



# 1 Alfred's Way, Barking

Palaeoenvironmental Assessment

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## Summary

Wessex Archaeology was commissioned by Lok'n Store Limited to undertake a palaeoenvironmental assessment of sub-samples taken during a purposive geoarchaeological borehole survey of c. 0.6 hectares of land at 1 Alfred's Way, Barking, London Borough of Barking and Dagenham. This Site is centred on National Grid Reference 546400, 183600 (TQ 4640 8360)

This report follows on from a purposive borehole survey, which identified a series of superficial deposits comprised Pleistocene sands and gravels, overlain by a Holocene alluvial sequence of minerogenic alluvium, organic alluvium and peat. The Pleistocene sands and gravels likely corresponded to the East Tilbury Marshes and/or Mucking Gravels to the north, and Shepperton Gravels in the south. Within borehole WA01, a fine-grained clay unit was encountered within the gravel sequence and was identified as high geoarchaeological potential. The series of organic alluvium and peat deposits have a high geoarchaeological potential to provide information of the environment and vegetation history during deposition, and to contain *in situ* archaeology. A programme of targeted palaeoenvironmental assessment and scientific dating was recommended on boreholes WA01 and WA04.

The principal aim of the palaeoenvironmental assessment is to determine the age, nature and depositional history of deposits recovered at the Site. The results will be used to assess the preservation potential of palaeoenvironmental remains, and to reconstruct past environments and landscapes change associated with local and regional archaeological records and settlement histories. The results will inform on the need for and scope of further analysis, where appropriate.

Radiocarbon dating of the peat places the deposition of the lowermost organic alluvium in the Early Neolithic (3425-3375 cal. BC), with peat formation spanning from the Middle Neolithic (3325-3250 cal. BC) to the Early/Middle Bronze Age (1615-1535 cal. BC).

OSL dating of fine-grained deposits within the river terrace deposits to the north of the Site produced a date of  $411 \pm 30$  thousand years ago (Kya). However, the  $D_e$  values associated with this date are higher than the highest independently verified date, which suggests that there may have been reworking of older sediments, resulting in an older date.

Within the fine-grained sediments within the terrace sequence, preservation of pollen was poor, with a high number of reworked grains, while diatoms and foraminifera/ostracods were absent. This poor preservation and concentration likely reflect aerobic conditions during deposition, allowing for microbial activity, and post-depositional activities, such as high water acidity/alkalinity.

Within the lower organic alluvium, pollen and plant macroremains had good preservation and concentrations, likely reflecting anaerobic conditions of deposition. Within the peat preservation of plant macroremains and pollen was good, but diatom preservation was poor. This likely reflects aerobic conditions resulting in good preservation of pollen, but post-depositional conditions, such as high water alkalinity/acidity resulting in damage to diatom frustules.

The sands and gravels across the Site represent two terraces, based on the elevation ranges, with the terrace subject to palaeoenvironmental assessment likely being the East Tilbury Marshes, deposited during Marine Isotope Stages 4-2. The fine-grained deposit may represent a warm-stage interglacial (MIS 3), as alder is present. However, pollen concentrations were very low, and this interpretation is tentative.

Organic deposition occurred from the Early Neolithic to the Early/Middle Bronze Age, which is consistent with many peat deposits within the Thames Floodplain sequence. During the deposition of the early peat, the wetland environment would have been an alder carr environment with a sedge understory, with the dryland comprised of mixed deciduous woodland. Further up the peat sequence,



there is a decline in sedge at the cost of bulrush, grasses and members of the goosefoot family, possibly due to a greater marine influence, but alder remains dominant. The dryland remains largely wooded, but there is some evidence of an increased number of clearings in the woodland. In the Early/Middle Bronze Age, there is a shift from peat deposition to that of organic alluvium. The wetland alder carr is replaced by a saltmarsh-like environment. The dryland woodland is replaced by more open environments, with grasses, daisies and plantains noted.

Due to the poor preservation of palaeoenvironmental proxies within the river terrace deposits, there is limited interpretation available. However, this terrace is likely that of the East Tilbury Marsh terrace, which is associated with megafaunal remains and Mousterian-type archaeology.

The peat deposits show some evidence of human activity, with microscopic charcoal occurring synchronously with a small increase in herbaceous taxa, which could reflect the development of small clearings within the woodland. Within the undated uppermost organic alluvium, there is evidence for widespread deforestation, with woodland being replaced by open, pastoral or arable environments. Taxa associated with disturbance become more frequent. Microscopic charcoal also becomes common, suggesting regular burning is occurring.

Based on the results of this assessment, it is recommended that a programme of palaeoenvironmental analysis is undertaken, which would comprise pollen analysis targeting the periods with evidence for human activity, and dating of the uppermost organic alluvium associated with human activity.

### **Acknowledgements**

Wessex Archaeology would like to thank Lok'n Store Limited for commissioning the work. The report was written by Dr Jack Oughton, with contributions from Dr John Athersuch (foraminifera/ostracods), Dr Nigel Cameron (diatoms), Dr Inés López-Dóriga (radiocarbon dating) and Dr Jack Oughton (pollen). The report was edited by Marijane Porter. The project was managed by Dr Alexander Brown on behalf of Wessex Archaeology.



# 1 Alfred's Way, Barking

## Palaeoenvironmental Assessment

### 1 INTRODUCTION

#### 1.1 Project and planning background

1.1.1 Wessex Archaeology was commissioned by Lok'n Store Limited ('the Client') to undertake a palaeoenvironmental assessment on sub-samples taken from boreholes obtained during a survey of c.0.6 hectares (ha) of land at 1 Alfred's Way, Barking, London Borough of Barking and Dagenham ('the Site'). This Site is centred on National Grid Reference (NGR) 546400, 183600 (TQ 4640 8360) (**Figure 1**).

1.1.2 The proposed development comprises the construction of a new self-storage facility (Class B8) with associated access, parking and landscaping. A planning application (22/01992/FULL) submitted to the London Borough of Barking and Dagenham was granted on 13/02/2023, subject to conditions. The following conditions relate to archaeology:

#### **Condition 8:**

*Reason: No demolition or development shall take place until a stage 1 written scheme of investigation (WSI) has been submitted to and approved by the local planning authority in writing. For land that is included within the WSI, no demolition or development shall take place other than in accordance with the agreed WSI, and the programme and methodology of site evaluation and the nomination of a competent person(s) or organisation to undertake the agreed works.*

*If heritage assets of archaeological interest are identified by stage 1 then for those parts of the site which have archaeological interest a stage 2 WSI shall be submitted to and approved by the local planning authority in writing. For land that is included within the stage 2 WSI, no demolition/development shall take place other than in accordance with the agreed*

*stage 2 WSI which shall include:*

- *a) The statement of significance and research objectives, the programme and methodology of site investigation and recording and the nomination of a competent person(s) or organisation to undertake the agreed works*
- *b) Where appropriate, details of a programme for delivering related positive public benefits*
- *c) The programme for post-investigation assessment and subsequent analysis, publication & dissemination and deposition of resulting material. This part of the condition shall not be discharged until these elements have been fulfilled in accordance with the programme set out in the stage 2 WSI.*

*Reason: To safeguard the archaeological interest of the site.*

1.1.3 The palaeoenvironmental assessment has been carried out in partial fulfilment of Condition 8 of planning application 22/01992/FULL.



1.1.4 Wessex Archaeology (2024) identified deposits with possible palaeoenvironmental potential from which sub-samples for paleoenvironmental assessment and scientific dating were taken. The Palaeoenvironmental Assessment will provide further information on the archaeological resource that may be impacted by the proposed development and facilitate an informed decision with regard to the requirement for, and methods of, any further work that may be required. This work may include analysis of the material assessed and/or further targeted sampling as part of archaeological and geoarchaeological mitigation.

## 1.2 Scope of works

1.2.1 Recommendations for Stage 3 Palaeoenvironmental Assessment we made in a Stage 2 report (Wessex Archaeology 2024). These recommendations are summarised in **Table 1**.

**Table 1** Recommendations for Stage 3 palaeoenvironmental assessment

Borehole	Deposit	Plant macroremains/ radiocarbon dating	Pollen	Diatoms	Foraminifera/ ostracods	OSL
WA01	Terrace silts		2	3	3	1
WA04	Peat/ organic alluvium	3	15	4		

1.2.2 Assessment of pollen, plant macroremains, foraminifera, ostracods and diatoms can provide insights into the palaeoenvironmental conditions and vegetational communities present during deposition of deposits, which can include evidence of anthropogenic land-use (e.g. agriculture or land clearance). Radiocarbon dating and Optically Stimulated Luminescence (OSL) dating provides information on the chronology of the Quaternary deposits preserved on the site.

## 1.3 Scope of document

1.3.1 Quaternary superficial sediments of Pleistocene and Holocene date may have potential to preserve environmental remains reflective of past human activity, landscapes and environments. Palaeoenvironmental assessment is therefore part of a staged-approach to assessing the archaeological potential of Quaternary deposits.

1.3.2 The staged approach to such investigations developed by Wessex Archaeology comprises four-stages, each encompassing different levels of investigation appropriate to the results obtained, accompanied by formal reporting of the results at the level achieved. The stages are summarised below (**Table 2**). This report represents Stage 3 of this process.

**Table 2** Staged approach to geoarchaeological investigations

<p><b>Stage 1:</b></p> <p>Geoarchaeological Desk-based Assessment (GDBA) and deposit modelling</p>	<p>A geoarchaeological desk-based assessment (DBA) examines a range of information (published and unpublished ("grey literature"), LiDAR, historic maps) and models existing Ground Investigation (GI) data to inform on the possible archaeological potential of Quaternary deposits within an assessment area.</p> <p>The GDBA may include a Geoarchaeological Landscape Characterisation (GLC) which divides an assessment area into different zones</p>
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	<p>(Geoarchaeological Characterization Zones – GCZs) based on variations in deposits and potential.</p> <p>The GDBA establishes the requirements for and scope of Stage 2 archaeological field evaluation. Should Stage 2 evaluation be required, appropriate and proportionate recommendations for each GCZ are provided.</p>
<p><b>Stage 2:</b>  Archaeological evaluation</p>	<p>Field evaluation to establish the archaeological potential of Quaternary deposits within an evaluation area, which informs on the requirements and scope of Stage 3 palaeoenvironmental assessment and/or Stage 4 mitigation.</p> <p>The principal methods of archaeological evaluation of Quaternary deposits are through targeted machine-dug trenches, test pits and boreholes.</p> <p>An archaeological evaluation report is produced, which includes updated deposit modelling and an updated GLC. If required, recommendations for Stage 3 sample assessment and/or Stage 4 mitigation are made.</p>
<p><b>Stage 3:</b>  Sample assessment</p>	<p>Palaeoenvironmental samples and/or sediment samples recovered during Stage 2 are assessed to inform on the archaeological potential of deposits and guide the scope and need for Stage 4 mitigation.</p> <p>Dating of samples taken during Stage 2 may be required to inform on the archaeological potential of deposits and to guide the scope and need for Stage 4 mitigation. If this is the case, dating will be carried out at this stage. Alternatively dating samples will be retained for Stage 4 mitigation, if required. Recommendations for dating requirements during Stage 3 are made in the Stage 2 report.</p> <p>A sample assessment report is produced outlining the palaeoenvironmental and dating potential of the deposits including targeted and proportionate recommendations for Stage 4 mitigation.</p>
<p><b>Stage 4:</b>  Archaeological mitigation</p>	<p>Based on the results of the Stage 2 and 3 investigations archaeological mitigation may be required to offset development impacts.</p> <p>Mitigation may include archaeological excavation, targeted geoarchaeological sampling for paleoenvironmental analysis and dating and artefact analysis.</p> <p>A final mitigation report is provided on completion of mitigation program.</p>
<p><b>Publication</b></p>	<p>The scope and location of a publication report will be agreed in consultation with the client and LPA advisor.</p> <p>The publication report may comprise a note in a local journal or a larger publication article or monograph, dependant on the significance of the archaeological work.</p>

1.3.3 This Palaeoenvironmental Assessment considers the potential of sediments sampled during the Stage 2 geoarchaeological borehole survey (Wessex Archaeology 2024) to preserve significant palaeoenvironmental datasets. The results inform the requirements for and scope of further work, which may include Stage 4 analysis, or targeted sampling as part of archaeological mitigation.

1.3.4 In format and content, it conforms to current best practice, as well as to the guidance in *Management of Research Projects in the Historic Environment* (MoRPHE, Historic England [HE] 2015) and *Environmental Archaeology. A Guide to the Theory and Practice of Methods, from Sampling and Recovery to Post-excavation* (English Heritage [EH] 2011).

## 2 BACKGROUND

### 2.1 Introduction

- 2.1.1 The section provides background information on the Quaternary deposits from which the assessed samples were recovered. The samples subject to this assessment were obtained during a purposive geoarchaeological borehole survey (Wessex Archaeology 2024).
- 2.1.2 Following the purposive borehole survey, a programme of deposit modelling was undertaken, and this work identified a sequence of superficial deposits comprising Pleistocene sands and gravels, overlain by a Holocene alluvial sequence comprised of minerogenic alluvium, organic alluvium and peat, and capped by modern made ground.

