DOCKLANDS LIGHT RAILWAY
3–Car Capacity Enhancement
Blackwall
London E14

London Boroughs of Tower Hamlets and Newham

Geoarchaeological evaluation

October 2009

MUSEUM OF LONDON ARCHAEOLOGY

REGISTERED ORGANISATION IfA

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Site Code: APE08
National Grid Reference: 537488 180566
539585 180995
537689 179792

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Docklands Light Railway
3-Car Capacity Enhancement
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Report
for Geoarchaeological Evaluation

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MUSEUM OF LONDON
Archaeology Service

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Summary

This report presents the results of a geoarchaeological evaluation carried out by the Museum of London Archaeology (MOLA) at the Blackwall site of the DLR 3-Car-Capacity Enhancement scheme. This work has been commissioned from the Museum of London Archaeology by Taylor Woodrow (on behalf of Docklands Light Railway).

The evaluation involved the drilling of purposive geoarchaeological boreholes, which confirmed that deposits of palaeo-environmental interest exist between about 0.0m OD and -2m OD. These deposits would be subject to impact by the piled foundations of the proposed development and the purpose of the evaluation was to obtain geoarchaeological records and samples for off-site examination.

The evaluation provides a basic record of the evolving environment of deposition in this area of the East London Thames floodplain since the last deglaciation. The retained borehole sequences from the evaluation have the potential to provide information on the nature and timing of environmental change in this locality. A better understanding of the evolution of the floodplain and how relative sea level changed throughout our current interglacial is pivotal to a better understanding of developing human communities, their patterns of resource exploitation and interaction with the natural environment.

The evaluation has integrated palaeo-environmental data with sub-surface deposit modelling to assess the archaeological potential of the core samples obtained from the boreholes. At the base of the sequence recorded are gravels (Shepperton Gravels) deposited in the arctic river of the Late Glacial. Overlying this are Early Holocene banked sands, which stabilised to form ephemeral Mesolithic landsurfaces. Silty clays and peats mark the inundation affects of relative sea level rise from the Early Neolithic to the Bronze Age. At Blackwall these deposits represent dense wooded (alder carr) environments that were freshwater to brackish/marine with the onset of tidal access. From the Iron Age onwards silty clays dominate as grass and herb fen mudflats formed and brackish marine conditions moved westwards.These mudflats appear to have dried out and been subject to soil formation in historic time prior to the build up of modern made ground.

Assessment of the deposits and samples obtained from the boreholes indicates that there is good microfossil preservation, in particular pollen has good potential to provide new information about past environmental change in the locality. Such work, together with the information provided by the evaluation and compared with the information obtained from other DLR sites, recently evaluated, would make a valuable contribution to our present understanding of the floodplain evolution of East London Thames.

It is recommended any available additional DLR borehole data is added to the deposit model and that limited analysis is undertaken of pollen samples from the Blackwall cores. An additional radiocarbon date would provide a better understanding of the profile in its regional context, by dating similar events at different locations. The objective of this further work would be to reconstruct the pattern of floodplain vegetation change and the impact of estuarine incursion for the locality of the site. The results, which would build on those presented in this report, should be published as a short article in a journal such as the London Archaeologist or LAMAS, together with the results from the other DLR sites, recently evaluated (Canning Town, Delta Junction, South Quay and East India Dock).

The core samples obtained from the boreholes will be held in the MOLA store until a decision has been made on whether they are required for further analysis.

Contents

List of tables

List of Figs (located at the end of the report)

1 Introduction

1.1 Origin and scope of the report

This Geoarchaeological Evaluation Report has been commissioned from the Museum of London Archaeology (MOLA) by Taylor Woodrow (on behalf of Docklands Light Railway). It concerns a geoarchaeological evaluation at one location along the route of the DLR 3-Car-Capacity Enhancement scheme, Blackwall (Fig 1) and has been prepared within the terms of the relevant standard specified by the Institute of Field Archaeologists (IFA 2000). The purpose of the report is to summarise the results of the assessment and to recommend further work off-site.

A preliminary archaeology scoping and design review of the whole scheme was previously undertaken (MOLAS 2007). This allowed the identification of any locations where the proposals may have archaeological implications. Each of these locations was subject to a more detailed desk-based assessment (DDBA). The DDBA for Blackwall identified potential archaeological survival in the form of an underlying alluvial sequence including peat deposits, which are likely to preserve prehistoric palaeo-environmental landscape evidence, as well as evidence for prehistoric activity.

The development proposal comprised the construction of new high-level platform, escalators, stairs and lifts. The impacts of these works on the potential archaeological resource are likely to be minor and localised. Piling would penetrate the alluvial sequence of archaeological interest in small areas, but the pile caps are unlikely to penetrate far into the alluvial sequence, owing to substantial depths of Victorian and modern ground raising associated with the former dockyards. As a result, the DDBA report recommended the drilling of geoarchaeological boreholes at selected locations to sample the alluvial sequence, which will be impacted upon by piling.

This document forms the Geoarchaeological Evaluation Report, which follows on from a written scheme of investigation (WSI) for the borehole works (Morley 2008).

1.2 Site background

The proposed development is an extension of the existing Docklands Light Railway, Blackwall Station, in the London Borough of Tower Hamlets (National Grid Reference 538340 180640). The development proposal comprises the extension of the existing platforms at the station and associated minor structural modifications. At ground level (the platform is elevated in this area) this work involves the construction of four new pile foundations with pile caps measuring 1.5 x 1.5 x 1.4 m deep. Each of these pile caps will be supported on an arrangement of nine piles, each with a diameter of 0.32m.

The site is located in the northeastern part of the Isle of Dogs, next to the Blackwall Reach stretch of the River Thames. In terms of its geomorphological setting, the site lies at the western edge of the confluence between the River Thames and the River Lea, a major northbank tributary. BGS mapping of this area of the Thames floodplain shows that the site is situated at the very southeastern edge of the Kempton Park river terrace. Given its location on the edge of this area of high ground, but in such close proximity to the floodplain, it is likely that the site would have been an area attractive to exploitation by human populations settling in the area. Any settlements are likely to have been situated further up onto the higher ground to the northwest.

However, forays into the resource-rich, low-lying flooplain would have been facilitated by the use of high ground jutting out into the marshy, channel-proximal area such as exists at the site. A previous geotechnical borehole (BH4001; Soil Mechanics 2008), located 30 m to the east of the site, indicates that the gravel surface is approximately 6 – 6.5 m below ground level in this area. However, given the often variable nature of the sub-surface topography, especially in a location transitional between two landscape types (i.e. high terrace ground and low-lying floodplain landscape), the elevation of the gravel could fall outside this across the Blackwall site. The thickness of made ground recorded in this borehole was a significant 4.40 m.

However, sandwiched between the made ground and the surface of the gravel there survived 1.4 to 2 m of fine-grained alluvial clay silts and organic peats.
No detailed investigation of the prehistoric topography and its network of islands, channels and wetlands has yet been made for the Isle of Dogs. Thus the fragments of data so far obtained from this area do not form part of a coherent picture of the evolving past landscape and its links with prehistoric activity.

It was proposed that two geoarchaeological boreholes were drilled at Blackwall Station in order to examine the characteristics of the alluvial sequence and it's potential for past landscape reconstruction and indirect evidence of past human activity, as well as tie this information into a chronological framework using radiocarbon dating of any organic sediments. These two boreholes were situated within the footprint of two of the four pile caps being constructed for these works. Owing to height limitations, associated with the existing overhead viaduct, which would hamper the method of drilling, the two northern pile-cap footprints were chosen for the site of the two boreholes.

1.3 The Planning and legislative background

The Planning and legislative background to the site has been adequately summarised in the *Method Statement* (Morley, 2008). The geoarchaeological works were conducted in accordance with the *Method Statement* and comprise the only fieldwork required in order to satisfy the archaeological condition applied to planning consent for the development scheme.

1.4 Geoarchaeological Background

Buried alluvial deposits from the floodplain of the East London Thames are a significant archaeological resource. They have revealed archaeological features and finds as well as environmental information, from which the changing landscape has been reconstructed and the interplay between wetland and dryland, and freshwater to estuarine environments over the past 10,000 years suggested (eg: Devoy 1979; Sidell et al. 2000; Bates and Whittaker 2004).

Extensive alluvial sequences underlying substantial depths of 19th and 20th century groundraising have produced sediment archives dating from the Early Mesolithic, when the modern floodplain was a dry landsurface, a valley exploited by freshwater streams. Extensive and probably impenetrable forests are known to have developed across the valley floor in the later Mesolithic and Neolithic. Rising sea level during the Holocene impacted on the drainage, causing wetland areas to expand and these in turn were subsequently replaced by saltmarsh and estuarine mud. These estuarine deposits record fluctuations in relative sea level and local environment change for the later prehistoric and historic period.

The changing landscape influenced the types of human activity undertaken in the area and an understanding of the pattern of streams, wetlands and islands in the past, together with the sequence of landscape change, is necessary in order to better understand the context of past human occupation in East London. Although a broad understanding of this environment change already exists, human activity was influenced by detailed local changes and local topography. It is this smaller scale information and, crucially, its relationship to the bigger picture, together with detailed mapping of former islands, stream channels and their dates that is needed in order to reconstruct the context in which past human activity on the floodplain took place.

1.5 Aims and Objectives

1.5.1 Geoarchaeological Evaluations

Borehole studies rarely provide direct evidence for archaeology, but may provide evidence of indirect human impact or indicate where humans may have been exploiting the environment. The overall objective is to understand the depositional and post-depositional processes operating on site in order to reconstruct Holocene environmental change. This will augment existing knowledge of palaeoenvironments and palaeogeography of the Blackwall DLR site.

The general objectives of a geoarchaeological evaluation are:

1. To report in detail on the nature of a site's stratigraphy and to determine how and when this formed
2. To assess the potential of any preserved ecological remains for reconstruction of the changing landscape and environment for specific time frames.
3. To identify horizons which may:
    (a) provide data on past environments and resource availability
    (b) represent events which are likely to have had an impact on local human occupation and activities
    (c) have been deposited or transformed as a result of human activities
    (d) contain indirect evidence of local human activity.
    (e) represent environments that are known to be the focus of human activity, such as: dryland / wetland interfaces, chalk cliff-tops etc

1.5.2 Site specific objectives

The objective of the geoarchaeological evaluation at Blackwall is to assess the archaeological (palaeoenvironmental) potential of the deposits likely to be impacted upon by the DLR 3-car-scheme in this area. In particular their potential to:

- add new information to our current understanding of the evolving environment of the floodplain of the East London Thames; and to
- reconstruct the landscape context in which past human activity on the floodplain took place.

