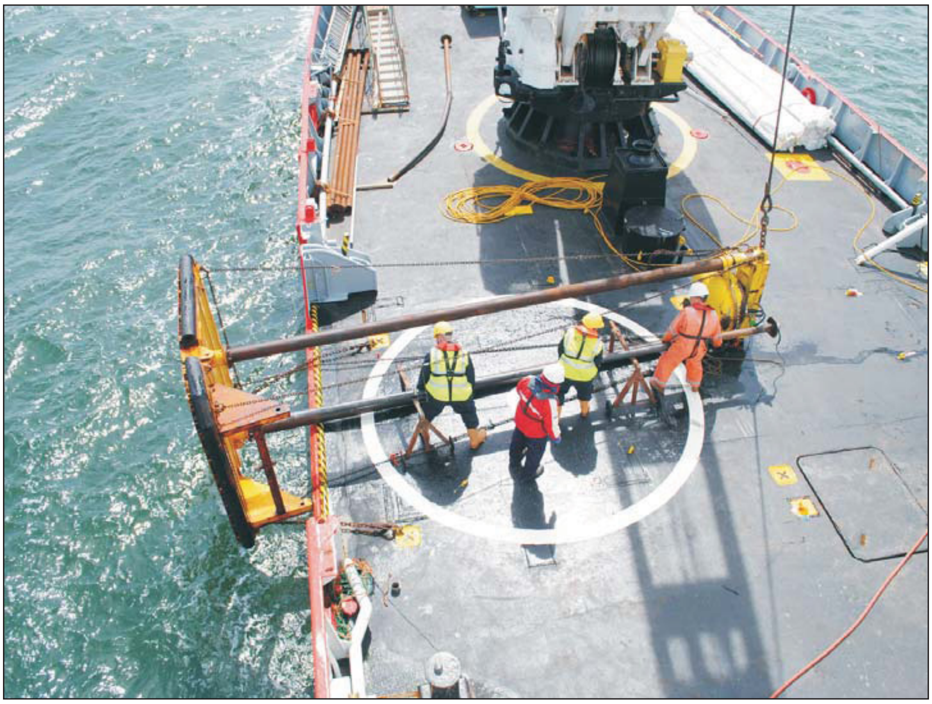

Plate 3: Removing the core barrel

Plate 4: Removing the core liner

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Scale:	N/A	Illustrator:	KJB
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