### 2.2 Chronology

- 2.2.1 Geoarchaeological investigations are typically undertaken with reference to geological periods (e.g., Quaternary), epochs (e.g., Pleistocene) and sub-epochs (e.g., Devensian) that reflect major climate sea-level and/or environmental changes. Here we adopt British nomenclature correlated to the Marine Isotope Stage (MIS) record to distinguish between different climatic periods, with dates given in Kya BP (thousands of years before present).
- 2.2.2 Marine Isotope Stages are deduced from marine palaeoclimatic records and reflect alternating warm (interglacial and interstadial) and cold (glacial and stadial) periods throughout the Quaternary (**Table 3**).
- 2.2.3 Where age estimates are available these are expressed in millions of years (Mya), thousands of years (Kya) and within the Holocene epoch as either years Before Present (BP), Before Christ (BC) and Anno Domini (AD). These are linked to the global Marine Isotope Stage (MIS) chronological framework.

**Table 3** British Quaternary chronostratigraphy

Geological Period	Chronostratigraphy		Age (Kya)	MIS
Holocene	Holocene interglacial		11.7 – present	1
Late Pleistocene	Devensian Glaciation	Loch Lomond Stadial	11.7 – 12.9	2 – 5d
		Windermere Interstadial	12.9 – 15	
		Dimlington Stadial	15 – 26	
		Upton Warren Interstadial	40 – 43	
		Early Devensian	60 – 110	
	Ipswichian interglacial	115 – 130	5e	
Middle Pleistocene		Unnamed cold stage	130 – 374	6
		Aveley interglacial		7
		Unnamed cold stage		8
		Purfleet interglacial		9
		Unnamed cold stage		10

Geological Period	Chronostratigraphy	Age (Kya)	MIS
	Hoxnian interglacial	374 – 424	11
	Anglian glaciation	424 – 478	12
	Cromerian Complex	478 - 780	13 – 19

## 2.3 Site location and topography

- 2.3.1 The Site is located within the Alfred's Way industrial estate, located towards the southwest of the London Borough of Barking and Dagenham. It covers an area of 0.6 ha and is bounded to the north by Ruppel Road and the A13, and to the east, west and south by existing industrial units.
- 2.3.2 The Site has been recently cleared of previous developments, with a large stockpile of rubble to the west of the Site (Soiltechnics 2021). The modern topography is broadly at an elevation of c.5.0 m above Ordnance Datum (OD).

## 2.4 Previous investigations

- 2.4.1 Previous investigations relevant to the evaluation are listed in **Table 4** and summarised below.

**Table 4** Previous investigations

Report type	Title	Report no.	Reference
Borehole survey	1 Alfred's Way: Ground Investigation borehole survey	NA	Soiltechnics 2021
Geoarchaeological borehole survey and deposit modelling	1 Alfred's Way, Barking, London Borough of Barking and Dagenham: Geoarchaeological Borehole Survey and Deposit Modelling	281991.02	Wessex Archaeology 2024

### *1 Alfred's Way: Ground Investigation borehole survey (Soiltechnics 2021)*

- 2.4.2 Soiltechnics (2021) undertook a ground investigation (GI) borehole survey at the Site in 2021. This consisted of two cable percussion and four window sample boreholes. The GI logs arising from these works were reviewed in Wessex Archaeology (2023), which provided context for targeting deposits for the purposive geoarchaeological borehole survey.

### *1 Alfred's Way, Barking, London Borough of Barking and Dagenham: geoarchaeological borehole survey and deposit modelling*

- 2.4.3 Wessex Archaeology (2024) undertook a purposive geoarchaeological borehole survey, followed by a programme of deposit modelling. This consisted of four window sample boreholes taken across the Site, targeting features of interest identified from Soiltechnics (2021). This work identified a sequence of superficial geology comprising Pleistocene sands and gravels, overlain by a Holocene sequence of minerogenic alluvium, organic alluvium and peat, capped by made ground across the Site.
- 2.4.4 The Pleistocene sands and gravels were composed of coarse-grained sands and sandy gravels, the surface of which rose steadily northwards. They likely correspond to the East Tilbury Marshes and/or Mucking Gravels towards the north, and the Shepperton Gravel towards the south, forming in a braided river system during more than one Pleistocene cold

stage. Within the gravel sequence in WA01, in the north of the Site, silts were present in the depositional series. These fine-grained deposits would likely have formed in a low-energy environment, such as a back channel or deactivated channel, possibly during a period of warmer conditions.

- 2.4.5 The lower alluvium is comprised of sandy silts, and would have formed in an estuarine environment under the influence of rising sea levels during the Holocene. These deposits were likely formed in the Mesolithic, coinciding with the highest rates of relative sea level rise in southern England.
- 2.4.6 Deposits of peat and organic alluvium overlie the lower alluvium. These would have formed in low energy environments where semi-terrestrial plant communities became established, supporting the growth of wetland vegetation.
- 2.4.7 An upper minerogenic alluvium overlay the peat, which was equivalent to the 'Upper Alluvium' recorded elsewhere in the Lower Thames Valley (Green et al 2014). This would have formed in a low-energy floodplain environment during the late Holocene, influenced by increased minerogenic run-off linked to deforestation and agricultural intensification, under the background influence of rising relative sea level.

## 2.5 Quaternary deposits and archaeological context

- 2.5.1 Wessex Archaeology (2024) identified a lithostratigraphy associated with the assessed samples comprising:
- River Terrace Deposits (Pleistocene)
  - Lower minerogenic alluvium (Holocene)
  - Peat/organic alluvium (Holocene)
  - Upper minerogenic alluvium (Holocene)
- 2.5.2 The bedrock geology underlying the Site is mapped by the British Geological Survey (BGS GeolIndex) as the London Clay Formation. This is clay, silt and sand that formed between 56 and 48 Mya during the Palaeogene period. The superficial geology of the Site is mapped by the BGS as Pleistocene river terrace deposits (sands and gravels), representative of the Taplow Gravel Member towards the north of the Site, and Alluvium of Holocene (11.7 Kya – present) date, described as sand, silt clay and peat towards the south of the Site.
- 2.5.3 Detailed background information on the Quaternary deposits and their archaeological context is provided in a Stage 2 evaluation report (Wessex Archaeology 2024). Summary information relevant to the assessment is provided below.

### *River Terrace Gravels (Pleistocene)*

- 2.5.4 Texturally variable deposits of sands and gravels, consisting of a mix of slightly gravelly silty sands to silty sandy gravels, were recorded across the Site during the purposive geoarchaeological borehole survey (Wessex Archaeology 2024). The upper unit of these deposits was typically comprised of sands, but in WA02A a thin unit of sandy gravels overlay the sands. The sands were typically medium to coarse, while the gravel clasts within the sand units were typically fine subrounded flint. Within the gravel units, the sand was typically coarse, and the gravel was largely fine-grained subangular flint, but with a lesser medium- and coarse-grained fraction, and generally sub-rounded. Gravel clasts had moderately low

sphericity. The gravels were typically moderately well sorted, and matrix supported. Fine-grained silt deposits were recognised within the river terrace sequence in WA01.

- 2.5.5 The Site lies within the Lower Thames Valley and within 2 km of the River Roding, a major left bank tributary of the River Thames. During MIS 8 to MIS 6 (c. 300-123 Kya) sand and gravel deposited under cold climate conditions and finer grained interglacial sediments formed the Taplow Gravel Terrace, equivalent to the Mucking Gravels upstream (Gibbard 1994). Geotechnical investigations across Barking show the Taplow Gravel lying between approximately 0.75–2.00 m OD and separated from the underlying Shepperton Gravel by a bluff (Green et al 2014).
- 2.5.6 Sands and gravels underlying the Holocene floodplain are equivalent to the Shepperton Gravel of the Lower Thames Valley (Gibbard 1994), although in places the Kempton Park/East Tilbury Marshes terrace (MIS 5d-3) is obscured by Holocene alluvium and at this point in the floodplain is not widely recognised in BGS mapping. The Shepperton Gravel was deposited during the Late Devensian (MIS 2; 16,000-11,500 years BP) within a high-energy braided river system associated with the River Thames. While active, the river would have been characterised by longitudinal gravel bars and intervening low-lying channels, observed today as remnant palaeolandscape features across the Thames Valley.
- 2.5.7 The Thames floodplain deposits overlying the Shepperton Gravel terrace form a tripartite sequence comprising a lower and more lithologically variable unit predominantly comprised of sand and silt and referred to as the Lower Alluvium; a peat bed equivalent in age to Devoy's (1979) Tilbury III peat (ca. 6500–3000 cal. BP); and an upper silty clay, commonly known as the Upper Alluvium (Green et al 2014). These fine-grained sediments were deposited throughout the Holocene when the natural floodplain of the Thames was low-lying and likely interrupted by substantial channels or tidal creeks (Green et al 2014).

#### *Lower minerogenic alluvium (Holocene)*

- 2.5.8 A basal minerogenic alluvium was present underlying peat deposits across the central and south of the Site. This deposit was described as a moderately soft, dark to light grey, structureless slightly sandy clay. Occasional wood fragments and bivalve shell material was present within this lower alluvium.
- 2.5.9 Across the Lower Thames Valley, the 'Lower Alluvium' occasionally contains detrital, herbaceous plant remains, Mollusca and thin beds of peat, which was observed at the Site. This unit is interpreted to have been deposited within a floodplain or active fluvial channel, with thin beds of peat likely representing short periods of stabilisation and drying of the riverbed. The uppermost alluvium is most likely estuarine in origin and reflects an increase in the rate of sea-level rise during the Holocene.

#### *Peat/organic alluvium (Holocene)*

- 2.5.10 Peat and organic alluvium were present within the Holocene alluvial sequence in boreholes across the south and central areas of the Site. Typically, the peat was characterised by a single unit, although in WA03 two peat units were present, separated by a unit of minerogenic alluvium. The peat was described as blackish brown clayey peat with frequent leaf fragments and wood, to reddish brown wood-rich peat. *Phragmites* was frequent in the peat. Organic alluvium, described as greyish brown peaty clays, with occasional plant macroremains, overlay the peat within WA02A and WA04, and underlay the peat in WA04.
- 2.5.11 Peat deposits of Holocene age are recognised as interbedding between the Lower and Upper Alluvium of the Lower Thames Valley. Devoy (1979) suggests that the initiation of peat development occurred around 6000 cal. BP (4050 cal. BC), with peat formation

occurring more rapidly and effectively outstripping the rate of relative sea-level rise, and continued until around approximately ca. 3500 cal. BP (1550 cal. BC).

- 2.5.12 A geoarchaeological survey undertaken by QUEST at Meadow Road (QUEST 2020), <1 km north-west of the site, revealed a tripartite sequence with thin (<0.2 m) peat beds between alluvial sediments. The peat was subsequently radiocarbon dated, suggesting that initial development occurred during the Late Neolithic at around 4520–4295 cal BP (2570–2345 cal. BC), with development ceasing during the Middle to Late Bronze Age around 3610–3460 cal BP (1660–1510 cal. BC; Batchelor et al 2020). Elsewhere peat of a similar age is present in thicknesses of between ca. 0.2 and 4.0 m (Green et al 2014), with thicknesses and composition of the peat varying horizontally and laterally.
- 2.5.13 The exploitation of wetland resources during the Neolithic and Bronze Age is well documented across the wider Thames floodplain, in particular within the former wetlands of East London (see Meddens 1996). Where thicker peat layers are encountered, they have increased potential to contain archaeology, including waterlogged wooden structures and artefacts. Waterlogged archaeology preserved within peat deposits near the site dating from the Late Neolithic (Hart et al 2015; Crockett et al 2015) to the Early Bronze Age (Stafford et al 2012) has been discovered, predominantly in the form of trackways and platforms. These wooden structures, and encompassing peat deposits, are archaeologically and geoarchaeologically significant, with the potential to inform on human exploitation of wetland environments.
- 2.5.14 The discovery of structures and human remains preserved within peat deposits immediately overlying Devensian sands and gravels further demonstrates the high potential for Late to Final Upper Palaeolithic and Mesolithic archaeology (Schulting 2013; Bates and Stafford 2013).
- 2.5.15 Where peat is preserved it will be of a high geoarchaeological significance with the potential to contain a range of palaeoenvironmental remains (e.g. pollen and macrofossils) and waterlogged archaeology that can inform on the nature of human exploitation of the wetland, and provide information on past vegetation, environment and land-use, as well as material suitable for radiocarbon dating.

2.5.16

#### *Upper minerogenic alluvium (Holocene)*

- 2.5.17 The upper minerogenic alluvium was described as moderately soft, dark to light grey structureless clay and was present across much of the central and south of the Site. Within WA03 *Phragmites* rooting and rhizomes were present at the top of this unit.

### **3 AIMS AND OBJECTIVES**

- 3.1.1 The principal aims of the Stage 3 Palaeoenvironmental Assessment were to:
- determine the nature, depositional history and approximate age of selected deposits;
  - determine the preservation potential and concentration of palaeoenvironmental remains within selected deposits;
  - interpret the results to inform reconstructions of past environmental and landscape change (e.g., vegetation and sea level), and

- assess geoarchaeological (paleoenvironmental) potential of selected deposits.