2 Methodology

All geoarchaeological on-site drilling and off-site core preparation work was carried out in accordance with the written scheme of investigation (Morley 2006).

2.1.1 On-Site

Two cable precussion rig boreholes were sunk for geoarchaeological examination under the supervision of a MOLA geoarchaeologist. Continuous cores were obtained for off-site examination, extending from the present ground surface through the made ground and underlying Holocene sediments into river terrace gravels. The U100 samples (0.45m long plastic tubes) were transported back to the MOLA laboratory for description and sampling.

The borehole locations were recorded and plotted on to the OS Grid (Fig 2). The Ordnance Datum (OD) of the ground level at each location was obtained from the contractor's Site Survey and depths of sediment unit boundaries converted to OD levels off-site.

2.1.2 Off-Site

Sediments
The cores were extruded and the sediments described using standard sedimentary criteria (relating to colour, compaction, texture, structure, bedding, inclusions, and clast-size). Depositional environments were preliminarily inferred and sub-samples cut from the cores at key locations for submission to external specialists for microfossil assessment (pollen, diatoms, foraminifera and ostracods) and radiocarbon dating. This will enable evaluation of the potential of the cores for more detailed analysis.

If the sequence is of sufficient interest to contribute to our understanding of the past environment and archaeological landscape context of the East London Thames, a strategy for analysis and publication of the results will be agreed with the client and GLAAS/EH.

Deposit modelling

The borehole logs were entered into a digital (Rockworks 2006) database, which included data from the surrounding area including the recent DLR sites (MOLA 2009). Each deposit component (gravel, sand silt etc) was given a colour and a pattern and, as a result, the two major variables of any deposit were stored in the RW2006 database and used to construct the deposit model.

A series of working cross-sections (transects: vertical slices through the sub-surface stratigraphy) were drawn through the boreholes and correlations were made between key deposits. Interpretation of the data is based to a large extent on examining these transects. Individual lithostratigraphic units with related characteristics within a borehole were grouped together and then linked with similar deposits, which may be made up of a number of individual contexts (lithostratigraphic units) in adjacent boreholes. Linking deposits between boreholes produced a series of site-wide deposits, which are representative of certain environments. Thus a sequence of environments both laterally and through time has been reconstructed for the site.

The transect (Fig 4) drawn through the Blackwall borehole profiles, linking them with data from nearby sites, forms a major means of illustrating and assessing the potential of the buried stratigraphy in this report. It illustrates the stratigraphic sequence and distribution of deposits across the site and its relationship to the surrounding area. A key to the lithostratigraphy and its interpretation is provided in with the transect. Where possible, landscape features (such as palaeochannels, cliff-lines and 'islands') have been identified and their changing morphology, or influence on the pattern of deposit accumulation, inferred.

The Rockworks data, which included data from other parts of the DLR scheme and elsewhere, was transferred to Arc GIS v.9 where the Spatial Analyst package was used to create a surface plot of the 'Early Holocene surface', which plots the surface topography of the Pleistocene gravels. This gives an approximation of the topography of the site as it existed at the beginning of the Holocene period (i.e. the early Mesolithic, *c* 10 000 years ago). The development of the Holocene floodplain is likely to have been influenced by the gravel topography inherited from the Pleistocene period. This surface (Fig 5) would have dictated the course of later channels, with gravel high points forming areas of dry land within the wetlands

Assessment of results
An outline of the development of the site and an assessment of the potential of the samples obtained for further investigation has been inferred from the lithostratigraphic characteristics of the sediments together with the results of dating.

Archive
The work has produced site and borehole location plans; two MOLA geoarchaeological borehole logs and two ^{14}C dating records. The records can be found under the site code APE08 in the MoL archive.

3 Results

3.1 Borehole Lithostratigraphy

Lithology descriptions of the borehole logs are tabulated below.

3.1.1 APE08 BH1

APE08 BH1			**Location:** 538434/180668	
Unit	**Depth of unit m bgl (Height of unit m OD)**	**Description**	**Interpretation**	**Facies**
	4.69 m OD	**Ground level adjacent to borehole**		
1.8	0.0–4.3	Moderately well consolidated, mid brown, gritty, sandy, silty gravel with soft grey brown silt clay pockets. Gravel is predominantly flint with occasional-moderate fragmented tile/CBM. Sharp horizontal contact but some gravel pressed into underlying.	Post Medieval / Modern Made Ground	Facies 5
	0.39 m OD			
1.7	4.30–4.85	Soft, greenish blue grey slightly silty clay (becoming firmer and browner downwards). Occasional-moderate dark grey flecking, especially in upper part (probably manganese precipitation). Moderate mid orangey brown mottled (oxidised) patches throughout, occasional plant remains. Very diffuse contact into below.	Estuarine mudflats and fringing fen – drying out through time.	Facies 4
1.6	4.85–5.33	Moderately firm, mid blue grey, slightly gleyed silty clay. Very similar to above but with moderate-frequent manganese and fine roots. Becomes brownish grey downwards. Very diffuse contact into below.		
1.5	**-0.64 m OD**			

	5.33–5.45	As base of above, with frequent fine organic inclusions including partially degraded wood and roots (matrix remains very slightly brownish grey silty clay). Very diffuse contact with below.	Flooded landsurface and wetland development, becoming wetter and more estuarine through time.	Facies 3
1.4	5.45–5.93	Variably soft to firm, brownish grey, slightly humic silty clay with moderate peaty rip-up clasts. Moderate fine organics throughout. Sharp, sub horizontal contact with below.		
13	5.93–6.0	Moderately firm, brownish grey, slightly humic (less humic than overlying unit) silty clay. Occaisional fine organic inclusions. Sharp contact with below. Not gleyed (as the overlying units are).		
1.2	6.0–6.45	Firm-friable, dark orangey brown, slightly clayey peat. Frequent woody inclusions. Becoming sandy with occasional flint gravel at base. Very diffuse contact with below.		
	-1.76 m OD			
1.1	6.45–6.60	Firm, very dark brown, very organic clayey fine-medium grained sand with occasional-moderate, fine-medium gravel. Occasional-moderate woody organics throughout. Becoming more sandy downwards.	Early Holocene banked sand deposits with evidence for soil formation	Facies 2
	-1.91 m OD	**Base of borehole**		

3.1.2 APE08 BH2

APE08 BH2: **Location:** 538416/180674				
Unit	**Depth of unit m bgl (Height of unit m OD)**	**Description**	**Interpretation**	**Facies**
	3.16 m OD	**Ground level adjacent to borehole**		
2.9	0-3.2	Mixed. Friable brown gritty gravely clay silt and soft grey brown silt clay. Occasional modern ceramic and CBM fragments. Sandy lenses at base. Sharp contact with underlying.	Post Medieval/Modern Made Ground	Facies 5
	-0.04 m OD			
2.8	3.2–3.45	Firm, light brownish grey silty clay. Moderate-frequent Iron oxide staining down root channels and flecked throughout.	Estuarine mudflats and fringing fen.	Facies 4
2.7	3.45–3.93	Soft, brownish/greenish grey silty clay (very clayey). Moderate-frequent Iron oxide flecking. Horizontal contact.		
	-0.77 m OD			
2.6	3.93-3.95	Soft, dark brown, near black in places, very organic clay. Moderate small plant inclusions (semi decayed wood and leaves). Basal contact not observable.	Flooded landsurface and wetland development - alder carr woodland.	Facies 3
2.5	3.95–4.08	Soft, spongy, very organic, sandy, peaty clay silt. Frequent semi decayed wood inclusions. Sand is medium grained. Sharp horizontal contact with below.		
	-0.92 m OD			
2.40	4.08–4.35	Firm, greenish grey brown, fine-medium sandy clay silt (very sandy, more so than below. Almost clayey sand). Occasional fine organic inclusions. Becomes more clayey downwards into gradual contact with below.	Early Holocene banked sand deposits with evidence for soil formation	Facies 2

2.3	4.35–4.80	Firm, greenish grey, slightly fine sandy silt clay. Occasional woody/rooty organic inclusions, occasional very small calcareous gritty inclusions, occasional vivianite at base.		
	-1.64 m OD			
2.2	4.80–4.95	Loose, yellowish brown (occasionally red, black and dark grey), poorly sorted, matrix supported, sub angular to rounded sandy gravel. Sand is coarse, gravel is fine-medium, of flint and occasional metaquartzite. Deposit is clayey in top 5cm.	Shepperton Gravels	Facies 1
	-1.79 m OD	**Base of borehole**		

3.2 Radiocarbon dating (chronostratigraphy)

Two samples taken one from the top and one from the base of the organic deposits present were submitted to for Beta Analytic, Miami, USA for standard radiometric radiocarbon (^{14}C) dating and provide a basis for the chronology of the site stratigraphy (Table 1).

Site Code	Borehole	m OD	MOLA Reference	Material Pretreatment	Measured Age	13C/ 12C	Conventional Age	2 Sigma Calibration	Averaged age used in text
APE0 8	BH1	-1.36	BLK/BH1-1.36	(organic sediment): acid washes	3630 +/- 60 BP	-27.9 o/oo	3580 +/- 60 BP	Cal BC 2130 to 2090 (Cal BP 4080 to 4040),Cal BC 2050 to 1750 (Cal BP 4000 to 3700)	2005 BC
APE0 8	BH1	-1.73	BLK/BH1-1.71	(organic sediment): acid washes	4680 +/- 70 BP	-27.8 o/oo	4630 +/- 70 BP	Cal BC 3630 to 3570 (Cal BP 5580 to 5520),Cal BC 3530 to 3320 (Cal BP 5480 to 5270),Cal BC 3230 to 3110 (Cal BP 5180 to 5060)	3398 BC

Table 1: Radiocarbon samples taken from the organic sediments

3.3 Pollen

Dr Rob Scaife

3.3.1 Introduction

The sediments analysed come from Borehole 1. The borehole profiles have revealed sequences of humic, alluvial silts overlying clayey peat which contains wood fragments. This sequence appears to relate to the late prehistoric extension of wetland marsh and alluvial deposits which occurred as a consequence of widespread post-glacial changes in sea level. The sequence clearly offered potential for pollen analysis and reconstruction of the past changing vegetation and environments. Consequently a pollen assessment study has been undertaken on sub-samples taken from Borehole 1 with the following principal aims.

a.) To ascertain if fossil pollen was present in the sequence, the quality of preservation and whether they are in sufficient numbers to allow an analysis to be carried out.

b.) If sub-fossil pollen is present, to provide a preliminary view of the past vegetation and environment of deposition during the time-span represented by sediment deposition.

c.) To ascertain if there was any evidence of prehistoric or later activity in the pollen record.

d.) To assess the potential for a more complete pollen analysis of the site at a future date.