3.1.2 These aims were addressed by achieving the following objectives:

- undertake optically stimulated luminescence dating on fine-grained deposits within the river terrace sequence to determine the age of deposition;
- undertake radiocarbon dating on peat deposits within the alluvial sequence to determine the age of deposition;
- undertake diatom, foraminifera, ostracod and pollen assessments of sub-samples taken within the fine-grained deposits within the river terrace sequence to provide reconstructions on palaeoenvironmental and vegetation conditions during deposition; and
- undertake plant macroremains, pollen and diatom assessments of sub-samples taken within the peat and organic alluvium to provide reconstructions on palaeoenvironmental and vegetation conditions during deposition.

## 4 METHODS

### 4.1 Introduction

4.1.1 A total of 31 samples from two interventions were selected for assessment (**Appendix 1**), which includes:

- one optically stimulated luminescence date sample from WA01
- three foraminifera/ostracod samples from WA01;
- three diatom samples from WA01;
- two pollen samples from WA01;
- three plant macro-remains/radiocarbon samples from WA04;
- four diatom samples from WA01; and
- 15 pollen samples from WA01.

### 4.2 Radiocarbon dating

4.2.1 Three samples of alder (*Alnus glutinosa*) twigs were selected from borehole WA04 for radiocarbon dating and were submitted to Vilnius Radiocarbon, Center for Physical Sciences and Technology (FTMC). The samples were treated with Acid-Alkali-Acid and the measurements were corrected using Accelerator Mass Spectrometry (AMS)  $\delta^{13}\text{C}$  values. Further detail is given in Vilnius Radiocarbon (2024).

4.2.2 The calendar age ranges were calculated with OxCal 4.4 (Bronk-Ramsey 2009) using the IntCal20 curve (Reimer et al. 2020) and modelled as a sequence with un-uniform deposition rates, with the mm as the unit for the spacing of events and with 1 event per unit length (P\_Sequence with 1 as interpolation value and 10 as k variable; Bronk Ramsey 2008, Bronk Ramsey and Lee 2013). Date estimates for particular events (i.e. end of peat formation) were calculated based on their depth in the sequence.

### 4.3 Luminescence dating

4.3.1 One sub-sample from silt deposits in borehole WA01 was submitted for luminescence dating. Sub-samples were analysed using conventional optically stimulated luminescence (OSL) dating of quartz.

4.3.2 Full methodological details are given in **Appendix 3**.

### 4.4 Plant macroremains

4.4.1 Three sub-samples from borehole WA04 were selected for plant macroremains assessment. The sub-samples were processed by wet sieving using a 0.125 mm mesh. After processing, the samples were kept wet and stored in a refrigerated unit prior to assessment.

4.4.2 The processed samples were rapidly scanned using a stereomicroscope at up to 40x magnification for uncharred and charred botanical remains, including organic/vegetative material, herbaceous epidermal tissues, wood remains, mosses, and other macroscopic plant remains. The presence of other material was noted where applicable (e.g., Coleoptera molluscs, etc.).

4.4.3 Macroscopic plant remains were identified through comparison with modern reference material held by Wessex Archaeology and relevant literature (Cappers *et al.* 2006). Selected wood fragments were identified through examination of the transverse, tangential longitudinal, and radial longitudinal sections at up to 400x magnification. Wood identifications were undertaken through comparison with Wessex Archaeology's reference collection and relevant literature (Gale and Cutler 2000; Hather 2000; Schweingruber 1990). Nomenclature follows Stace (1997), with additional habitat information taken from Hill *et al.* (2004) and Stroh *et al.* (2023). Seeds and fruits were classified following Cappers *et al.* (2006).

4.4.4 Remains were recorded semi-quantitatively on an abundance scale: C = <5 ('Trace'), B = 5–10 ('Rare'), A = 10–30 ('Occasional'), A\* = 30–100 ('Frequent'), A\*\* = 100–500 ('Common'), A\*\*\* = >500 ('Abundant').

### 4.5 Pollen and non-pollen palynomorphs (NPPs)

4.5.1 A total of 17 sub-samples of 5 ml volume were processed using standard pollen extraction methods (see Branch *et al.* 2005). This includes two sub-samples from silt deposits within the Pleistocene terrace sequence within borehole WA01 and 15 sub-samples from a sequence of organic alluvium and peat within borehole WA04.

4.5.2 The palynomorphs were extracted as follows: (1) sampling a recorded volume of sediment; (2) deflocculation of the sample in 1% Sodium pyrophosphate; (3) sieving of the sample to remove coarse mineral and organic fractions (>125 $\mu$ ); (4) removal of finer minerogenic fraction using Sodium polytungstate (specific gravity of 2.0g/cm<sup>3</sup>); (5) acetolysis; (6) staining with safranin and mounting of the sample in glycerol jelly. Each stage of the procedure was preceded and followed by thorough sample cleaning in filtered distilled water. Quality control was maintained by periodic checking of residues and assembling sample batches from various depths to test for systematic laboratory effects.

4.5.3 Slides were logged in traverses, using a 'Leitz laborlux' binocular transmitted light microscope with a mechanical stage. Assessments aimed to identify >100 terrestrial pollen grains and also noted non-pollen palynomorphs (including dinoflagellate cysts and reworked palynomorphs) of potential palaeoenvironmental or biostratigraphic significance.

Counts were entered into an excel spreadsheet for each borehole. For each slide, a summary was recorded, including description of concentration and preservation, gross assemblage compositions and provisional interpretation (where appropriate).

4.5.4 At assessment stage the results are not presented as pollen diagrams but are presented in tabular form as raw data.

#### **4.6 Diatoms**

4.6.1 A total of seven sub-samples were prepared for diatom assessment. This includes three sub-samples from the silts within the Pleistocene river terrace sequence within borehole WA01, and four sub-samples from the peat sequence within borehole WA04.

4.6.2 Diatom preparation followed standard techniques (Battarbee et al. 2001). Two 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 x400 and x1000 under phase contrast illumination.

4.6.3 Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendeby (1964), Van der Werff & Huls (1957-1974), Hartley et al. (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski et al. (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953, 1957), these salinity groups are summarised as follows:

- 1. Polyhalobian: marine >30 gl-1 salinity
- 2. Mesohalobian: brackish 0.2-30 gl-1 salinity
- 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.

#### **4.7 Foraminifera and ostracods**

4.7.1 A total of three sub-samples from the silt deposits within the Pleistocene river terrace sequence from borehole WA01 were prepared for foraminifera and ostracod assessment.

4.7.2 The sub-samples were weighed, then broken into small pieces by hand, placed into ceramic bowls, and dried in an oven. Boiling-hot water was then poured over them and a small amount of sodium carbonate added to help disaggregate the clay fraction. Each sub-sample was left to soak overnight. Washing was with hand-hot water through a 75-micron sieve, with the remaining residue being returned to the ceramic bowl for final drying in the oven. The residues were then stored in labelled plastic bags.

4.7.3 For examination, each sample was placed in a nest of sieves (>50, >250, >150µm, and base pan) and thoroughly shaken. Each grade was then sprinkled onto a picking tray, a little at a time, and viewed under a binocular microscope. "Contained material" were logged on a presence(x)/absence basis as shown in accompanying tables.

4.7.4 The abundance of each foraminiferal and ostracod species was estimated semi-quantitatively (one specimen, several specimens, common and abundant/superabundant) by experience and by eye. Species identification comes from Murray (2006) for the

foraminifera, Athersuch et al. (1989) for the brackish and marine ostracods, and Meisch (2000) for the freshwater ostracods, in addition to expert judgement.

## 5 RESULTS

### 5.1 Radiocarbon dating

5.1.1 The three samples from borehole WA04 were successfully measured (**Table 5**) and provided consistent results, with peat extending from the Early Neolithic to Middle Bronze Age.

**Table 5** Radiocarbon dates from 1 Alfred's Way

Laboratory reference	Provenance	Material	Radiocarbon Age (BP)	Calibrated date range (95% probability)	Modelled date range (68% probability)
FTMC-CF13-1	WA04_2.36-2.38	Wood (waterlogged): <i>Alnus glutinosa</i> (alder) twig	3313±29	1670–1510 cal. BC	1615–1535 cal. BC
FTMC-CF13-2	WA04_3.96-3.98	Wood (waterlogged): <i>Alnus glutinosa</i> (alder) twig	4437±29	3330–2930 cal. BC	3325–3250 cal. BC
FTMC-CF13-3	WA04_4.06-4.08	Wood (waterlogged): <i>Alnus glutinosa</i> (alder) twig	4722±29	3630–3380 cal. BC	3425–3375 cal. BC

### 5.2 Luminescence dating

5.2.1 A single sample from WA01 was submitted and measured (**Table 6**), which provided a Lower Palaeolithic date.

**Table 6** OSL results from 1 Alfred's Way

Lab code	Depth (m bgl)	Total D <sub>r</sub> (Gy.ka <sup>-1</sup> )	D <sub>e</sub> (Gy)	Age (Kya)
GL22	2.88	1.63±0.07	669.40±40.52	411±30

5.2.2 The result of the OSL date is tentative due to high D<sub>e</sub> values. Where samples produce D<sub>e</sub> values exceeding 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. The D<sub>e</sub> value of 669.40 exceeds the highest verified age of 600 Gy (Pawley et al 2010), and thus the result is taken tentatively. This high D<sub>e</sub> value could have been caused by reworking of older material, such as bedrock or an older river terrace.

### 5.3 Plant macroremains

5.3.1 The assessed subsamples contain well-preserved wood fragments and macroscopic plant remains. Full results are included in **Appendix 4**, and summarised below.

5.3.2 All the subsamples are predominantly comprised of wood fragments including twigs of alder (*Alnus glutinosa*), herbaceous stems and fine rootlets. Additionally, the subsample from 3.96–3.98 m bgl produced small numbers of plant and invertebrate remains. Plant remains recorded include sedges (Cyperaceae), celery family (Apiaceae), nightshades (*Solanum*

sp.), brambles (*Rubus* sp.), nettles (*Urtica dioica*), gypsywort (*Lycopus europaeus*), and seeds and cones of alder. Invertebrate remains include water-flea (*Daphnia*) egg cases, unidentified mites and insect parts.

## 5.4 Pollen and spores

### Introduction

- 5.4.1 A total of two sub-samples were taken from borehole WA01 targeting minerogenic silts within the Pleistocene river terrace sequence between 2.82 and 2.96 m bgl, and 15 sub-samples taken from borehole WA04 targeting organic alluvium and peat deposits between 2.16 and 4.06 m bgl. The tabulated results are shown in **Appendix 5**, and summarised below.

### Borehole WA01

- 5.4.2 Within the minerogenic silts from the Pleistocene river terrace sequence, preservation was good to good/moderate. However, concentrations in both samples were poor, and assessment counts were not reached in either sample.
- 5.4.3 Quaternary pollen grains were rare in the samples from WA01, and comprised of low values of *Alnus* (alder), *Pinus* (pines) and Poaceae (grasses).
- 5.4.4 Reworked palynomorphs were frequent, and included unidentified bisaccate pollen grains, *Tricolporopollenites* and *Apectodinium* dinocysts. Reworked dinoflagellate cysts were more frequent than reworked pollen grains. These palynomorphs were likely reworked from the Palaeogene age London Clay bedrock.

### Borehole WA04

- 5.4.5 Within the peat and organic alluvium, preservation ranged from moderate to excellent/good, being typically good. Concentration ranged from poor to excellent, being typically excellent, however, assessment counts were not reached in the basal sample. The pollen assemblages within WA04 can be broadly split into three distinct assemblages.
- 5.4.6 From 4.06 to 3.67 m bgl the assemblage is typically dominated by tree pollen (58.2-83.5% total land pollen; hereafter TLP). The tree assemblage is dominated by *Alnus* and *Quercus* (oaks), although *Tilia* (limes) is frequent, and *Betula* (birches) and *Pinus* were occasional. Shrub pollen (6.9-9.8% TLP) were regular, being largely *Corylus-Myrica* type (hazel-bog myrtle type), with occasional grains of *Hedera* (ivy) and rare grains of *Salix* (willows) and *Crataegus* (hawthorn). Herbaceous taxa (16.5-41.8% TLP) were almost entirely represented by Cyperaceae (sedges), although Poaceae was frequent, and Lamiaceae (mint family) and *Artemisia*-type (mugworts) were present as single grains. Fern spores were frequent (5.1-12.0% TLP), being predominately *Polypodium* (polypodies) and Pteropsida monolete undifferentiated (undetermined fern species), with occasional grains of *Dryopteris dilatata*-type (buckler fern type). *Sphagnum* (bog moss) was only present in a single sample. Aquatic pollen (0.0-4.4 TLP) was comprised of occasional grains of *Typha* (bulrush). Microscopic charcoal was very rare or absent in all samples, excluding the basal sample where microscopic charcoal was frequent, possibly representing reworked grains. Non-pollen palynomorphs (NPP) were represented by occasional testate amoebae and *Glomus* sp. within the upper samples of this section.
- 5.4.7 From 3.57 to 2.85 m bgl the assemblage continues to be dominated by tree pollen (79-90.1% TLP). Like the basal assemblage, *Alnus* and *Quercus* are the most common taxa, although *Tilia* typically shows an increase. Rare or single grains of *Betula*, *Ulmus* (elms) and *Pinus* are present. Shrubs (4.7-12.2% TLP) were again largely represented by *Corylus*-

*Myrica* type, although low numbers of *Salix* and *Hedera* also occur. The herbaceous pollen (9.9-20.3% TLP) shows a change from the basal section, showing a decline in Cyperaceae, and an increase in diversity of other taxa present. Poaceae shows increases in values, while occasional grains of Amaranthaceae (goosefoot family) and *Plantago lanceolata* (ribwort plantain) occur, and single grains of Rosaceae (rose family), *Solanum* (nightshades), Cichoriaceae (dandelions) and Apiaceae (umbellifers) are recorded. Ferns (4.7-19.8% TLP) show an increase in values, and are comprised of *Dryopteris dilitata*-type, *Polypodium* and Pteropsida undiff. monolet. *Sphagnum* are regular in low values. Aquatic pollen (0-4.5% TLP) are largely represented by *Typha*, with rare *Sparganium* (bur-reed) grains. Microscopic charcoal is typically very rare to rare, but is frequent at 2.95 m bgl. NPP are represented by *Glomus* sp.

- 5.4.8 From 2.75 to 2.33 m bgl the assemblage sees an increase in tree pollen (88.0-96.0% TLP), with an increase in *Alnus* pollen, although *Quercus* is still common. *Tilia* is still frequent, but declines up sequence and *Betula*, *Ulmus*, *Fraxinus* (ash) and *Pinus* are represented by rare or single grains. Values for shrub pollen (6.1-9.2% TLP) remain consistent through the sequence and largely represented by *Corylus-Myrica* type. *Salix*, *Hedera* and *Ilex* (holly) are represented by rare or single grains. Herbaceous taxa (4.0-12.0% TLP) show a decline in this section, and a drop in diversity. Here, herbaceous taxa are represented by Poaceae and Cyperaceae, with a single grain of *Aster*-type (daisies). Ferns (0.9-7.4% TLP) were largely represented by Pteropsida undiff., with occasional to single grains of *Polypodium* and *Dryopteris dilitata*-type. *Sphagnum* is rare. Aquatics (0.0-3.7% TLP) were represented by rare grains of *Typha*. Microscopic charcoal was very rare or absent throughout this section.
- 5.4.9 The uppermost sample (2.16 m bgl) shows a distinct assemblage compared to the rest of the sequence. Tree pollen (37.2% TLP) has shown a large decline, being largely represented by *Alnus*. *Quercus* is present in smaller values, and *Betula* is present in very low values. Shrub taxa (6.1% TLP) also show a decline, being represented entirely by *Corylus-Myrica* type. Herbaceous taxa (62.8% TLP) show a large increase in relative abundance and diversity. Herbaceous taxa show high values of Poaceae, Cyperaceae and Cichoriaceae. Amaranthaceae and *Aster*-type are present in low values, while singles of *Urtica* (nettles), *Centaurea nigra* (common knapweed), *C. cyanus* (cornflower), *Anthemis*-type (chamomiles), Malvaceae (mallow family), *Epilobium* (willowherbs), *Ameria*-type (thrift/sea lavender), *Rumex acetosella* (sheep's sorrel), *Plantago lanceolata*, and Apiaceae are present. Ferns (2.4% TLP) are represented by Pteropsida undiff. Aquatic pollen (13.4% TLP) show an increase, being entirely represented by *Typha*. Microscopic charcoal is common.

## 5.5 Diatoms

### Introduction

- 5.5.1 A total of three sub-samples were taken from borehole WA01, targeting minerogenic silts within the Pleistocene river terrace sequence between 2.82 and 2.96 m bgl, and four sub-samples taken from borehole WA04 targeting organic alluvium and peat deposits between 2.36 and 3.97 m bgl. The tabulated results are shown in **Appendix 2**, and summarised below.

### Borehole WA01

- 5.5.2 Diatoms are absent from all three samples from the borehole WA01.
- 5.5.3 The absence of diatoms in the sediments may reflect unfavourable conditions for diatom silica preservation rather than initial absence of diatoms from the deposits (Flower 1993,

Ryves et al. 2001). Given the ubiquity of diatoms in water and in many semi-terrestrial habitats, the absence of their remains from the samples assessed here can be attributed to taphonomic processes. This may be the result of diatom silica dissolution and breakage, caused by factors such as high sediment acidity or alkalinity, through flow of water in the sediments, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion.

#### *Borehole WA04*

- 5.5.4 A low or very low number of diatoms are present in samples taken at 2.36 and 3.57 m bgl. Diatoms are absent from samples taken at 2.95 and 3.97 m bgl.
- 5.5.5 The sample at 3.57 m bgl is dominated by brackish-marine diatoms, common taxa include the estuarine planktonic species *Cyclotella striata* and *Thalassiosira bramaputrae*. Benthic brackish-marine species include *Diploneis didyma*, *Caloneis westii*, *Campylodiscus echeneis*, *Nitzschia navicularis* and *Diploneis smithii*. Allochthonous, marine planktonic diatoms present include *Paralia sulcata*, *Podosira stelligera* and *Coscinodiscus* sp. A low number of freshwater diatoms were recorded at 3.57 m bgl, these include *Synedra ulna* and *Aulacoseira* sp. In addition, a small number of chrysophyte stomatocysts are present, these may represent freshwater or brackish water habitats.
- 5.5.6 The dominance of brackish-marine planktonic, and benthic diatoms (that inhabit shallow-water mud-surface environments), with an allochthonous coastal diatom component indicates that an estuarine environment is represented by the diatoms at 3.57 m bgl.
- 5.5.7 The diatom assemblage at 2.36 m bgl is very poorly preserved and there are a very low number of diatoms present, with low species diversity. The poor quality of diatom preservation here means that most diatom fragments were identifiable only to the generic level and most could not be assigned to a salinity group.
- 5.5.8 A possible fragment of a diatom from the marine genus *Rhaphoneis* was recorded at 2.36 m bgl. The acidophilous, halophobous species *Eunotia naegelii* is present and is likely to represent in-wash of material from a peat habitat. Fragments of taxa such as *Pinnularia* sp. may represent semi-terrestrial freshwater habitats.

## **5.6 Foraminifera and ostracods**

### *Introduction*

- 5.6.1 A total of three sub-samples were taken from borehole WA01, targeting minerogenic silts within the Pleistocene river terrace sequence between 2.82 and 2.96 m bgl.

### *Borehole WA01*

- 5.6.2 Foraminifera and ostracods are absent from all three samples within WA01.
- 5.6.3 The absence of foraminifera and ostracods within the sediments could reflect unfavourable conditions for preservation of the carapace/test. Ostracods, and to a lesser degree foraminifera, are recorded from a range of palaeoenvironmental conditions, including freshwater environments, and the lack of any remains could reflect calcite dissolution and breakage, caused by factors such as high acidity.

## 6 DISCUSSION

### 6.1 Chronology

#### *Peat*

- 6.1.1 The samples processed for radiocarbon dating were successfully measured, providing a chronology for the sequence. Deposition of organic alluvium began during the Early Neolithic (3425-3375 cal. BC), with deposition of the peat during the Middle Neolithic (3325-3250 cal. BC). Peat cessation occurred during the Early/Middle Bronze Age (1615-1535 cal. BC).

#### *River terrace deposits*

- 6.1.2 OSL dating of the fine-grained sediments within the river terraces of WA01 produced a date of  $411 \pm 30$  Kya. However, this date is tentative, as high  $D_e$  values suggests reworking of sediment. This would result in a date which is older than what would be expected. Within the fine-grained deposit the palynomorphs showed evidence of reworking, with pre-Quaternary dinoflagellates, pollen and spores being present within the sediment, supporting that the cause of the high  $D_e$  values likely reflects from reworking of bedrock.
- 6.1.3 The elevation of c. -2.0 m OD recorded in the north of the Site is comparable to that of the East Tilbury Marshes terrace, as mapped by Bridgeland et al (1993). These are cold-stage deposits formed during the Devensian (MIS 2-4, 30-80 Kya). A sequence of sandy gravels, becoming sandier up-profile, overlying gravels were identified at Movers Lane from +1.0 to -3.0 m OD, located c. 1 km to the west of the Site (Stafford et al 2012). OSL dates from these sands produced a date range from  $15,800 \pm 850$  BP to  $23,900 \pm 1,300$  BP. These sands at Manor Road were attributed to colluvial processes acting on the East Tilbury Marshes post-deposition (Stafford et al 2012). Reworking of the London Clay bedrock into the sediment resulting in high  $D_e$  values would be consistent with the older-than-expected date.

### 6.2 Preservation and concentration of palaeoenvironmental proxies

- 6.2.1 The preservation of palaeoenvironmental proxies was variable across the two boreholes assessed, and within the depositional sequence. This is summarised in **Table 7** and discussed below of the preservation and concentration of palaeoenvironmental remains in the samples assessed.

**Table 7** Typical preservation of proxies in sub-samples at 1 Alfred's Way.

Borehole	Deposit	Preservation			
		Plant macroremains	Pollen	Diatoms	Foraminifera/ostracods
WA01	Clays	-	Poor	Absent	Absent
WA04	Lower organic alluvium	Good	Good	-	-
	Peat	Good	Good	Poor	-
	Upper organic alluvium	-	Good/moderate	-	-

- 6.2.2 Ostracods and foraminifera were absent from borehole WA01. The absence of foraminifera and ostracods likely reflects a combination of the environmental conditions and post-depositional/depositional conditions. Foraminifera typically thrive in marine or brackish environments, and samples taken from the fine-grained silts, which formed in freshwater environments, are unlikely to have foraminifera present. Ostracods occur more widely, being present in many freshwater environments. Conditions such as high acidity or alkalinity

are likely to damage the tests of foraminifera and ostracods, leading to decreased preservation, which may have occurred on the Site.

- 6.2.3 Preservation of diatoms across the sequence ranged from absent to poor. Concentrations of diatoms reflect this, with concentrations ranging from very low to low. These low values may reflect unfavourable conditions for diatom silica preservation rather than initial absence of diatoms from the deposits (Flower 1993; Ryves et al 2001). Given the ubiquity of diatoms in water and in many semi-terrestrial environments, the absence of their remains from the sub-samples assessed here may be attributed to taphonomic processes. This may be the result of diatom silica dissolution and breakage, caused by factors such as high sediment acidity or alkalinity, through flow of water in the sediments, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion.
- 6.2.4 Pollen preservation in the peat ranged from moderate to excellent/good, typically being good, while in the Pleistocene silts clays preservation was typically poor. In some samples, grains of the bi-saccate *Pinus* were recorded as split grains. Pollen concentrations reflected this, where they were typically excellent/good in the peat deposits and poor in the Pleistocene clays. Plant macroremains also showed good preservation within the peat deposits. The good preservation of organic remains within the peat likely reflects anoxic conditions which the peat would have been deposited under, which would allow for minimal sub-surface biological activity, and thus good preservation of organic material. However, post-depositional processes, such as fluctuating water tables, can cause degradation of organic remains, which can affect preservation and concentration. These post-depositional processes are unlikely to have been particularly prominent at the Site, given the generally good preservation of organic microfossils. Poor preservation of organic remains in the Pleistocene clays again is likely associated with oxygen levels, where deposition in an aerobic conditions would have allowed for high levels of biological activity, and thus decay of organic remains such as pollen (Havinga 1967; Havinga 1984).

### 6.3 Depositional and vegetational history

#### *Pleistocene*

- 6.3.1 The basal Quaternary deposits across the Site are Pleistocene fluvial sands and gravels. These sediments would have been deposited in a cold-climate, high-energy braided river. Deposit modelling undertaken by Wessex Archaeology (2024) recognised that there was more than one phase of deposition, with an earlier Pleistocene terrace located to the north of the Site, and a later terrace underlying the Holocene alluvial sequence.
- 6.3.2 Within the Lower Thames, there are a sequence of river terrace deposits associated with different Pleistocene cold stages, summarised in **Table 8**.