Site Code	BH	Sample Number	Sample Depth (m)	Sample Height (m.OD)	Pollen Zone
APE08	1	P1	4.36	0.33	APE08:2
APE08	1	P2	4.83	-0.14	
APE08	1	P3	5.25	-0.56	
APE08	1	P4	5.4	-0.71	
APE08	1	P5	5.9	-1.21	
APE08	1	P6	5.97	-1.28	
APE08	1	P7	6.1	-1.41	APE08:1
APE08	1	P8	6.39	-1.7	

Table 2 Table 5 Samples examined for pollen assessment

3.3.2 Method

Sub-samples of 1.5ml were processed using standard techniques for the extraction of the sub-fossil pollen and spores (Moore and Webb 1978; Moore *et al.* 1992). Micromesh sieving (10u) was also used to aid with removal of the clay fraction from the minerogenic sediments. The pollen and spores were identified and counted using an Olympus biological research microscope fitted with Leitz optics. A total pollen sum of up to 200 grains per sample level was counted where preservation allowed. Other, miscellaneous microfossils, including numbers of algal *Pediastrum*, dinoflaggellates and pre-Quaternary palynomorphs, were also recorded. Data are presented in pollen diagram form, plotted using Tilia and Tilia Graph (Fig 3). Where percentages are given, these have been calculated as follows:

Sum =	% Dry land pollen. (*Alnus* included).
Marsh =	% Sum + Dry Land
Spores =	% total pollen + sum of spores.
Miscellaneous =	% total pollen + sum of misc. taxa.

Taxonomy, in general, follows that of Moore and Webb (1978) modified according to Bennett *et al.* (1994) for pollen types and Stace (1992) for plant descriptions. These procedures were carried out in the Palaeoecology Laboratory of the School of Geography, University of Southampton.

3.3.3 Results and *Interpretation*

Pollen was extracted from all of the 8 samples analysed. Although the lowest at 1.70m.OD was poor in quantity and preservation with smaller absolute pollen values, counts were easily attainable from all of the samples. Two local pollen assemblage zones have been recognised and are detailed from the base of the profile upwards as follows.

Zone APE08: 1 (-1.7 to -1.34m OD).

Quercus-Tilia-Alnus-Corylus avellana type. This basal zone is characterised by high values of *Alnus glutinosa* (alder; to 69%) and specifically corresponds with the lower humic/peat in which wood fragments are present. Other trees and shrubs are more important in this zone with *Quercus* (oak; 18%), *Tilia* (lime/lindens; to 9%) and *Corylus avellana* type (hazel but may include bog myrtle; 15%). There are few herbs with only small numbers of Poaceae (grasses; 3-4%) and sporadic Cyperaceae (sedges). Spores of ferns include relatively small numbers of monolete forms including *Dryopteris* type and *Polypodium vulgare* (polypody fern).

Zone APE 08: 2 (-1.34 to 0.33m OD).

Quercus-Corylus avellana type-Chenopodiaceae-Poaceae. This zone is characterised by a marked expansion of herb pollen and reduction in trees (*Tilia* and *Alnus*). These palynological changes are also associated with a stratigraphical change to largely mineral sediments. There are also some changes within this zone which, with a fuller analysis might result in differentiation of additional pollen zones. These changes are attributed to increasing local wetness.

Tilia of zone 1 is reduced to low levels and absence. *Quercus* and *Corylus avellana* type remain consistent from the preceding zone. There is a small increase in *Pinus* (pine; 2-3%) with sporadic *Betula* (birch), *Ulmus* (elm), *Fagus sylvatica* (beech) and *Fraxinus* (ash). The latter are present at the lower zone boundary. Herbs become important with a marked increase in diversity and numbers. Poaceae (to 40%) along with Cereal type (cereals; to 4%) and large (non-cereal) Poaceae are dominant. Also of note are consistent records of *Plantago lanceolata* (ribwort plantain; 3-4%), *Sinapis* type (charlocks; to 7%) and Chenopodiaceae (goosefoots and oraches; to 10%). The latter become more important in the upper section of the profile (from *ca.* –0.30m.OD upwards. The halophyte *Armeria* 'A' line (thrift or sea-lavender) is present at –0.56m.OD (90cm). There is an increase in marsh/fen taxa with Cyperaceae (sedges; increasing to 16%) with *Typha angustifolia* type (bur reed and reed mace) and *Typha latifolia* (greater reed mace). Cysts of algal *Pediastrum*, Hystrichospheres (dinoflaggellates) and reworked pre-Quaternary palynomorphs are present in this zone alone.

3.3.3.1.1 VEGETATION INTERPRETATION

The stratigraphical interpretation suggests that there was an old land surface developed on the sandy substrate. This is overlain by clayey peat deposited in a semi-terrestrial environment. A change to alluvial sediments containing reworked peat clasts occurs with evidence of increasing wetness and ultimately development of mudflat. This sequence shows very clearly the transgressive effects of rising water tables and finally inundation caused by regionally rising post-glacial sea-level (relative to land) which impacted on the Thames and its tributaries. These changes were diachronous throughout the Thames basin (as in other regions of the country) and have been discussed in detail (Devoy 1977, 1979, 1980, 1982, 2000; Wilkinson *et al.* 2000;' Sidell *et al.* 2000). The changes described here relate to the final late-prehistoric (Bronze Age) and early historic phase which saw terrestrial zone (soils) adjacent to the floodplain being finally subjected to brackish water/saline influences by the Iron Age and Romano-British periods.

The pollen data substantiate the above view showing a change from a semi-terrestrial habitat to one of salt marsh/mud flat. Initially, in pollen zone 1, the on or very near site vegetation was dominated by alder which formed typically floodplain carr woodland which colonised drier soils as the local water table rose. This can be seen as transitional, transgressive colonisation ahead of full alluvial and brackish water inundation. During this early period (zone 1), the terrestrial/dry land vegetation was dominated by lime (*Tilia*) with oak (*Quercus*) and hazel (*Corylus avellana*). This is diagnostic of the late-prehistoric, Bronze Age period and seen within the London region (Greig 1989; Scaife 2000 a, b, c., 2002; Thomas and Rackham 1996). It is probable that these taxa (especially *Tilia*) are under represented in the pollen spectra and diagram due to the statistical over representation of the on-site (autochthonous) alder and the filtering effects of this woodland preventing ingress of airborne pollen onto the floodplain site. *Tilia* is know to be poorly under represented in pollen assemblages due to entomophily and the fact that it flowers during summer when other trees are in full leaf which further inhibits its dissemination. It was, however, the dominant woodland taxon over wide areas of southern and eastern England during the middle and later Holocene (Neolithic-Bronze Age).

In zone 2, the sharp expansion of herbs dominated by grasses is associated with change to mineral sediments and thus, a strong change in the pollen taphonomy. That is, fluvial transport from the rivers catchment as well as normal airborne dissemination. This has also resulted in a much greater diversity of types which includes some evidence of cereal cultivation (i.e. cereal pollen) and grassland (? pasture). The latter indicated by ribwort plantain (*Plantago lanceolata*) as well as the grass pollen which may have come from various habitats. Reduction of woodland on-site definitely occurred as conditions became too wet for alder to survive (> 3months water logging). It is probable that the apparent reduction of the lime pollen is caused by the change in local environmental conditions. The increasing wetness may have pushed areas of its growth farther from the site/location and, given its poor pollen dispersion a resultant reduction in pollen numbers present. This taphonomic effect has been discussed by Waller (1994). However, lime woodland was also cleared for occupation and agriculture during the late-prehistoric period during the late Neolithic and Bronze Age periods (Scaife 2000b). It is probable that both influences are evident here.

With a change to more alluvial conditions, the upper surface of the peats was eroded or reworked resulting in the presence of some degraded lime pollen grains in the lower part of zone 2. During this phase, oak and hazel woodland remained as important constituents of the terrestrial woodland. The small expansion of pine in zone 2 is not of great significance and results from the typical over representation of pine in fluvially derived sediments due to the buoyancy of its pollen grains.

From the base of zone 2, Chenopodiaceae (goosefoots and oraches) are present and these along with *Armeria* (thrift or sea-lavender and possibly *Sinapis* type (charlocks). The presence of these possible halophytes suggest that there were saline influences. This may have been ephemeral ingress at time of high water or from more local development of salt marsh and mud flat. There is clearly an admixture of both salt marsh elements and fen vegetation as would be expected from a freshwater fluvial system discharging into an estuarine zone.

3.3.4 Summary and Conclusions

The following principal points have been established from this study.

- Pollen was present in all of the samples analysed including the most minerogenic as well as the more humic peats. This allowed pollen counts and a pollen diagram to be constructed.
- Two pollen zones have been recognised. A lower zone (1) is associated with the basal peat and is dominated by trees and shrubs and especially by alder indicating its importance on or near site. An upper zone (2) is associated with mineral/alluvial sediments. This zone is characterised by a substantial increase in herb pollen types dominated by grasses but with some evidence of arable agriculture and possibly pasture.
- Zone 2 also has pollen from probable halophytes (salt marsh/salt tolerant plant). These suggest that local salt marsh or mud flat existed or at least, that there was periodic ingress of brackish water containing pollen of salt marsh plants.
- The changes noted in the profile show the progressive, increasing wetness of the site caused by post glacial rise in sea-level setting in motion a transgressive and retrogressive hydrosere across what had been a terrestrial surface.
- Suggested age of the site: Pollen is not a means of dating but by comparison with existing site studies, it is suggested that the sequence spans the middle Bronze Age to Romano-British or later.

This site clearly has potential for a more detailed analysis and reconstruction of the vegetation and environment. If this is carried out, the following are required:

  - Radiocarbon dating to fit the date within the established vegetation framework/model.
  - Sampling at a much closer interval of 8cm in general and 4cm at points of interest and change. This will provide much better

stratigraphic resolution and especially establish the possible changes which are tentatively seen in zone 2.

- Increased pollen counts to a standard of 500 or more grains where preservation permits. This may provide increased taxonomic/ecological resolution.

- The base of this profile does not include the soil and old land surface of the underlying sandy substrate. Pollen analysis of this would establish the dry land/terrestrial vegetation prior to the transgressive influences. It was probably lime but it would be useful to establish this.

- These data should be integrated within the models of vegetation change established for London.

3.4 Diatoms

Dr. Nigel Cameron

3.4.1 Introduction

Eight sediment sub-samples have been assessed for diatoms. These were taken from a borehole (BH1) at the DLR APE08 Blackwall site. The sample depths and numbers of the sub-samples assessed for diatoms and the sediment types are shown in Table 3.

The purpose of the diatom assessment here is to assess the potential to use diatom analysis of the DLR APE08 BH1 sequence for environmental reconstruction. Information about the environment of deposition, salinity, aquatic/terrestrial conditions are of particular interest here. The diatom assessment takes into account the numbers of diatoms, their state of preservation, species diversity and diatom species environmental preferences.

3.4.2 Method

Site Code	BH	Sample Number	Sample Depth (m)	Sample Height (m.OD)
APE08	1	D1	4.36	0.33
APE08	1	D2	4.83	-0.14
APE08	1	D3	5.25	-0.56
APE08	1	D4	5.4	-0.71
APE08	1	D5	5.9	-1.21
APE08	1	D6	5.97	-1.28
APE08	1	D7	6.1	-1.41
APE08	1	D8	6.39	-1.7

Table 3 Samples examined for diatom assessment

Diatom preparation followed standard techniques (Battarbee 1986, Battarbee *et al.* 2001). Coverslips were made from each sample and fixed in Naphrax for diatom microscopy. A large area of the coverslips on each slide was scanned for diatoms at magnifications of x200, x400 and x1000 under phase contrast illumination.

Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Werff & Huls (1957-1974), Hartley *et al.* (1996) and Krammer & Lange-Bertalot (1986-1991). Diatom species' salinity preferences are discussed using the classification data in Denys (1992) and the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l^{-1}

2. Mesohalobian: 0.2-30 g l^{-1}

3. Oligohalobian - Halophilous: optimum in slightly brackish water

4. Oligohalobian - Indifferent: optimum in freshwater but tolerant of slightly brackish water

5. Halophobous: exclusively freshwater

6. Unknown: taxa of unknown salinity preference.

3.4.3 Results

The results of the diatom evaluation for the borehole sequences from the three sites are summarised in Table 4 and the diatom species recorded are shown in Table 5 along with their halobian classifications.

No.	**Diatoms**	Diatom numbers	**Quality of preservation**	**Diversity**	**Assemblage type**	**Potential for % count**
D1	present	ex low	ex poor	1 sp.	pos mar	none
D2	present	ex low	ex poor	ex low	bk	none
D3	present	low	poor/ v poor	mod	mar bk	some low sum
D4	present	low	poor/ v poor	mod	bk mar	some low sum
D5	present	high	mod to good	high	bk fw mar	good
D6	present	high	mod to good	high	bk fw mar	good
D7	present	ex low	ex poor	ex low	possible bk	none
D8	possible	-	ex poor	-	-	none

Table 4 Summary of diatom evaluation results DLR 3 car capacity enhancement site APE08

(mod – moderately high, ex.low- extremely low, fw – freshwater, pk – plankton, non-pk, non-planktonic, aero- aerophilous, epiphy – epiphytes, mar – marine, bk – brackish, halophil – halophilous, halophobous - hb)

	Sample Number							
Diatom Taxon	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**
Polyhalobous								
Coscinodiscus sp.			1		1			
Cymatosira belgica					1			
Paralia sulcata			2	2	1	3		
Podosira stelligera						1		
Rhaphoneis amphiceros			1			1		
Rhaphoneis minutissima					1	2		
Rhaphoneis sp.	cf			1				
Rhaphoneis surirella			1		1			
Triceratium favus			1					
Polyhalobous to Mesohalobous								
Actinoptychus undulatus			1	1	1	1		
Cocconeis scutellum						1		
Navicula flanatica						1		
Synedra gaillonii				1				
Mesohalobous								
Caloneis westii			1					
Catenula adhaerans			1					
Cyclotella striata		1	2	2	3	3	cf	
Navicula gregaria					1			
Navicula salinicola					1	3		
Nitzschia granulata			1	1				
Nitzschia navicularis			1	1	1	1		
Nitzschia sigma					1			
Synedra tabulata			1					
Mesohalobous to Oligohalobous Halophilous								
Actinocyclus normanii			1	1	1	2		
Nitzschia levidensis						1		
Oligohalobous Halophilous								
Navicula cincta					1			
Navicula mutica					1			
Oligohalobous Halophilous to Indifferent								
Melosira varians					1	1		
Rhoicosphaenia curvata					1	2		
Surirella brebissonii					1			
Oligohalobous Indifferent								
Achnanthes lanceolata					1			
Amphora pediculus					1	1		
Cocconeis disculus						1		
Cocconeis placentula & var.			1		2	2		
Cymatopleura solea					1			
Cymbella minuta					1			
Cymbella sinuata					1			
Diatoma vulgare					1			
Fragilaria brevistriata					1	1		
Fragilaria pinnata				1	2	2		
Fragilaria pseudoconstruens					1			
Gomphonema angustatum & var.					1			

productum								
Gyrosigma attenuatum					1			
Opephora martyii					1			
Stephanodiscus parvus						1		
Oligohalobous Indifferent (Continued)								
Stephanodiscus sp.						1		
Synedra ulna				1				
Unknown Salinity Group								
Chrysophyte cysts							2	cf
Cocconeis sp.						1		
Cyclotella sp.					1			
Cymbella sp.					1			
Gomphonema sp.						1		
Gyrosigma sp.				1		1		
Inderminate centric sp.				1			1	cf
Inderminate pennate sp.		1		1				
Navicula sp.						1		
Nitzschia sp.				1		1		
Unknown diatom fragment		1	2	1				

Table 5 Counts of diatom species along with their halobian classifications

3.4.4 Discusion

The possible diatom fragments in sample D8 (-1.70 m OD) at the base of the sequence are extremely poorly preserved and comprise: a fragment of a possible indeterminate centric species and a possible chrysophyte cyst. The semi-terrestrial, peaty nature of the sediment here is reflected by the presence of *Alnus* pollen grains and higher plant cells that have survived diatom preparation. Diatoms are present in extremely low numbers in D7 (-1.41 m OD) where the quality of preservation is very poor and species diversity extremely low. Chrysophyte cysts are relatively common in D7. These cysts are often common in ephemeral aquatic habitats and their heavily silicified walls favour their preservation. In addition to the rim of an indeterminate centric diatom species in D7, the possible remains of the central area of the mesohalobous planktonic species *Cyclotella striata* were identified. There is no further potential for diatom analysis of either sample D7 or D8.

Diatom sample D6 at -1.28 m OD from the base of a silty clay has a high concentration of well preserved diatom valves and species diversity is high. The most abundant taxa are the planktonic estuarine species *Cyclotella striata*, with the benthic mesohalobous species *Navicula salinicola* and polyhalobous planktonic species *Paralia sulcata*. Other common taxa in D6 are the marine species *Rhaphoneis minutissima*, the mesohalobous to halophilous planktonic diatom *Actinocyclus normanii*, and the halophilous to indifferent attached diatom *Rhoicosphaenia curvata*. In addition to the marine, brackish and halophilous elements of the assemblage, some oligohalobous indifferent species are present or common, for example *Fragilaria pinnata* which has wide salinity tolerance, however the epiphyte *Cocconeis placentula* which is also common, has a narrower salinity tolerance and is restricted to freshwater. The latter may be derived from upstream habitats. Overall the diatom assemblage of D6 reflects a tidal, brackish-marine habitat. Similarly the well-preserved diatom assemblage of sample D5 (-1.21 m OD) from silty clay alluvium is a mixture of brackish, freshwater and marine elements. However in D5 the marine component is restricted to the presence of a number of planktonic species (*Paralia sulcata, Rhaphoneis* spp., *Coscinodiscus* sp., *Actinoptychus undulatus*) whilst the qualitative evaluation indicates that the mesohalobous species *Cyclotella striata* is abundant and freshwater taxa such as *Cocconeis placentula* and *Fragilaria pinnata* remain common. In addition to the apparent decline in allochthonous marine plankton a greater number of halophilous and oligohalobous indifferent taxa, mostly from shallow water attached and benthic habitats, are present. For example the halophilous (aerophiles) *Navicula cincta* and *Navicula mutica*, halophilous to indifferent taxa *Melosira varians* (semi-planktonic and associated with flowing water), *Rhoicosphaenia curvata* (attached) and *Surirella brebissonii* (benthic). The non-planktonic oligohalobous indifferent taxa that are present in D5 include *Cymatopleura solea* (benthic), *Cymbella minuta, Cymbella sinuata, Diatoma vulgare, Fragilaria brevistriata, Gomphonema angustatum* and *Gyrosigma attenuatum*. Some poorly-preserved valves of the planktonic freshwater genus *Stephanodiscus* were also recorded. The species of this genus generally prefer higher nutrient levels, but here the poorly-preserved valves of this planktonic genus may be derived from upstream freshwater habitats. Both samples D6 and D5 have good potential for percentage diatom analysis.