**Table 8** Summary of the terraces of the Lower Thames, adapted from Bridgeland et al (2001).

Terrace Formation Middle/Lower Thames	Lower Thames member	Age	MIS
Black Park	Orsett Heath Formation	Anglian cold stage	12
Boyn Hill/Orsett Heath	Orsett Heath lower gravel	Anglian cold stage	12
	Swanscombe interglacial deposits	Hoxnian Interglacial	11
	Orsett Heath upper gravel	Unnamed cold stage	10
Lynch Hill/Corbets Tey	Corbets Tey lower Gravel	Unnamed cold stage	10

	Purfleet-Grays Interglacial deposits	Purfleet Interglacial	9
	Corbets Tey upper gravel	Unnamed cold stage	8
Taplow/Mucking Gravels	Mucking lower gravel	Unnamed cold stage	8
	Aveley Silts and Sands	Aveley Interglacial	7
	Mucking upper gravel	Unnamed cold stage	6
Kempton Park/East Tilbury Marshes Gravels	East Tilbury Marshes lower gravel	Unnamed cold stage	6
	Trafalgar Square and Peckham deposits	Ipswichian Interglacial	5e
	East Tilbury Marshes upper gravel	Devensian cold stage	5d-3
Shepperton	Shepperton Gravel	Devensian cold stage	2
	Tilbury Alluvial Deposits	Holocene	1

- 6.3.3 The BGS (BGS GeoIndex) maps the gravels to the north of the Site as the Taplow Gravel Member, with the gravel terrace to the south obscured by Holocene alluvium in BGS mapping. The base of these gravels towards the north of the Site lies at an elevation of c. -2.0m OD, whilst to the south, the base of the gravels is recorded at a minimum of c. -7.0 m OD. This difference in basal elevation is indicative of at least two separate phases of downcutting and erosion of the bedrock surface, and confirms the presence of two distinct gravel terraces.
- 6.3.4 Due to the high  $D_e$  values and resulting uncertainty surrounding the OSL date, the timing of deposition of the river terrace gravel sequence at the Site is uncertain. But the elevation of the higher terrace is consistent with East Tilbury Marshes terrace (MIS 4-2). The deposition of fine-grained deposits suggest lower energy conditions than that of the overlying and underlying sands and gravels. This could reflect a shift in deposition reflecting less glacial conditions, or the formation of an inactive/back channel.
- 6.3.5 While pollen concentration was poor within the assessed samples, there is evidence for trees including alder, pine and grasses occurring locally. While grasses and pines could be present during glacial periods, the presence of alder is suggestive of more interglacial conditions. Alder has been recorded during the Windermere Interstadial (MIS 3) across England (Hill et al 2008; Young et al 2021), which would be consistent with deposits within the East Tilbury Marshes terrace.
- 6.3.6 Following deposition of the upper terrace, there would have been a hiatus of deposition, before deposition of the second, younger terrace occurred, located in the south of the Site. This deposit, while undated, likely corresponds to the Shepperton Gravel.
- 6.3.7 The Shepperton Gravel is the youngest gravel terrace of the Lower Thames, being deposited during the late Devensian (MIS 2; c. 15 – 11.7 Kya). The Shepperton Gravel is typically present underlying thick Holocene floodplain deposits, and as such has been subject to little investigation. While there is variation of the upper surface of the Shepperton Gravel across the lower Thames, ranging from lows of -10 m OD near Mucking to highs of +2 m OD near Battersea, within the Barking-Dagenham area it is typically recorded between -3 and -5 m OD (Green et al 2014). This is comparable to the lower of the gravel terraces present in the south of the Site.

### *Holocene*

- 6.3.8 Across the Site, a sequence of fine-grained deposits is recorded overlying the Sands and Gravels. These deposits represent floodplain alluvium, formed under the influence of relative sea-level rise during the Holocene. These sediments likely formed in a range of floodplain environments, including tidal mudflats and saltmarshes, and as a result of overbank flooding.
- 6.3.9 Within this sequence a widespread peat unit was recorded, generally present at elevations between c. -4 and -1 m OD. This unit represents a transition to semi-terrestrial environments supporting the growth of wetland vegetation, likely forming as a result of a reduced rate of relative sea-level rise. Radiocarbon dating of this peat unit shows deposition of the organic alluvium began during the Early Neolithic (3425-3375 cal. BC) and the peat began during Middle Neolithic (3325-3250 cal. BC). Peat formation continued until its cessation in the Middle Bronze Age (1615-1535 cal. BC). During periods of peat formation, vegetation communities such as reed swamp, sedge fen and alder carr are likely to have developed, which would have been attractive to a range of fauna (e.g. wildfowl, browsers) and human communities, who would have exploited these environments.
- 6.3.10 This Early Neolithic to Middle Bronze Age peat deposit is comparable to other peat deposits from the Barking and Dagenham area, where widespread peat accumulation has been shown to occur (Sidell et al 2003). These peats show a range of dates, from the Late Mesolithic to Late Bronze Age. At Movers Lane, c. 1 km to the west of the Site, radiocarbon dates were indicative of peat accumulation from the Early Neolithic to the Late Bronze Age (Stafford et al 2012). At the Barking Riverside, c. 1 km to the south of the Site, peat formation span from the Late Mesolithic to the Middle/Late Bronze Age (Green et al 2014). However, radiocarbon dates from Remploy, c. 1.3 km to the southwest, indicate that peat accumulation was much shorter lived with deposition occurring within the Early Bronze Age (QUEST 2022). Peat deposits of an Early Bronze Age date were also recorded at Fresh Wharf, c. 2 km to the east of the Site (MOLA 2021). At Barking Power Station, two stages of peat formation were identified, with the initial phase from the Late Mesolithic and the second phase spanning from the Late Mesolithic to the Late Bronze Age/Early Iron Age (Wessex Archaeology 2024).
- 6.3.11 During the initiation of peat accumulation during the Early Neolithic, the wetland would likely have been deposited within an alder carr environment. Sedges would have been prevalent within the understory of the alder carr, with smaller numbers of grasses present. The diatom flora indicates a marine-brackish signal across the Site, suggesting that the wetland areas of the Site were likely tidally active. While brackish conditions can allow for establishment of saltmarshes and other coastal habitats, alder can tolerate brackish environments to some degree (Deptula et al 2020) and could allow for the development of an alder carr in a tidally influenced site, likely on the banks of the estuary. Alder carr woodland is commonly recorded in the Neolithic of the Lower Thames, with alder carr being recorded at local sites including Ripple Road (Divers 1994b), Mover's Lane (Stafford et al 2012) and at Dagenham Power Station (Wessex Archaeology 2024). The nearby dryland would have comprised mixed woodland, dominated by oaks, with hazel, limes, elms and birches interspersed in smaller numbers. High relative abundances of tree pollen within the pollen assemblages suggest that dryland woodland cover would have been prevalent, with few clearings present within the environment. The presence of lime in the pollen record suggests the dryland is local, as lime is sensitive to high water levels, and wetland environments would cause the loss of lime. Such mixed dryland woodland comprised of oaks, lime and elm were observed within Late Mesolithic organic deposits at Dagenham Power Station (Wessex Archaeology 2024).

- 6.3.12 As the peat formation continued, the wetland shifted to be less sedge-rich, with relative increases of grasses, members of the goosefoot family (which include several species which are abundant in saltmarshes and tolerate saline conditions), although the alder carr would have continued to be prevalent. This is likely due to an increased marine/brackish influence upon the Site associated with continual sea level rise acting upon the Site. Indeed, bulrush becomes more frequent within the pollen samples, a species which is frequent in coastal ditches and is saline tolerant. On the dry land, there is limited evidence for localised clearings present, which were colonised by herbaceous taxa such as ribwort plantain and daisies. Following the evidence of more open conditions, there is evidence for declines in lime within the dryland woodland, which could be driven by anthropogenic deforestation of marine inundation (Grant et al 2011). Within the Thames Valley, there is evidence for lime declines associated with marine inundation and with anthropogenic deforestation. Given the evidence for brackish conditions upon the Site at this time, and limited evidence for anthropogenic activity at the Site it is possible that marine inundation may be responsible for the decline in lime at the Site.
- 6.3.13 Following the cessation of peat deposition during the Early/Middle Bronze Age, there is an interval of deposition of organic alluvium. During this period of organic alluvium deposition, there is a shift in the vegetation assemblage recorded at the Site. The alder carr shifts to becoming more open, with saltmarsh vegetation establishing, with local stands of alder. The herbaceous community would have included taxa such as sedges, members of the goosefoot family, thrift/sea lavender, and mallows, species which can be common in saltmarsh environments. The dryland also exhibits a change in vegetational community, with the replacement of extensive mixed woodland to a more open environment with a rich and diverse herbaceous component, including species such as willowherbs, dandelions and knapweeds. The cause of this shift in vegetation is likely to be driven by human activity, including deforestation. Many of the herbaceous taxa are indicative of frequent disturbance, which could be linked to a local human community to the Site. The Site at this time would have been on the boundary of the dryland and saltmarsh, with the dryland likely occur on the river terrace deposits in the north, or just north of the Site. The alder carr/saltmarsh environment would have provided a rich resource to human companies, offering resources such as game, which could have attracted humans to the area. Evidence for a shift from alder carr woodland to a more open environment has been recorded locally in the Lower Thames, including at Ripple Road in deposits associated with causeways (Divers 1994b).
- 6.3.14 Overlying the peat at the Site were minerogenic clays equivalent to the 'Upper Alluvium' recorded elsewhere within the Lower Thames Valley. These deposits are typical of the uppermost Holocene sediments underlying most floodplains in southern and southeast England, and are typically considered to reflect increased sediment loads, resulting from the intensification of agricultural land use from the later prehistoric period, combined with rising sea levels.

## 6.4 Evidence for human activity

- 6.4.1 There is limited evidence for human activity within the palaeoenvironmental record, as determined by the pollen and plant macroremains record.

### *Pleistocene*

- 6.4.2 Given the uncertainty of the produced OSL date, likely caused by reworking of older sediments, the terrace deposit in the north of the Site is likely to be the East Tilbury Marshes terrace based on elevation mapping. Megafauna have been recovered from the East Tilbury Marshes Gravel, including *Mammathus primigenius* (woolly mammoth), *Equus ferus* (wild horse) and *Coelodonta antiquitatis* (woolly rhinoceros) (Gibbard 1994). The surface of the

gravels is of moderate potential to contain *in situ* prehistoric archaeology. The sands and gravels are equivalent to either the East Tilbury Marshes gravels, deposited during the Devensian (MIS 2-4). While this is during a period of human occupation in Britain, there are relatively little lithic material recovered from the Devensian gravels of the Thames. However, Mousterian-type handaxes have been recovered from the submerged gravels at Tilbury (Wymer 1988).

- 6.4.3 Microscopic charcoal was uncommon to frequent within the palynological slides. This could reflect a low rate of sediment accumulation during the deposition of the fine-grained deposits. Charcoal is chemically inert (Scott 2010), which could allow for it to be over-represented in the sediment record in locations where low levels of sediment accumulation or reworking of older sediment occurs. There is evidence that natural burning does occur in glacial periods during the Pleistocene in Britain, with the arid climate promoting burning (Tsakiridou et al 2020).

#### *Peat*

- 6.4.4 The peat has been dated from the Early Neolithic to Middle Bronze Age, an interval where human activity has been documented in the lower Thames valley. During the Neolithic, rising sea level and an encroaching tidal influence on the Lower Thames resulted in the area becoming wetter and wetter. Typically during the Neolithic, deforestation of woodland for clearance, and early agriculture lead to the widespread decline in primary woodlands in Britain. However, in the Thames valley, while some areas witnessed clearance early during the Neolithic, overall it remained wooded throughout the period.
- 6.4.5 However, there is a lot of evidence of human activity within the Lower Thames valley during the Neolithic, including Neolithic trackways at Belmarsh (Hart et al 2015), evidence of forest clearance and cereal cultivation at North Woolwich (Stastney et al 2021) and find spots such as wooden clubs and flint lithics.
- 6.4.6 Within the pollen record, tree pollen is typically present at high values throughout the peat, having relative abundances typically above 80% TLP. These high values suggest that primary woodland characterised the Site, likely on the dryland to the north of the Site. The high pollen values and tree assemblage suggest that limited deforestation has occurred. High values of tree pollen are observed in the wetland community (alder carr) and dryland community (mixed oak woodland) throughout most of the peat sequence. However, locally within the peat, between 3.57 and 2.75 m bgl there is a small increase in herbaceous taxa diversity, which could reflect an increase in the number of clearings within the dryland woodland, possibly caused by human activity.
- 6.4.7 Microscopic charcoal is largely absent from much of the record within the peat, though does show a brief increase within the middle of peat deposition. While this could reflect a natural fire, increased values in charcoal is often associated with anthropogenic burning. This increase in microscopic charcoal occurs during the period of increased herbaceous diversity during peat deposition, which could be a result of localised land cleared by anthropogenic burning.

#### *Upper organic alluvium*

- 6.4.8 While the deposition of the upper organic alluvium is undated, it directly overlies the top of the peat which has been dated to the Middle Bronze Age. Human activity continued to increase in the Lower Thames valley during the Bronze Age, including evidence for increasing number of trackways and causeways during this period, such as at Ripple Road (Divers 1994b), Highbridge Road (Meddens 1996) and Beckton (Beasley 1993; Divers 1994a).

6.4.9 During the deposition of the upper organic alluvium, there is evidence for human activity close to the Site. Tree pollen values decrease to relative abundances of <40%, suggesting larger scale deforestation, with more open environments present. Many of these herbaceous taxa are typical of disturbed environments, such as willowherbs, dandelions and nettles, which could be driven by human activity. Alongside this shift in vegetation, microscopic charcoal becomes frequent during the deposition of the organic alluvium. Given the shift in vegetation, it is likely that human disturbance and anthropogenic burning is occurring on the dryland close to the Site.

## 7 RECOMMENDATIONS

7.1.1 A program of palaeoenvironmental assessment and scientific dating has established the age and preservation of biological remains of boreholes WA01 and WA04. Recommendations are made for targeted further analysis, based on the results of the palaeoenvironmental assessment presented in **Sections 5 to 6**.

7.1.2 Given the poor preservation of foraminifera, ostracods, diatoms and pollen within the fine-grained deposits within borehole WA01, no further work is recommended upon this deposit.

7.1.3 Radiocarbon dating of the peat deposits within WA04 has produced a chronology for peat deposition, which show peat deposition occurred from the Early Neolithic to the Middle Bronze Age. This is comparable to peat sequences in the Barking and Dagenham area, where thick peat sequences spanning from the Late Mesolithic to Late Bronze Age have been recorded. This demonstrates that peat deposition occurs during an interval where important archaeology has been recovered from the Barking and Dagenham area within peat sequences, such as Neolithic and Bronze Age wooden trackways.