Samples D4 (-0.71 m OD) and D3 (-0.56 m OD) are taken from silty clay alluvium with peat and other organic material present. The oligohalobous indifferent component of both D4 and D3 is small with only *Synedra ulna* and *Fragilaria pinnata* present in D4, and only *Cocconeis placentula* present in D3. Both samples are dominated by mesohalobous and polyhalobous diatoms, in particular the planktonic species *Cyclotella striata* and *Paralia sulcata* respectively. In addition benthic mesohalobous diatoms such as *Nitzschia granulata* and *Nitzschia navicularis* are present in both and *Caloneis westii* and *Catenula adhaerans* are present in D3. Other, polyhalobous, diatoms present in D3 include *Rhaphoneis amphiceros, Rhaphoneis surirella, Cymatosira belgica* and *Triceratium favus*. The diatom assemblages of D4 and D3 suggest increasing salinity compared with the underlying alluvium sampled in D5, and the flora of D3 perhaps indicates a greater number and diversity of marine and brackish marine species compared with D4 and is consistent with the mudflat interpretation indicated on the section drawing. Both samples D4 and D3 have low diatom numbers and the quality of valve preservation is relatively poor, although species diversity is moderately high. Therefore there is only low potential to carry out percentage diatom analysis for D4 and D3 where low sum diatom counts might be possible.

Diatom samples D2 (-0.14 m OD) and D1 (0.33 m OD) from the base and top of silty clay have extremely low diatom numbers and very poor preservation. The single species identified in D2 was the mesohalobous diatom *Cyclotella striata*. A valve fragment probably from the marine genus *Rhaphoneis* was present in D1. Both support the indication on the section drawing of a mudflat habitat. However, diatom preservation in mudflat sediments is usually good. There is no further potential for diatom analysis of these samples.

3.4.5 Conclusions

- Diatoms are present in six samples and were tentatively identified from poorly preserved remains present in two samples assessed from the Blackwall DLR site.
- More than 50 diatom taxa were identified in the assessment counts from APE08.

- Diatoms are more or less absent from the basal sample (D8) of the sequence and a single estuarine species was tentatively identified from the overlying sample (D7) along with chrysophyte cysts.
- Diatoms are present in high numbers and are generally well preserved in samples D6 and D5. The diatom assemblages of these samples are mixtures of brackish, freshwater and marine diatoms. Estuarine diatoms are common in both whilst the marine component is greater in D6 and freshwater elements more important in D5. Both D6 and D5 have good potential for percentage diatom analysis.
- Samples D4 and D3 have low numbers of poorly preserved diatom valves. However, species diversity is moderately high and the evaluation shows increasing dominance of mesohalobous and polyhalobous taxa and very small numbers of freshwater diatoms. There is some potential for low sum diatom counting.
- Diatoms are extremely poorly preserved in the top two samples D2 and D1 with a single estuarine species identified in D2 and a marine diatom species tentatively identified in D1. Neither sample has further potential for diatom analysis.
- The sequence of diatom assemblages in BH1 appears to show changes in diatom sources and salinity. Percentage analysis of these diatom assemblages may show further details of these changes.

3.5 Foraminifera and Ostracoda

Dr. John Whittaker

3.5.1 Introduction

Six samples from borehole 1 put down at Blackwall Station, Docklands Light Railway, for an archaeological evaluation during its enhancement to take longer trains, were submitted in early December 2008 by Mike Morley and Jane Corcoran of the Museum of London Archaeology (MOLA) for assessment. A few pages of supporting notes from the Method Statement from the initial geoarchaeological investigation were kindly provided (MOLAS, 2008). The purpose of the Assessment Report, submitted here, was to make a preliminary reconstruction of the environment in which the sediments of BH 1 were deposited, from any microfossils (especially the foraminifera and ostracods) they might contain.

Materials and Methods

Site Code	BH	Sample Depth (m)	Sample Height (m.OD)	Weight
APE08	1	4.36	0.33	50g
APE08	1	4.83	-0.14	55g
APE08	1	5.25	-0.56	55g
APE08	1	5.4	-0.71	50g
APE08	1	5.9	-1.21	50g
APE08	1	5.97	-1.28	60g

Table 6 samples examined from BH1 for formaminfera and Ostracoda assessment

After weighing, each sample was put in a ceramic bowl. The sediment was first broken by hand into very small pieces and then thoroughly dried in the oven. Boiling water was then poured on the sample and a little sodium carbonate added to help remove the clay fraction on washing. It was then left to soak overnight. The sample was then washed with hot water through a 75 micron sieve. Breakdown was not achieved initially, however, due to the high organic and clay content in most samples, and the procedure had to be repeated, whereupon a satisfactory breakdown was reached. The resulting residue was finally decanted back into the bowl for drying in the oven. When dry the sample was stored in a labelled plastic bag. Examination of the residue was undertaken under a binocular microscope. First the residue was put through a nest of dry sieves (>500, >250 and >150 microns) and then sprinkled out a fraction and a little at a time onto a tray. Any organic remains or items of interest were noted and the data incorporated, on a presence (x)/absence basis, into Table 7. The ostracods and foraminifera, if they occurred, were picked out and placed on 3x1" faunal slides for archive purposes, the species being listed in this case also on a presence/absence basis, and colour-coded for their ecological preferences, also in Table 7.

3.5.2 Results

ORGANIC REMAINS

SAMPLE	F/O1	F/O2	F/O3	F/O4	F/O5	F/O6
Depth O.D.	+0.33m	-0.14m	-0.56m	-0.71m	-1.21m	-1.28m
plant debris + seeds	x	x	x	x	x	x
Molluscs	x		x			
Bithynia opercula	x					
earthworm granules	x					
brackish foraminifera			x	x		
brackish ostracods			x	x	x	x
freshwater ostracods			x	x	x	x
Diatoms (>75 microns)			x	x	x	x
cladoceran ephippia					x	x
Insects					x	x

BRACKISH FORAMINIFERA

SAMPLE	F/O1	F/O2	F/O3	F/O4	F/O5	F/O6
Depth O.D.	+0.33m	-0.14m	-0.56m	-0.71m	-1.21m	-1.28m
Ammonia sp.			x	x		
Haynesina germanica			x	x		
Elphidium williamsoni			x			

BRACKISH OSTRACODS

SAMPLE	F/O1	F/O2	F/O3	F/O4	F/O5	F/O6
Depth O.D.	+0.33m	-0.14m	-0.56m	-0.71m	-1.21m	-1.28m
Leptocythere porcellanea			x		x	x

FRESHWATER OSTRACODS

SAMPLE	F/O1	F/O2	F/O3	F/O4	F/O5	F/O6
Depth O.D.	+0.33m	-0.14m	-0.56m	-0.71m	-1.21m	-1.28m
Candona neglecta			x	x	x	x
Ilyocypris biplicata					x	
Limnocythere inopinata					x	
Cyclocypris laevis						x

Ecology	*mudflats, becoming semiterrestrial*	*vegetated mudflats of tidal river (both brackish and freshwater influences)*

Organic remains, foraminifera and ostracods are listed on a presence (x)/absence basis only

calcareous foraminifera of low-mid saltmarsh and tidal flats
brackish ostracods of tidal flats and creeks

Table 7 Microfaunal results for APE08 BH1

3.5.3 *Discussion*

All the six samples produced microfossil remains, but only two samples contained foraminifera and four samples, ostracods. Plant remains were found in all six samples and a palynological analysis would therefore be essential for any fuller palaeoecological reconstruction of this Blackwall sequence through time. Large diatoms were much in evidence in the lowermost four samples and similarly, a specialist diatom survey would also be beneficial. Molluscs were only seen in two samples and their value might thus be peripheral in this context.

The bottom four samples (F/O3 - F/5), covering the interval -0.56 to -1.28m OD, suggest vegetated mudflats of a tidal river with both brackish and freshwater influences (Table 7). The freshwater component comprises four species of non-marine ostracods (colour-coded light green on Fig 1), all indicative of slow-flowing water with aquatic vegetation; there are also ephippia (egg-cases) of cladocerans (*Daphnia* and the like) present. The brackish component comprises three species of calcareous foraminifera of low-mid saltmarsh and tidal flats (colour-coded light grey), in this case indicating tidal flats (in the absence of any agglutinating saltmarsh foraminifera). This is reinforced by the presence of the brackish ostracod *Leptocythere porcellanea*, a species of tidal flats and creeks (colour-coded lime green).

The top two samples (F/O1 – F/O2), comprising the interval +0.33 to -0.14m OD, are devoid of any foraminifera or ostracods, and although the sedimentary facies seems to indicate continuing mudflats, the environment of the site may have become by now semi-terrestrial and beyond any tidal influence. The presence of earthworm granules in the top sample even suggests primitive soil development. Palynology will again be the best tool here to develop the ecology more fully.

3.6 Integrated Palaeoenivironmental Discussion

The tabulated sedimentary units (section 3.1) have been grouped into sediment packages or facies with key markers in the sequence that denote major events used as points of correlation. These principally comprise the change from clast supported gravels to Early Holocene sands (at -1.8m OD); inundation and wetland development (between -1.76 and -0.64m OD); and estuarine encroachment from -0.77 to 0.39m OD.

Gravels (facies 1) are superseded by fluvial sands and freshwater peat (facies 2 and 3). Following this, rising sea levels lead to tidal access and inundation of freshwater to estuarine mudflats and marine clays (facies 4). The deposit sequence is compared with data from other sites and is illustrated in one transect drawn across the area (**Error! Reference source not found.**), which puts the information from the site itself within the context of the surrounding area.

3.6.1 Pleistocene: Facies 1 (-1.64 to -1.79m OD)

The basal deposit recorded in the deposit model are sands and gravels, which were deposited in a braided river environment during the final phases of the last (Devensian) glaciation (*c* 15,000 to 10,000 years ago). These sediments belong to the Shepperton Gravels. Transect 1 records the surface of these gravels between -0.53 and -3.77m OD, and the surface variation is probably a result of preferential scouring of softer underlying beds of Tertiary sedimentary units. The transect includes the previous DLR sites of Delta Junction and Canning Town (MOLA 2009) as well as the Blackwall site. Within the boreholes from Blackwall the gravel surface lies between -1.76 and -0.92m OD. At the end of cold stage episodes, downcutting events were initiated by the great volume of meltwater introduced into the system during the initial thawing of ground ice. This combined with very low sea-levels during these periods ultimately led to river incision and downcutting, creating deeper channel areas and leaving remnants of older gravels forming islands within the floodplain. As seen on Transect 1 (**Error! Reference source not found.**) to the east of the Blackwall site an area of high gravel around -1m OD is recorded (low island, **Error! Reference source not found.**). This may be a remnant of the Kempton Park Terrace, which lies to the north of the site or it may have a similar origin to the Early Holocene sands discussed below.