7.1.4 Dating of the top of the upper organic alluvium within WA04 would provide information on when human activity was occurring on/close to the Site, as determined by the pollen assessment. Plant macroremains analysis would also look for macrofossils to support evidence for human activity. We also recommend an additional date to be taken from within the peat sequence, where there is evidence for human activity. This would produce a more concrete chronology in association of archaeological activities. Analysis of pollen would provide more conclusive evidence suggested by the pollen assessment presented here, providing further information on vegetation shifts within the peat sequence where increases in microscopic charcoal and more open vegetation taxa occur, and from the organic alluvium. Additional sub-sampling of pollen would target sampling during the organic alluvium deposition where there is a clear shift in vegetation communities, and close to microscopic charcoal spike within the peat unit, to see if there is more evidence for temporally established human activity during this interval. A summary of further recommendations is included in **Table 8**.

**Table 9** Recommendations for further work

Borehole	Deposit	Pollen (existing to analysis)	Pollen (new)	Radiocarbon date
WA04	Upper organic alluvium	2	2	1
	Peat	14	3	1

7.1.5 This targeted palaeoenvironmental analysis would help meet the Research Framework for London Archaeology (2002), in particular the focus of reconstructing palaeoenvironments and palaeoecology, changes in agriculture and constructing chronologies during prehistory.

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## APPENDICES

### Appendix 1: Sub-samples

Borehole	Deposit	Depth (m bgl)	Assessment
WA01	Silts	2.82	Diatoms
WA01	Silts	2.82-2.83	Foraminifera/ostracods
WA01	Silts	2.82	Pollen
WA01	Silts	2.90	Diatoms
WA01	Silts	2.90-2.91	Foraminifera/ostracods
WA01	Silts	2.96	Diatoms
WA01	Silts	2.96-2.97	Foraminifera/ostracods
WA01	Silts	2.96	Pollen
WA01	Silts	XXX	OSL
WA04	Organic alluvium	2.16	Pollen
WA04	Organic alluvium	2.33	Pollen
WA04	Peat	2.35	Pollen
WA04	Peat	2.36-2.38	Plant macroremains/ radiocarbon dating
WA04	Peat	2.36	Diatoms
WA04	Peat	2.45	Pollen
WA04	Peat	2.55	Pollen
WA04	Peat	2.65	Pollen
WA04	Peat	2.75	Pollen
WA04	Peat	2.85	Pollen
WA04	Peat	2.95	Pollen
WA04	Peat	2.95	Diatoms
WA04	Peat	3.57	Pollen
WA04	Peat	3.57	Diatoms
WA04	Peat	3.67	Pollen
WA04	Peat	3.77	Pollen
WA04	Peat	3.87	Pollen
WA04	Peat	3.96-3.98	Plant macroremains/ radiocarbon dating
WA04	Peat	3.97	Diatoms
WA04	Peat	3.97	Pollen
WA04	Organic alluvium	4.06	Pollen
WA04	Organic alluvium	4.06-4.08	Plant macroremains/ radiocarbon dating

## Appendix 2: Diatom assessment

### Introduction

Wessex Archaeology have been commissioned to undertake a geoarchaeological and palaeoenvironmental assessment for 1 Alfred's Way, Barking. As part of this evaluation, seven diatom samples from 2 sequences of alluvium, organic alluvium and peat have been selected for diatom assessment.

The diatom assessment considers the numbers of diatoms, the state of preservation of the diatom assemblages, species diversity, diatom species environmental preferences and the potential of the sediments for further diatom analysis.

### Methods

Diatom preparation followed standard techniques (Battarbee *et al.* 2001). Two 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 x400 and x1000 under phase contrast illumination.

Diatom floras and taxonomic publications were consulted to assist with diatom identification; these include Hendey (1964), Werff & Huls (1957-1974), Hartley *et al.* (1996), Krammer & Lange-Bertalot (1986-1991) and Witkowski *et al.* (2000). Diatom species' salinity preferences are indicated using the halobian groups of Hustedt (1953, 1957: 199), these salinity groups are summarised as follows:

1. Polyhalobian: >30 g l<sup>-1</sup>
2. Mesohalobian: 0.2-30 g l<sup>-1</sup>
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.

### Results & Discussion

The diatom samples, borehole sequence and depths are shown in Table 1 (details taken from sample bags).

**Table 1. 1 Alfred's Way, Barking Diatom samples**

Diatom sample	Borehole	Top Depth (m) bgl
D1	WA01	2.82
D2	WA01	2.90
D3	WA01	2.96
D4	WA04	2.36
D5	WA04	2.95
D6	WA04	3.57
D7	WA04	3.97

Table 2 shows a summary of the results from the diatom evaluation. The records of diatom taxa and their salinity classifications are shown in Table 3 (Excel file attached): 1 – present; 2 – common.

**Table 2. Summary of diatom evaluation results for 1 Alfred's Way, Barking, samples from WA01 and WA04 (+ present; - absent; fw – freshwater; bk – brackish; mar – marine; mod – moderate)**

Core & Diatom Sample Number	Diatoms	Diatom Numbers	Quality of Preservation	Diversity	Assemblage type	Potential for % Count
D1	-	-	-	-	-	none
D2	-	-	-	-	-	none
D3	-	-	-	-	-	none
D4	+	v low	v poor	low	mixed	none
D5	-	-	-	-	-	none
D6	+	low	v poor	mod	bk mar (fw)	some/low
D7	-	-	-	-	-	none

#### WA01 (Samples D1 to D3)

Diatoms are absent from all three samples from the WA01 sediment sequence. There is no further potential for diatom analysis of these samples.

The absence of diatoms in the sediments may reflect unfavourable conditions for diatom silica preservation rather than initial absence of diatoms from the deposits (Flower 1993, Ryves *et al.* 2001). Given the ubiquity of diatoms in water and in many semi-terrestrial habitats, the absence of their remains from the samples assessed here can be attributed to taphonomic processes. This may be the result of diatom silica dissolution and breakage, caused by factors such as high sediment acidity or alkalinity, through flow of water in the sediments, the under-saturation of sediment pore water with dissolved silica, cycles of prolonged drying and rehydration, or physical damage to diatom valves from abrasion.

#### WA04 (Samples D4 to D7)

A low or very low number of diatoms are present in samples D6 and D4. Diatoms are absent from samples D7 and D5.

Sample D6 is dominated by brackish-marine diatoms, common taxa include the estuarine planktonic species *Cyclotella striata* and *Thalassiosira bramaputrae*. Benthic brackish-marine species include *Diploneis didyma*, *Caloneis westii*, *Campylodiscus echeneis*, *Nitzschia navicularis* and *Diploneis smithii*. Allochthonous, marine planktonic diatoms present include *Paralia sulcata*, *Podosira stelligera* and *Coscinodiscus* sp. A low number of freshwater diatoms were recorded in sample D6, these include *Synedra ulna* and *Aulacoseira* sp. In addition, a small number of chrysophyte stomatocysts are present, these may represent freshwater or brackish water habitats.

The dominance of brackish-marine planktonic, and benthic diatoms (that inhabit shallow-water mud-surface environments), with an allochthonous coastal diatom component indicates that an estuarine environment is represented by the diatoms in sample D6. The diatom assemblage is of moderate diversity and there is some potential for percentage diatom analysis of the sample.

The diatom assemblage in sample D4 is very poorly preserved and there are a very low number of diatoms present, with low species diversity. The poor quality of diatom preservation in sample D4

means that most diatom fragments were identifiable only to the generic level and most could not be assigned to a salinity group.

A possible fragment of a diatom from the marine genus *Rhaphoneis* was recorded in sample D4. The acidophilous, halophobous species *Eunotia naegelii* is present and is likely to represent inwash of material from a peat habitat. Fragments of taxa such as *Pinnularia* sp. may represent semi-terrestrial freshwater habitats. There is no further potential for diatom analysis of sample D4.

**Table 3. 1 Alfred's Way Barking (WA01 WA04). Diatoms and salinity groups. 1 – present 2 - common**

Diatoms/Sample	D4	D6
<b>Polyhalobous</b>		
Coscinodiscus sp.		1
Paralia sulcata		1
Podosira stelligera		1
Rhaphoneis sp.	cf	
<b>Polyhalobous to Mesohalobous</b>		
Diploneis smithii		1
<b>Mesohalobous</b>		
Caloneis westii		1
Campylodiscus echeneis		1
Cyclotella striata		2
Diploneis didyma		1
Nitzschia navicularis		1
Thalassiosira bramaputrae		2
<b>Oligohalobous Indifferent</b>		
Aulacoseira sp.		1
Synedra ulna		1
<b>Halophobous</b>		
Eunotia naegelii	1	
<b>Unknown Salinity Group</b>		
Chrysophyte cysts		1
Cocconeis sp.	1	
Diploneis sp.	1	1
Pinnularia sp.	1	
Inderminate pennate sp.	1	
Nitzschia sp.	1	
Opephora sp.		1
Unknown naviculaceae		1

### **Conclusions**

A total of 7 samples from 2 sediment sequences have been assessed for diatoms. Diatoms are absent from all 3 samples assessed from the WA01 sediment sequence and there is no further potential for diatom analysis of these samples.

Diatoms are present in 2 samples from WA03 and absent from 2 samples. The lower diatomaceous sample (D6) has a diatom assemblage dominated by estuarine diatom taxa with both planktonic and benthic brackish-marine diatoms common or present. There are also allochthonous marine diatoms present, with a small component of freshwater taxa. The mixed assemblage represents an estuarine environment. There is some potential for further diatom analysis of this sample.

In sample D4 from WA03 the poor quality of diatom preservation means that most diatom fragments were identifiable only to the generic level and therefore many taxa could not be assigned to a salinity group. The diatoms identified indicate a mixed diatom assemblage composed of diatoms from disparate habitats. There is no further potential for diatom analysis of this sample.

### **Acknowledgements**

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## Appendix 3: Luminescence dating laboratory report

Field code	Lab code	Overburden (m)	Grain size (µm)	Moisture content (%)	G <sub>e</sub> γ-spectrometry ( <i>ex situ</i> )			α D <sub>r</sub> (Gy.ka <sup>-1</sup> )	β D <sub>r</sub> (Gy.ka <sup>-1</sup> )	γ D <sub>r</sub> (Gy.ka <sup>-1</sup> )	D <sub>ps,oc</sub> D <sub>r</sub> (Gy.ka <sup>-1</sup> )	Preheat (°C for 10s)	Repeat Dose Ratio	Post-IR OSL Ratio
					K (%)	Th (ppm)	U (ppm)							
2.88	GL24052	2.88	5-15	26	K (%)	Th (ppm)	U (ppm)	0.19±0.02	0.83±0.06	0.48±0.03	0.13±0.01	220	1.01±0.06	0.94±0.06
					1.14±0.05	5.86±0.37	0.97±0.07							

Field code	Lab code	Total D <sub>r</sub> (Gy.ka <sup>-1</sup> )	D <sub>e</sub> (Gy)	Age (ka)
2.88m	GL22	1.63±0.07	669.40±40.52	411±30 (25)

**Table 1** Dr, De and Age data of submitted samples located at c. 51°N, 0°E, 1m. Age estimates expressed relative to year of sampling. Uncertainties in age are quoted at 1σ confidence, are based on analytical errors and reflect combined systematic and experimental variability and (in parenthesis) experimental variability alone (see 6.0). **Blue** indicates samples with accepted age estimates, **red**, age estimates with caveats (see Table 2).

Generic considerations	Field code	Lab code	Sample specific considerations
Absence of <i>in situ</i> γ spectrometry data (see section 4.0)	2.88m	GL24052	High De value (see Table 1 and Section 3.1.3. Accept age estimate tentatively

**Table 2** Analytical validity of sample suite age estimates and caveats for consideration.

### 1.0 Mechanisms and principles

Upon exposure to ionising radiation, electrons within the crystal lattice of insulating minerals are displaced from their atomic orbits. Whilst this dislocation is momentary for most electrons, a portion of charge is redistributed to meta-stable sites (traps) within the crystal lattice. In the absence of significant optical and thermal stimuli, this charge can be stored for extensive periods. The quantity of charge relocation and storage relates to the magnitude and period of irradiation. When the lattice is optically or thermally stimulated, charge is evicted from traps and may return to a vacant orbit position (hole). Upon recombination with a hole, an electron's energy can be dissipated in the form of light generating crystal luminescence providing a measure of dose absorption.

Herein, quartz is segregated for dating. The utility of this minerogenic dosimeter lies in the stability of its datable signal over the mid to late Quaternary period, predicted through isothermal decay studies (e.g. Smith *et al.*, 1990; retention lifetime 630 Ma at 20°C) and evidenced by optical age estimates concordant with independent chronological controls (e.g. Murray and Olley, 2002). This stability is in contrast to the anomalous fading of comparable signals commonly observed for other ubiquitous sedimentary minerals such as feldspar and zircon (Wintle, 1973; Templer, 1985; Spooner, 1993)

Optical age estimates of sedimentation (Huntley *et al.*, 1985) are premised upon reduction of the minerogenic time dependent signal (Optically Stimulated Luminescence, OSL) to zero through exposure to sunlight and, once buried, signal reformulation by absorption of litho- and cosmogenic radiation. The signal accumulated post burial acts as a dosimeter recording total dose absorption, converting to a chronometer by estimating the rate of dose absorption quantified through the assay of radioactivity in the surrounding lithology and streaming from the cosmos:

$$Age = \frac{Mean\ Equivalent\ Dose\ (De, Gy)}{Mean\ Dose\ Rate\ (Dr\ Gy.ka - 1)}$$

Aitken (1998) and Bøtter-Jensen *et al.* (2003) offer a detailed review of optical dating.

### 2.0 Sample Preparation

One sediment sample was collected within opaque tubing and submitted for Optical dating (Table 1). To preclude optical erosion of the datable signal prior to measurement, all samples were opened and prepared under controlled laboratory illumination provided by Encapsulite RB-10 (red)

filters. To isolate that material potentially exposed to daylight during sampling, sediment located within 10 mm of each tube-end of each light-exposed face was removed.

The remaining sample was dried and then sieved. The fine silt fraction was segregated and subjected to acid and alkaline digestion (10% HCl, 15% H<sub>2</sub>O<sub>2</sub>) to attain removal of carbonate and organic components respectively. Fine silt sized quartz, along with other mineral grains of varying density and size, was extracted by sample sedimentation in acetone (<15 µm in 2 min 20 s, >5 µm in 21 mins at 20°C). Feldspars and amorphous silica were then removed from this fraction through acid digestion (35% H<sub>2</sub>SiF<sub>6</sub> for 2 weeks, Jackson *et al.*, 1976; Berger *et al.*, 1980). Following addition of 10% HCl to remove acid soluble fluorides, grains degraded to <5 µm as a result of acid treatment were removed by acetone sedimentation. Six multi-grain aliquots (ca. 1.5 mg) were then mounted on aluminium discs for De evaluation.

All drying was conducted at 40°C to prevent thermal erosion of the signal. All acids and alkalis were Analar grade. All dilutions (removing toxic-corrosive and non-minerogenic luminescence-bearing substances) were conducted with distilled water to prevent signal contamination by extraneous particles.

### 3.0 Acquisition and accuracy of De value

All minerals naturally exhibit marked inter-sample variability in luminescence per unit dose (sensitivity). Therefore, the estimation of De acquired since burial requires calibration of the natural signal using known amounts of laboratory dose. De values were quantified using a single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle 2000; 2003) facilitated by a Risø TL-DA-15 irradiation-stimulation-detection system (Markey *et al.*, 1997; Bøtter-Jensen *et al.*, 1999). Within this apparatus, optical signal stimulation is provided by an assembly of blue diodes (5 packs of 6 Nichia NSPB500S), filtered to 470±80 nm conveying 15 mW.cm<sup>-2</sup> using a 3 mm Schott GG420 positioned in front of each diode pack. Infrared (IR) stimulation, provided by 6 IR diodes (Telefunken TSHA 6203) stimulating at 875±80nm delivering ~40 mW.cm<sup>-2</sup>, was used to indicate the presence of contaminant feldspars (Hütt *et al.*, 1988). Stimulated photon emissions from quartz aliquots are in the ultraviolet (UV) range and were filtered from stimulating photons by 7.5 mm HOYA U-340 glass and detected by an EMI 9235QA photomultiplier fitted with a blue-green sensitive bialkali photocathode. Aliquot irradiation was conducted using a 1.48 GBq 90Sr/90Y β source calibrated for multi-grain aliquots of 5-15 µm quartz against the 'Hotspot 800' 60Co γ source located at the National Physical Laboratory (NPL), UK.

SAR by definition evaluates De through measuring the natural signal (Fig. 1) of a single aliquot and then regenerating that aliquot's signal by using known laboratory doses to enable calibration. For each aliquot, five different regenerative-doses were administered so as to image dose response. De values for each aliquot were then interpolated, and associated counting and fitting errors calculated, by way of exponential plus linear regression (Fig. 1). Weighted (geometric) mean De values were calculated from 6 fine silt aliquots using the central age model outlined by Galbraith *et al.* (1999) and are quoted at 1σ confidence (Table 1). The accuracy with which De equates to total absorbed dose and that dose absorbed since burial was assessed. The former can be considered a function of laboratory factors, the latter, one of environmental issues. Diagnostics were deployed to estimate the influence of these factors and criteria instituted to optimise the accuracy of De values.

### 3.1 Laboratory Factors

#### 3.1.1 Feldspar contamination

The propensity of feldspar signals to fade and underestimate age, coupled with their higher sensitivity relative to quartz makes it imperative to quantify feldspar contamination. At room temperature, feldspars generate a signal (IRSL; Fig. 1) upon exposure to IR whereas quartz does not. The signal from feldspars contributing to OSL can be depleted by prior exposure to IR. For all aliquots the contribution of any remaining feldspars was estimated from the OSL IR depletion ratio (Duller, 2003). The influence of IR depletion on the OSL signal can be illustrated by comparing the regenerated post-IR OSL De with the applied regenerative-dose. If the addition to OSL by

feldspars is insignificant, then the repeat dose ratio of OSL to post-IR OSL should be statistically consistent with unity (Table 1). If any aliquots do not fulfil this criterion, then the sample age estimate should be accepted tentatively. The source of feldspar contamination is rarely rooted in sample preparation; it predominantly results from the occurrence of feldspars as inclusions within quartz.

### 3.1.2 Preheating

Preheating aliquots between irradiation and optical stimulation is necessary to ensure comparability between natural and laboratory-induced signals. However, the multiple irradiation and preheating steps that are required to define single-aliquot regenerative-dose response leads to signal sensitisation, rendering calibration of the natural signal inaccurate. The SAR protocol (Murray and Wintle, 2000; 2003) enables this sensitisation to be monitored and corrected using a test dose, here set at 5 Gy preheated to 220°C for 10s, to track signal sensitivity between irradiation-preheat steps. However, the accuracy of sensitisation correction for both natural and laboratory signals can be preheat dependent.

The Dose Recovery test was used to assess the optimal preheat temperature for accurate correction and calibration of the time dependent signal. Dose Recovery (Fig. 2) attempts to quantify the combined effects of thermal transfer and sensitisation on the natural signal, using a precise lab dose to simulate natural dose. The ratio between the applied dose and recovered  $D_e$  value should be statistically concordant with unity. For this diagnostic, 4 aliquots were each assigned a 10 s preheat between 220°C and 280°C.

That preheat treatment fulfilling the criterion of accuracy within the Dose Recovery test was selected to generate the final  $D_e$  value from a further 6 aliquots. Further thermal treatments, prescribed by Murray and Wintle (2000; 2003), were applied to optimise accuracy and precision. Optical stimulation occurred at 125°C in order to minimise effects associated with photo-transferred thermoluminescence and maximise signal to noise ratios. Inter-cycle optical stimulation was conducted at 280°C to minimise recuperation.

### 3.1.3 Irradiation

For all samples having  $D_e$  values in excess of 100 Gy, matters of signal saturation and laboratory irradiation effects are of concern. With regards the former, the rate of signal accumulation generally adheres to a saturating exponential form and it is this that limits the precision and accuracy of  $D_e$  values for samples having absorbed large doses. For such samples, the functional range of  $D_e$  interpolation by SAR has been verified up to 600 Gy by Pawley *et al.* (2010). Age estimates based on  $D_e$  values exceeding this value should be accepted tentatively.

### 3.1.4 Internal consistency

Abanico plots (Dietze *et al.*, 2016) are used to illustrate inter-aliquot  $D_e$  variability (Fig. 3).  $D_e$  values are standardised relative to the central  $D_e$  value for natural signals and are described as overdispersed when >5% lie beyond  $\pm 2\sigma$  of the standardising value; resulting from a heterogeneous absorption of burial dose and/or response to the SAR protocol. For multi-grain aliquots, overdispersion of natural signals does not necessarily imply inaccuracy. However where overdispersion is observed for regenerated signals, the efficacy of sensitivity correction may be problematic. Murray and Wintle (2000; 2003) suggest repeat dose ratios (Table 1) offer a measure of SAR protocol success, whereby ratios ranging across 0.9-1.1 represent effective sensitivity correction. However, this variation of repeat dose ratios in the high-dose region can have a significant impact on  $D_e$  interpolation.

## 3.2 Environmental factors

### 3.2.1 Incomplete zeroing

Post-burial OSL signals residual of pre-burial dose absorption can result where pre-burial sunlight exposure is limited in spectrum, intensity and/or period, leading to age overestimation. This effect is particularly acute for material eroded and redeposited sub-aqueously (Olley *et al.*, 1998, 1999;

Wallinga, 2002) and exposed to a burial dose of <20 Gy (e.g. Olley *et al.*, 2004), has some influence in sub-aerial contexts but is rarely of consequence where aerial transport has occurred. Within single-aliquot regenerative-dose optical dating there are two diagnostics of partial resetting (or bleaching); signal analysis (Agersnap-Larsen *et al.*, 2000; Bailey *et al.*, 2003) and inter-aliquot De distribution studies (Murray *et al.*, 1995).

Within this study, signal analysis was used to quantify the change in De value with respect to optical stimulation time for multi-grain aliquots. This exploits the existence of traps within minerogenic dosimeters that bleach with different efficiency for a given wavelength of light to verify partial bleaching. De (t) plots (Fig. 4; Bailey *et al.*, 2003) are constructed from separate integrals of signal decay as laboratory optical stimulation progresses. A statistically significant increase in natural De (t) is indicative of partial bleaching assuming three conditions are fulfilled. Firstly, that a statistically significant increase in De (t) is observed when partial bleaching is simulated within the laboratory. Secondly, that there is no significant rise in De (t) when full bleaching is simulated. Finally, there should be no significant augmentation in De (t) when zero dose is simulated. Where partial bleaching is detected, the age derived from the sample should be considered a maximum estimate only. However, the utility of signal analysis is strongly dependent upon a samples pre-burial experience of sunlight's spectrum and its residual to post-burial signal ratio. Given in the majority of cases, the spectral exposure history of a deposit is uncertain, the absence of an increase in natural De (t) does not necessarily testify to the absence of partial bleaching. Where requested and feasible, the insensitivities of multi-grain single-aliquot signal analysis may be circumvented by inter-aliquot De distribution studies. This analysis uses aliquots of single sand grains to quantify inter-grain De distribution. At present, it is contended that asymmetric inter-grain De distributions are symptomatic of partial bleaching and/or pedoturbation (Murray *et al.*, 1995; Olley *et al.*, 1999; Olley *et al.*, 2004; Bateman *et al.*, 2003). For partial bleaching at least, it is further contended that the De acquired during burial is located in the minimum region of such ranges. The mean and breadth of this minimum region is the subject of current debate, as it is additionally influenced by heterogeneity in microdosimetry, variable inter-grain response to SAR and residual to post-burial signal ratios.

### 3.2.2 Turbation

As noted in section 3.1.1, the accuracy of sedimentation ages can further be controlled by post-burial trans-strata grain movements forced by pedo- or cryoturbation. Berger (2003) contends pedogenesis prompts a reduction in the apparent sedimentation age of parent material through bioturbation and illuviation of younger material from above and/or by biological recycling and resetting of the datable signal of surface material. Berger (2003) proposes that the chronological products of this remobilisation are A-horizon age estimates reflecting the cessation of pedogenic activity, Bc/C-horizon ages delimiting the maximum age for the initiation of pedogenesis with estimates obtained from Bt-horizons providing an intermediate age 'close to the age of cessation of soil development'. Singhvi *et al.* (2001), in contrast, suggest that B and C-horizons closely approximate the age of the parent material, the A-horizon, that of the 'soil forming episode'. Recent analyses of inter-aliquot De distributions have reinforced this complexity of interpreting burial age from pedoturbated deposits (Lombard *et al.*, 2011; Gliganic *et al.*, 2015; Jacobs *et al.*, 2008; Bateman *et al.*, 2007; Gliganic *et al.*, 2016). At present there is no definitive post-sampling mechanism for the direct detection of and correction for post-burial sediment remobilisation. However, intervals of palaeosol evolution can be delimited by a maximum age derived from parent material and a minimum age obtained from a unit overlying the palaeosol. Inaccuracy forced by cryoturbation may be bidirectional, heaving older material upwards or drawing younger material downwards into the level to be dated. Cryogenic deformation of matrix-supported material is, typically, visible; sampling of such cryogenically-disturbed sediments can be avoided.