3.6.2 Mesolithic to Early Neolithic: Facies 2 (-0.92 to -1.91 m OD)

In the boreholes at Blackwall, which lie in the centre of transect 1, organic sands and sand clays and silts were recorded at the base of the sequence, with a surface between –0.92 and -1.76m OD. These coarse sediments were most likely laid down during the early Holocene as the high water flux, fed by ice melt, abated, resulting in a reduction in the size of the particles which the river could entrain. However, medium to coarse sand was still available in the fluvial system and was being transported along the river until it was deposited and banked up against gravel highs, or formed point and mid-channel bars within the network of anastomosing channels. The elevation of these sandy deposits suggest that they may have formed a dry land surface that would have been exposed for a short period during the Mesolithic and then inundated as the effects of relative sea level rise resulted in the ponding back of inland rivers during the Late Mesolithic or Early Neolithic.

3.6.3 *Neolithic to Bronze Age: Facies 3 (-0.64 to -1.76 m OD)*

The nature of the deposits represented by facies 3 is generally slightly sandy humic silty clays to clayey peats. The surface of these deposits lie between -0.64 and -0.77m OD at Blackwall and are coarser in the western borehole, being predominantly an organic sand with occasional gravels. The pollen data from the base of facies 3 (see section 3.3) indicates landsurface development with the presence of lime and some oak and hazel and may relate to the (Mesolithic) landsurface development suggested in facies 2 above. The pollen results then show a transgressive environment of alder carr floodplain as the affects of RSL alter the vegetation environment. The diatom report suggests that these sediments initially accumulated in a semi terrestrial environment fringing more estuarine conditions. Evidence found within the microfaunal samples suggest that mudflats dominated in a brackish to fresh water, slow flowing environment of tidal flats and creeks. Radiocarbon dates from these deposits give a Late Neolithic to Early Bronze Age date (3398 BC, section 3.2) to the onset of organic clay deposition with it continuing into the Mid Bronze Age (2005 BC, section section 3.2).

Although this sequence continues westwards to the previous DLR site of Delta Junction, the onset of wetland development was later on that site, where it occurred during the Mid Bronze Age (MOLA 2009). The wetland deposits also continue eastwards (see Transect 1) with deposits thinning as they rise up and on to the low island. Further eastward the deposits are replaced by thick alluvial deposits which fill a suspected palaeochannel (**Error! Reference source not found.**). The elevation of the gravel lowers significantly in this area to around -3m OD (**Error! Reference source not found.**).

3.6.4 *Iron Age to Historic: Facies 4 (0.39 to -0.77m OD)*

Facies 4 is a silty clay, representing estuarine mudflats, which was about 1m thick at Blackwall, although it is as much as 6m in thickness in other parts of the area, as shown in the transect (Fig 4). At Blackwall the surface of facies 4 lies between 0.39 and -0.04m OD. The pollen evidence illustrates the increasing wetness of the area during facies 4 with the development of a grass-sedge and herb fen environment (section 3.1). This is supported by the diatom evidence, which records increasing salinity in a brackish marine mudflat. However, the poor preservation of the diatoms (section 3.4) and the evidence of earthworm activity from the foram and ostracod report (section 3.5) does suggest some evidence of drying out and possible soil formation in ts upper part, possibly following historic embanking of the river.

3.6.5 *Historic: Facies 5 (4.69 to -0.04m OD)*

Facies 5 is variably a made ground dump and redeposited/disturbed alluvial deposit. Within the boreholes from the Blackwall site it ranges from *c.* 4 to 3m in thickness and is of a post-medieval to modern date.

4 Archaeological and Palaeoenvironmental Potential

4.1 Discusion

The potential of the core samples and records from Blackwall is discussed in chronological order below:

4.1.1 Pleistocene (facies 1)

The surface of the Pleistocene gravels formed the topography that influenced succeeding Holocene environments (see section 2.1.2). The levels of the gravel surface from Blackwall has potential to contribute to our understanding of the Early Mesolithic floodplain topography in the Isle of Dogs and Thames/Lea confluence area, when incorporated into a surface model (as has been done in Fig 5). By utilising data from previous sites and past geotechnical work along the DLR route it might be possible to refine the picture of where some of these past channels and islands existed. As a result there is good potential for adding more data to the models produced to refine our understanding of the past topography still further.

4.1.2 Mesolithic to Early Neolithic (facies 2)

Sand units found in localised areas along the route and highlighted at previous DLR sites (MOLA 2009) are thought to represent point and mid-channel bar formation, and likely also form as sand banked up against, and sometimes possibly over, gravel highs. Channel proximal sand accumulations, such as these, may have formed small islands at the margins of, and sometimes in, channels on the floodplain. These islands would have been attractive to early and middle Mesolithic hunter-fisher-gatherers roaming the landscape and travelling via channel margins in search of resources. The potential for finds of Mesolithic age, such as flint scatters, is therefore moderately high within sand units, especially where possible palaeosols have formed within these deposits. However, such finds were not found in the core samples (and indeed would be unlikely given the small size of the cores). Although some organic remains existed at the top of the sand, where a Mesolithic landsurface has been inferred, environmental preservation is generally poor in sand deposits and the potential for recovering information about the Mesolithic environment is likely to be low, although the pollen report suggested examining a sample from this level, in case pollen representing the Mesolithic vegetation survives.

The sandy clays recorded in BH2 and thought to be contemporary with the BH1 sands, but accumulated in pools or backwater areas within the river, might have better potential for pollen preservation, although its survival in similar deposits on the previous DLR sites (MOLA 2009) was poor. However, the higher organic content of unit 2.3 in borehole 2 (and of unit 1.1 in borehole 1) indicates that facies 2 at Blackwall may have more paleo-environmental potential than found in facies 2 in this area so far. Any information gained from the sediments of facies 2 would provide us with more of an insight into how the environment evolved prior to 3398 BC, the date of the immediately overlying sediments in borehole 1 (section 3.2).

4.1.3 Neolithic to Bronze Age (facies 3)

During this time the floodplain comprised a dense mixed 'dryland' woodland of oak, lime and hazel which gradually changed to a thick, wet and most likely impenetrable alder-carr woodland. Although this is the general picture, it is likely that a mix of both alder-carr and dry woodland, as well as open areas, would have existed as a mosaic across the floodplain, as dictated by local factors (such as proximity to channels and surface elevation for example). This was confirmed by a study of the Neolithic woodland in the submerged forest downstream at Erith (Seel 2000), which showed that the composition and distribution across the floodplain of tree species in this area can vary markedly.

Prehistoric activity may have focused on the unusual aspects and openings of the forested floodplain – the watercourses that crossed it, the ecotonal areas where one type of environment passed into another and areas of differing woodland composition, such as might have been associated with changes in the underlying topography and the incursion of estuarine water. It is in these types of environment that trackways and platforms have been found in the East London Thames. To understand and identify these locations a better understanding of the local variation in vegetation and past environment is needed, as it is this scale of information that might have been meaningful to prehistoric communities.

There is good potential to compare the pollen evidence for Neolithic to Bronze Age woodland at Blackwall with that from the previous DLR sites (in particular Canning Town and Delta Junction), which occupy different contemporary landscape positions;

4.1.4 Iron Age to Historic (facies 4)

The late Bronze Age rise in RSL, associated with Devoy's (1979) Thames IV estuarine expansion event is recorded across the area as a whole from about 2600 BC, by the deposition of estuarine clay. The floodplain landscape changed dramatically as it was inundated by the rising river levels. The timing of estuarine incursion varies across the floodplain, however, depending on elevation, distance from the river and other factors. For the Blackwall site the onset of this estuarine expansion and any subsequent affects of water ponding back was recorded later than at Canning Town, but further dating is needed to confirm if it is as late as the Delta Junction site to the west of the transect (**Error! Reference source not found.**). The latest date from the underlying organic clays of facies 3 was Mid Bronze Age (2005 BC, section 3.2). However, this date was taken from the middle of facies 3. The microfossil evidence from facies 3 suggested a gradual increase in brackish / marine species and in wettness, and the interface between the varous units was diffuse, indicating a gradual transition from marsh to estuarine mudflats through time. As the effect of estuary expansion was felt at Blackwall woodland became waterlogged and died off and the whole area changed to a much more open landscape, with an expansion in herbs and grasses to match the reduction in local alder woodland. During this time the surface of the contemporary landscape began to level out and any previous undulations in the floodplain became masked by the deposition of estuarine silts and clay. At the northern margins of the meandering River Thames, watermeadows formed which would have been prone to episodic flooding, depositing silt, which would have gradually built up as an accretionary floodplain soil. Later in the medieval period this land may have been used as pasture, and sometimes was reclaimed by making up the surface of the ground with domestic and industrial waste. Generally, microfossil and palaeo-environmental remains are moderately preserved in the sediments of facies 4. Diatom preservation is poor but pollen preservation is good within the Blackwall boreholes and could provide valuable insights into the evolution of the mixed fen, saltmarsh and nearby environment.

4.2 Realisation of the original research aims

To add new information to our current understanding of the evolving environment of the floodplain of the East London Thames.

The opportunity provided by the project has enabled us to examine discrete sites within their wider landscape contexts. It has also allowed us to compare similar deposits between this and previous DLR sites and this has shown that dates and environments represented by apparently similar deposits vary laterally and through time. The potential additional detail this could provide to our understanding of the evolving floodplain environment is considerable.

To reconstruct the landscape context in which past human activity on the floodplain took place.

The landscape evolution represented by the sediments examined has been related to known and potential archaeology in section 4.1.

4.3 Significance

The geoarchaeological samples obtained from the site provide information about the local environment at Blackwall from the midHolocene onwards. The deposits sampled preserve pollen, ostracods, foraminfera and diatom assemblages that document the changing landscape and possible human activities on this part of the East Thames River floodplain. By taking advantage of the strengths of the different micro- and macrofossils the samples have potential for analysis. By combining the results from Blackwall with those from other DLR sites evaluated as part of the 3 Car Capacity Enhancement Scheme, there is potential for examining contemporary lateral variation across the floodplain, the results of which would be of regional significance.

5 Recommendations

The evaluation has shown that good potential for microfossil analysis exists, in particular pollen, in the sediments cored and that this analysis might allow comparison of contemporary environments in different parts of the floodplain, in particular the variation within the Neolithic to Bronze peat. This local variation is likely to have been influenced by topography and by refining the topographic model produced for the evaluation with additional borehole data from the DLR project, a more robust model of the buried topography might be obtained. The local topography and vegetation characteristics are likely to have been significant to the Prehistoric inhabitants of the area.

Geoarchaeological evaluations often look at discrete sites but in order to understand the past landscape evidence from individual sites the information needs to be synthesised and examined as a whole. The linear nature of the DLR 3 Car Capacity Enhancement Scheme and the good preservation of microfossils within the deposits sampled, provides an opportunity to compare contemporary information from Blackwall with three other local sites, in order to better understand lateral variation within the prehistoric environment, along a tract of the floodplain from the Isle of Dogs to Canning Town. Such information is likely to provide significant insights into the actual nature of the landscape as perceived by prehistoric people. The results of the evaluation and any further work are likely to be of use and interest to archaeologists working on the floodplain of the East London Thames. Although much work is done by geoarchaeologists and environmental archaeologistsworking in this area, it is rarely published and thus little known.

It is therefore recommended that the deposit model produced for this evaluation is refined, if possible, by the inclusion of any additional borehole data held by the DLR; and by limited additional pollen analysis of the cores that should be compared with that of previous DLR sites and the evaluation and analysis results integrated into a publication in a local journal (London Archaeologist or LAMAS).

The core samples obtained will be held in the MOLA store until a decision has been made on whether they are required for further analysis.

6 Acknowledgements

The author would like to thank PJ Drilling and Taylor Woodrow for their onsite work; Dr Mike Morley, Tom Hoyle and Jason Stewart for the on and off site recording and labwork; Dr Nigel Cameron, Dr Rob Scaife and Dr John Whittaker for specialist work and advice; Judit Pereztegi for work on the Figs; Jane Corcoran for geoarchaeology advice; and Stewart Hoad for overall project management.

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8 Appendix:

8.1 OASIS DATA COLLECTION FORM

OASIS ID: MOLAs1-65036

Project details

Project name	Docklands Light Railway 3-Car Capacity Enhancement Blackwall Report for Geoarchaeological Evaluation
Short description of the project	This report presents the results of a geoarchaeological evaluation carried out by the Museum of London Archaeology (MOLA) at the Blackwall site of the DLR 3-Car-Capacity Enhancement scheme. This work has been commissioned from the Museum of London Archaeology by Taylor Woodrow (on behalf of Docklands Light Railway). The Evaluation involved the monitoring of purposive geoarchaeological boreholes, which confirmed that deposits of palaeo-environmental interest exist between about 0.0m OD and -2m OD. These deposits will be subject to impact by the piled foundations of the proposed development and the purpose of the evaluation was to obtain geoarchaeological records and samples for off-site examination. Integrating specialist palaeo-environmental data with sub-surface deposit modelling records Late Devensian Glacial formation of the Shepperton Gravels at the base of the Holocene deposits. Overlying this are Early Holocene banked sands, which stabilised to form ephemeral Mesolithic landsurfaces. Silty clays and peats mark the inundation affects of relative sea level rise from the Early Neolithic to the Bronze Age. At Blackwall these densesemi terrestrial to increasingly dense wooded environments were freshwater to brackish/marine to the east of the route with the onset of tidal access. From the Iron Age onwards silty clays dominate as grass and herb fen mudflats form and brackish marine conditions move westwards and a full estuary environment is indicated to the east. At this time evidence suggests cereal cultivation to the margins of this environment.
Project dates	Start: 01-08-2008 End: 01-09-2009
Previous/future work	Yes / Not known
Any associated project reference codes	MOLAs1-65030 - OASIS form ID
Type of project	Field evaluation
Site status	None

Current Land use	Transport and Utilities 2 - Other transport infrastructure
Monument type	BURIED LAND SURFACE Mesolithic

Project location

Country	England
Site location	GREATER LONDON TOWER HAMLETS POPLAR Docklands Light Railway 3-Car Capacity Enhancement Blackwall
Postcode	E14
Study area	2.00 Kilometres
Site coordinates	538340 180640 538340 00 00 N 180640 00 00 E Point
Lat/Long Datum	Unknown
Height OD / Depth	Min: -1.79m Max: -1.64m

Project creators

Name of Organisation	MoL Archaeology
Project brief originator	Docklands Light Railway
Project design originator	Taylor Woodrow
Project director/manager	George Dennis
Project supervisor	Stewart Hoad
Type of sponsor/funding body	Taylor Woodrow Developments Limited and George Wimpey South London Limited

Project archives

Physical Archive	No

Exists?	
Digital Archive recipient	LAARC
Digital Archive ID	APE08
Digital Media available	'Database','GIS'
Paper Archive recipient	LAARC
Paper Archive ID	APE08
Paper Media available	'Notebook - Excavation',' Research',' General Notes'

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	Docklands Light Railway 3-Car Capacity Enhancement Blackwall Report for Geoarchaeological Evaluation
Author(s)/Editor(s)	Yendell, V.
Date	2009
Issuer or publisher	MOLA
Place of issue or publication	London
Description	Report for Geoarchaeological Evaluation

Entered by	Virgil Yendell (vyendell@MOLAs.org.uk)
Entered on	1 October 2009

Fig 1 Location of geoarchaeological boreholes

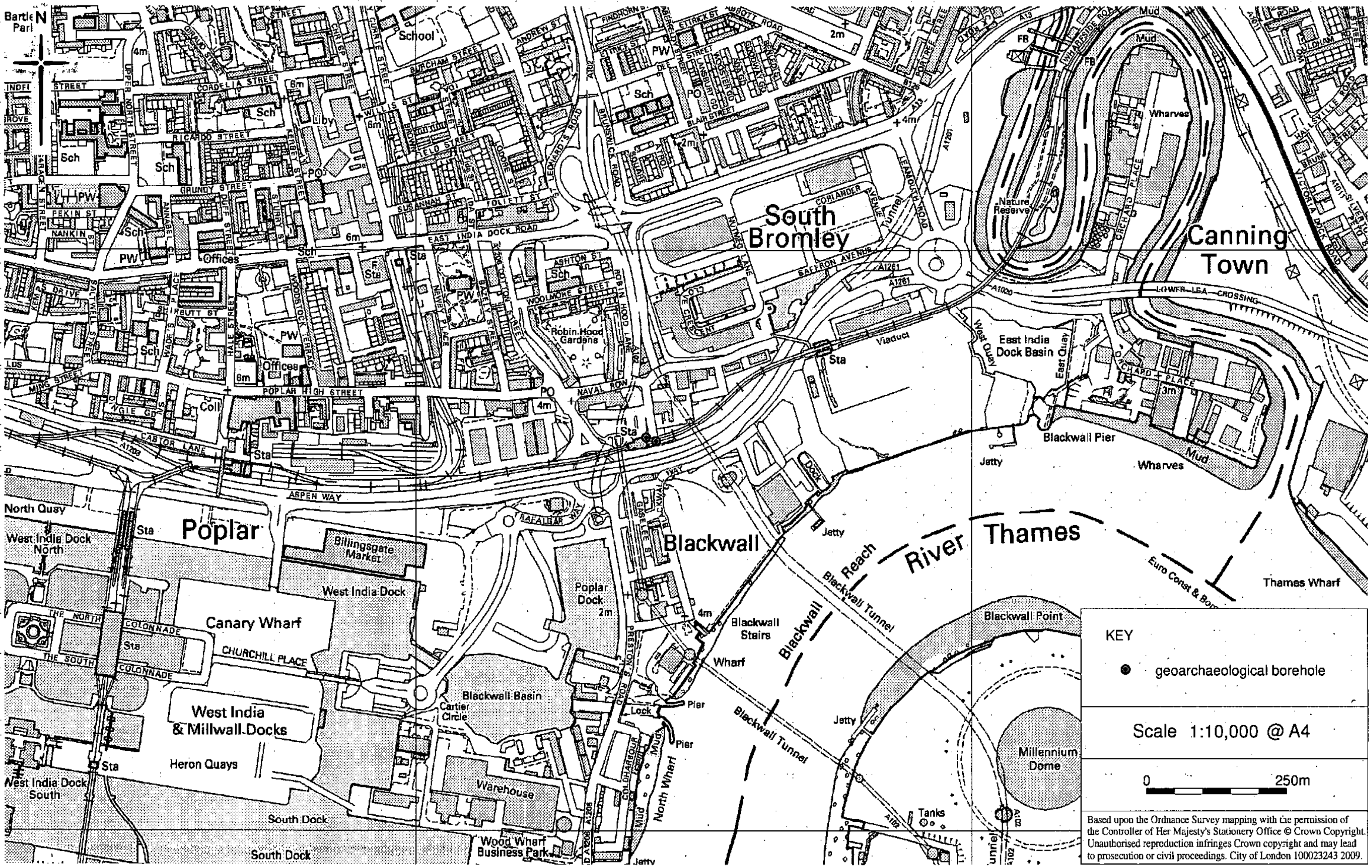


Fig 2 Location of geoarchaeological boreholes

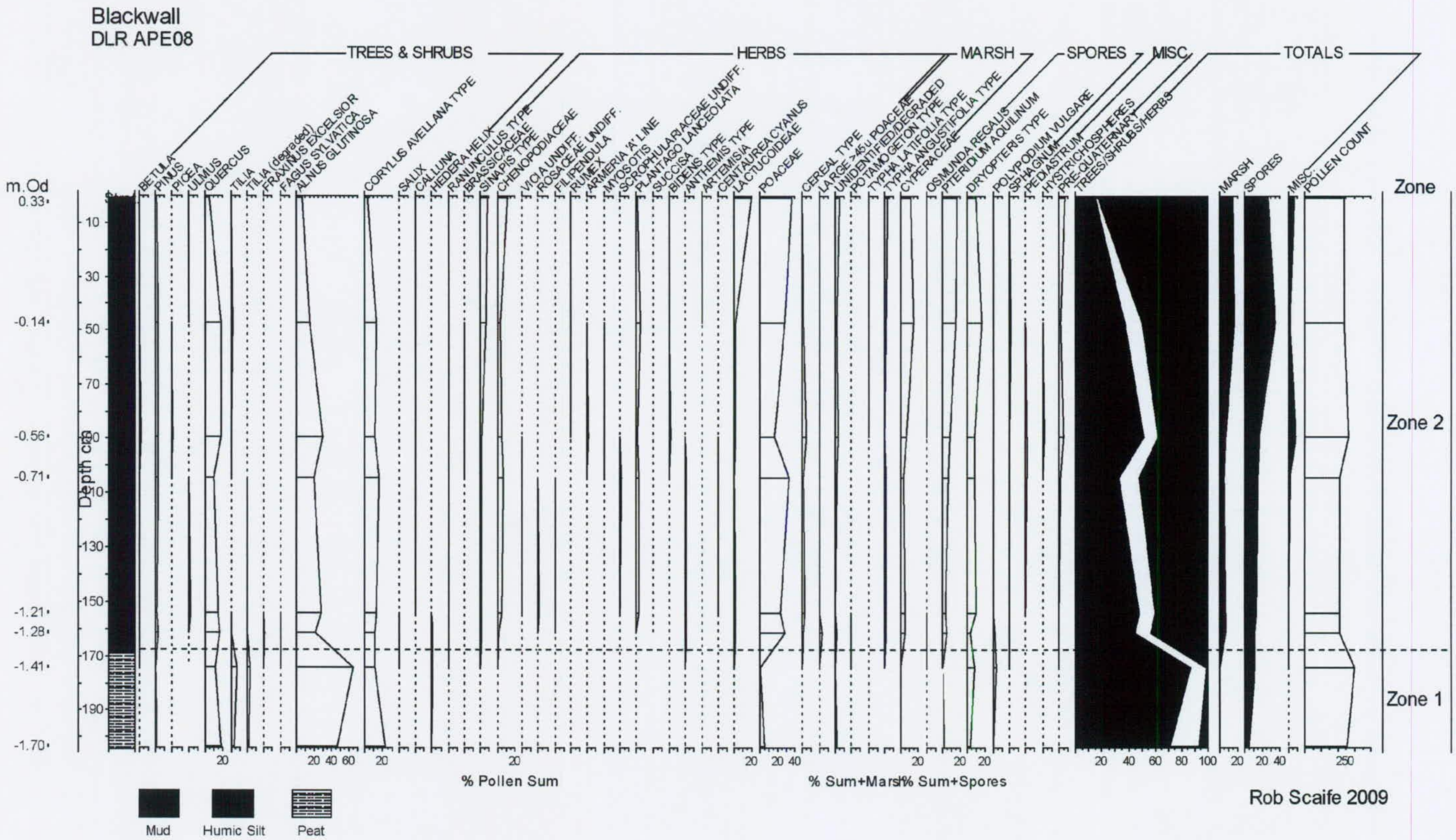
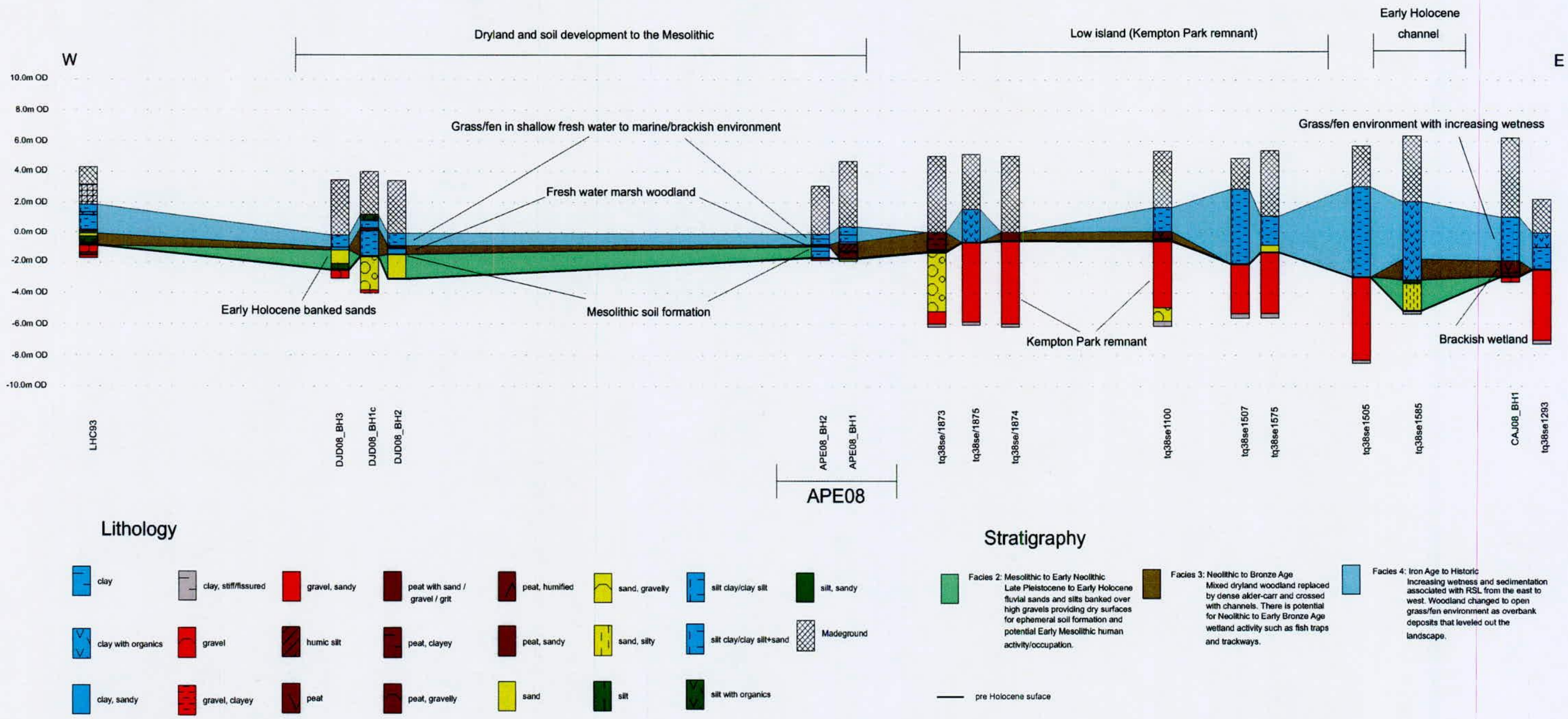


Fig 3 Pollen Diagram: Canning Town BH1



MULTI1113GEO_Blackwall09#04

Georchaeological Evaluation © MOLA 2009

Fig 4 Transect 1: West to east transect

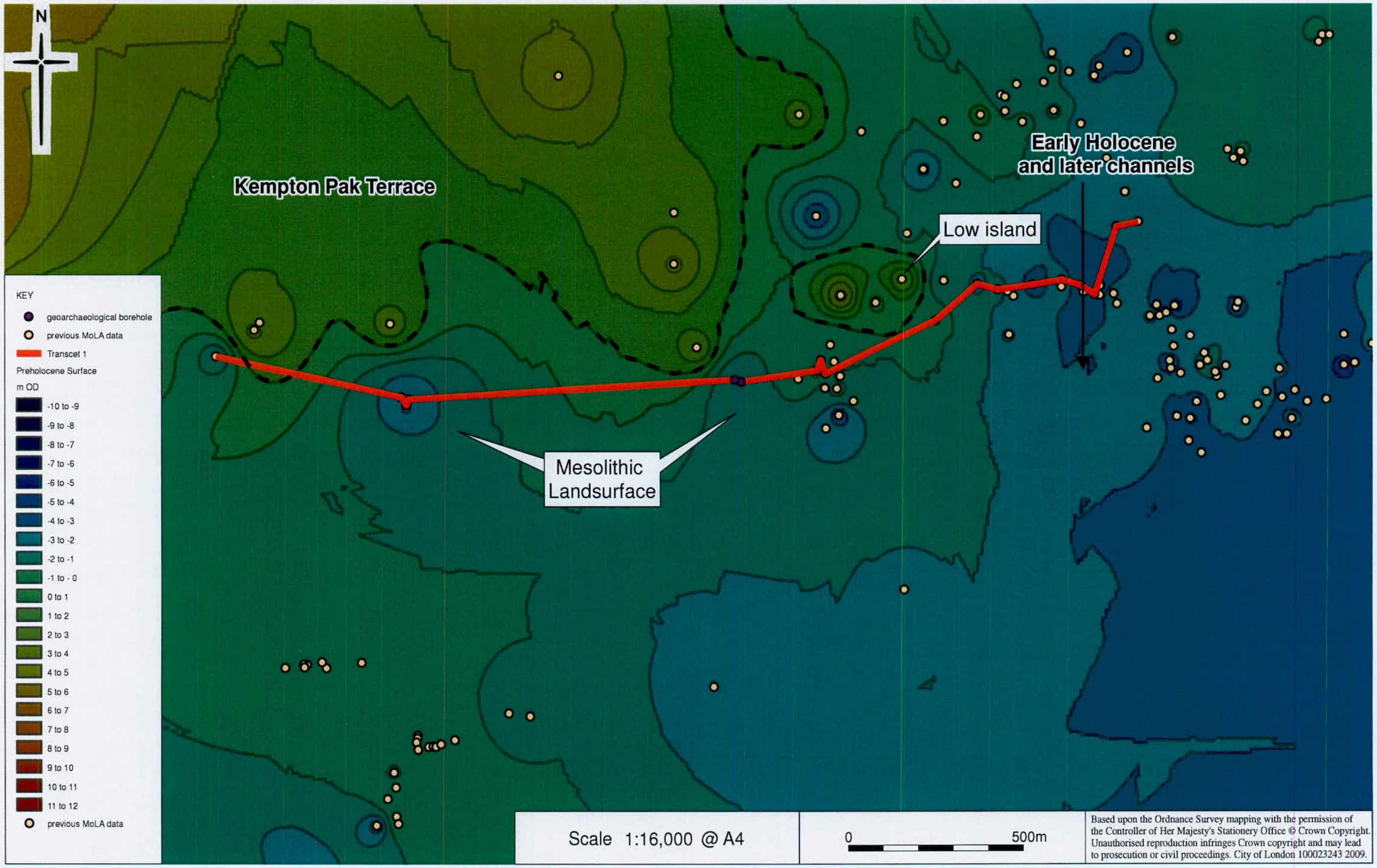


Fig 5 Pre Holocene surface and transect locations