### 4.0 Acquisition and accuracy of Dr value

Lithogenic Dr values were defined through measurement of U, Th and K radionuclide concentration and conversion of these quantities into  $\alpha$ ,  $\beta$  and  $\gamma$  Dr values (Table 1).  $\alpha$  and  $\beta$  contributions were

estimated from sub-samples by laboratory-based  $\gamma$  spectrometry using an Ortec GEM-S high purity Ge coaxial detector system, calibrated using certified reference materials supplied by CANMET.  $\gamma$  dose rates can be estimated from *in situ* NaI gamma spectrometry or, where direct measurements are unavailable as in the present case, from laboratory-based Ge  $\gamma$  spectrometry. *In situ* measurements reduce uncertainty relating to potential heterogeneity in the  $\gamma$  dose field surrounding each sample. The level of U disequilibrium was estimated by laboratory-based Ge  $\gamma$  spectrometry. Estimates of radionuclide concentration were converted into Dr values (Adamiec and Aitken, 1998), accounting for Dr modulation forced by grain size (Mejdahl, 1979), present moisture content (Zimmerman, 1971) and, where De values were generated from 5-15  $\mu\text{m}$  quartz, reduced signal sensitivity to  $\alpha$  radiation ( $\alpha$ -value  $0.050 \pm 0.002$ ). Cosmogenic Dr values were calculated on the basis of sample depth, geographical position and matrix density (Prescott and Hutton, 1994). The spatiotemporal validity of Dr values can be considered a function of five variables. Firstly, age estimates devoid of *in situ*  $\gamma$  spectrometry data should be accepted tentatively if the sampled unit is heterogeneous in texture or if the sample is located within 300 mm of strata consisting of differing texture and/or mineralogy. However, where samples are obtained throughout a vertical profile, consistent values of  $\gamma$  Dr based solely on laboratory measurements may evidence the homogeneity of the  $\gamma$  field and hence accuracy of  $\gamma$  Dr values. Secondly, disequilibrium can force temporal instability in U and Th emissions. The impact of this infrequent phenomenon (Olley *et al.*, 1996) upon age estimates is usually insignificant given their associated margins of error. However, for samples where this effect is pronounced (>50% disequilibrium between  $^{238}\text{U}$  and  $^{226}\text{Ra}$ ; Fig. 5), the resulting age estimates should be accepted tentatively. Thirdly, pedogenically-induced variations in matrix composition of B and C-horizons, such as radionuclide and/or mineral remobilisation, may alter the rate of energy emission and/or absorption. If Dr is invariant through a dated profile and samples encompass primary parent material, then element mobility is likely limited in effect. Fourthly, spatiotemporal detractors from present moisture content are difficult to assess directly, requiring knowledge of the magnitude and timing of differing contents. However, the maximum influence of moisture content variations can be delimited by recalculating Dr for minimum (zero) and maximum (saturation) content. Finally, temporal alteration in the thickness of overburden alters cosmic Dr values. Cosmic Dr often forms a negligible portion of total Dr. It is possible to quantify the maximum influence of overburden flux by recalculating Dr for minimum (zero) and maximum (surface sample) cosmic Dr.

### 5.0 Estimation of Age

Ages reported in Table 1 provide an estimate of sediment burial period based on mean De and Dr values and their associated analytical uncertainties. Uncertainty in age estimates is reported as a product of systematic and experimental errors, with the magnitude of experimental errors alone shown in parenthesis (Table 1). Cumulative frequency plots indicate the inter-aliquot variability in age (Fig. 6). The maximum influence of temporal variations in Dr forced by minima-maxima in moisture content and overburden thickness is also illustrated in Fig. 6. Where uncertainty in these parameters exists this age range may prove instructive, however the combined extremes represented should not be construed as preferred age estimates. The analytical validity of each sample is presented in Table 2.

### 6.0 Analytical uncertainty

All errors are based upon analytical uncertainty and quoted at  $1\sigma$  confidence. Error calculations account for the propagation of systematic and/or experimental (random) errors associated with De and Dr values.

For De values, systematic errors are confined to laboratory  $\beta$  source calibration. Uncertainty in this respect is that combined from the delivery of the calibrating  $\gamma$  dose (1.2%; NPL, pers. comm.), the conversion of this dose for  $\text{SiO}_2$  using the respective mass energy-absorption coefficient (2%; Hubbell, 1982) and experimental error, totalling 3.5%. Mass attenuation and bremsstrahlung losses during  $\gamma$  dose delivery are considered negligible. Experimental errors relate to De interpolation

using sensitisation corrected dose responses. Natural and regenerated sensitisation corrected dose points ( $S_i$ ) were quantified by,

$$S_i = (D_i - x.L_i) / (d_i - x.L_i) \text{ Eq.1}$$

where  $D_i$  = Natural or regenerated OSL, initial 0.2 s

$L_i$  = Background natural or regenerated OSL, final 5 s

$d_i$  = Test dose OSL, initial 0.2 s

$x$  = Scaling factor, 0.08

The error on each signal parameter is based on counting statistics, reflected by the square-root of measured values. The propagation of these errors within Eq. 1 generating  $\sigma S_i$  follows the general formula given in Eq. 2.  $\sigma S_i$  were then used to define fitting and interpolation errors within exponential plus linear regressions.

For  $D_r$  values, systematic errors accommodate uncertainty in radionuclide conversion factors (5%),  $\beta$  attenuation coefficients (5%),  $a$ -value (4%; derived from a systematic  $\alpha$  source uncertainty of 3.5% and experimental error), matrix density (0.20 g.cm<sup>-3</sup>), vertical thickness of sampled section (specific to sample collection device), saturation moisture content (3%), moisture content attenuation (2%) and burial moisture content (2.5%, unless direct evidence exists of the magnitude and period of differing content). Experimental errors are associated with radionuclide quantification for each sample by Ge gamma spectrometry.

The propagation of these errors through to age calculation was quantified using the expression,

$$\sigma y (\delta y / \delta x) = (\sum ((\delta y / \delta x_n) \cdot \sigma x_n)^2)^{1/2} \text{ Eq. 2}$$

where  $y$  is a value equivalent to that function comprising terms  $x_n$  and where  $\sigma y$  and  $\sigma x_n$  are associated uncertainties.

Errors on age estimates are presented as combined systematic and experimental errors and experimental errors alone. The former (combined) error should be considered when comparing luminescence ages herein with independent chronometric controls. The latter assumes systematic errors are common to luminescence age estimates generated by means identical to those detailed herein and enable direct comparison with those estimates.

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#### Appendix 4: Raw plant macroremains result

Borehole	Depth	Bulk volume (ml)	Net volume (ml)	Sample composition
WA04	2.36- 2.38	200	120	Wood and wood fragments, incl. twigs of <i>Alnus glutinosa</i> (A***), herbaceous stems and fine rootlets (A**)
WA04	3.96- 3.98	150	100	Wood and wood fragments, incl. twigs of <i>Alnus glutinosa</i> (A***), herbaceous stems and fine rootlets (A**), <i>Daphnia</i> egg cases (A*), indet insect parts (A), mites (A), <b>Seeds/Fruit etc:</b> <i>Rubus</i> sp. (x1), Cyperaceae (x7), <i>Solanum</i> sp. (x4), Apiaceae (x1), <i>Alnus</i> seds (x3), <i>Alnus</i> cone (x1), <i>Urtica</i> sp. (x2), <i>Lycopus europaeus</i> (x1)
WA04	4.06- 4.08	150	25	Wood and wood fragments, incl. twigs of <i>Alnus glutinosa</i> (A***), herbaceous stems and fine rootlets (A*), fine sand (A**)



## Appendix 5: Raw pollen counts

WA01		Depth (m bgl)	
		2.82	2.96
Trees	Pinus	3.5	
	Alnus	1	2
Herbs	Poaceae	1	
Microcharcoal		xxx	xx
Reworked	Tricolporopollenites		1
	Interpollis	5	
	Unidentified pollen	2	
	Unidentified bisaccate	11	9.5
	Unidentified trilete spore	3	2
	Apectodinium	12	7
	?Achromosphaera	19	8
	Deflandria	1	
	Glaphyrocysta	3	2
	Unidentified dinocyst	3	3
Lycopodium		345	239
Preservation		Good/ moderate	Good
Concentration		Poor	Poor
Total pollen		6.5	2



		281992 1 Alfred's Way															
		Depth (m bgl)															
		2.16	2.33	2.35	2.45	2.55	2.65	2.75	2.85	2.95	3.57	3.67	3.77	3.87	3.97	4.06	
WA04																	
Trees	Pinus							1				1	0.5		1		
	Ulmus			2	2				1								
	Quercus	17	25	20	35	35	35	25	44	42	32	40	34	29	38	8	
	Betula	2	1		2	2	3	1		3		2	1	1		2	
	Alnus	32	54	72	48	62	47	55	57	45	64	18	26	42	56	10	
	Tilia		4	2	2	3	3	13	1	10	7	19	7	2	4		
	Fraxinus		1	1					1								
Shrubs	Crataegus													1			
	Corylus-Myrica type	10	9	7	5	7	7	14	9	14	4	10	6	5	12	4	
	Salix		1	1			1	1	1	4	2		2				
	Ilex				2				1								
	Hedera			1	1				1	2			1	3	1	1	
Herbs	Rosaceae											1					
	Urtica	1															
	Epilobium	1															
	Ameria type	1															
	Malvaceae	1															
	Rumexacetosella	1															
	Amaranthaceae	3							1		2						
	Solanum								1								
	Plantago lanceolata	1							2	1	2						
	Lamiaceae													1			
	Aster-type	5							1								
	Cichorioideae	15								1		1					
	Centaurea nigra	1															
	Centaurea cyanus	1															
	Artemisia- type												1				
	Anthemis type	1															
	Apiaceae	1								1							
	Cyperaceae	42	6	2	2	1			1	3	6	6	5	52	19	22	4
	Poaceae	28	7	4	2	4	4	6	9	23	8	4	4	4	1		
Spores	Dryopteris dilitata type		1		1				1	1		3			3		
	Polypodium		2	3	2				4	7	8	4	8	4	4	6	
	Pteropsida undiff.	4	5	4	1	1			4	2	2	9	3	5	7	1	
	Sphagnum		5					3		1	1	1		3			
Aquatics	Sparganium								1								
	Typha	22	4			1	2	7	5		1	2	6				
	Microcharcoal	xxx	-	x	-	x	-	-	x	xxx	xx	x	-	-	x	xxx	
	Testate amoeba											1					
	Glomus sp.		1						2	1		7					
	Lycopodium	22	55	30	21	21	13	7	6	20	27	46	23	59	18	273	



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Preservation	G	G/M	G/M	G/M	G/M	G/M	G	G	M	G/M	G/M	E/G	M	E/G	G
Concentration	E	M	E	E/G	E	E	E	E	E/G	E/G	MP	E/G	P	E/G	P
Total pollen	164	108	112	101	114	100	121	133	148	128	101	136.5	101	133	29

Preservation/concentration: E – excellent, G – good, M – moderate, P – poor



## Appendix 6: OASIS

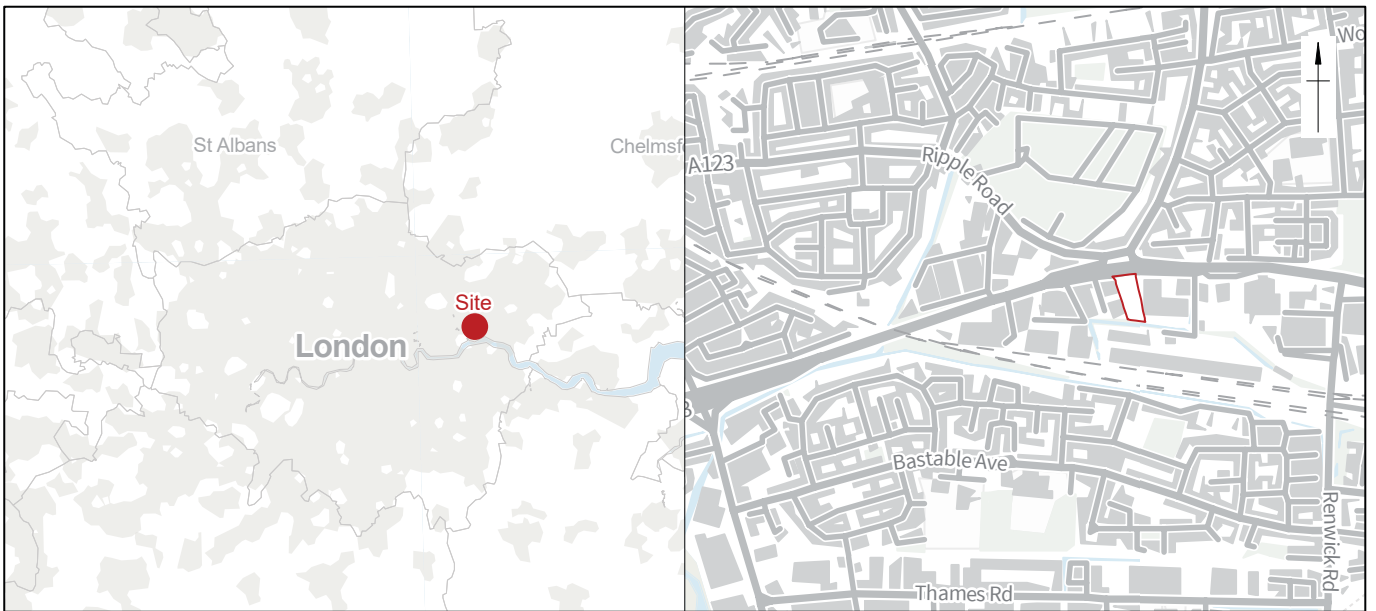
OASIS ID (UID)	wessexar1-532585
Project name	Environmental Sampling at 1 Alfred's Way, Barking, London. Palaeoenvironmental Assessment Report
Sitename	1 Alfred's Way, Barking, London. Palaeoenvironmental Assessment Report
Sitecode	281992.01
Project Identifier(s)	281992
Activity type	Environmental Sampling
Planning Id	22/01992/FULL
Reason for Investigation	Planning: Between application and determination
Organisation Responsible for work	Wessex Archaeology
Project dates	02-Sep-2024 - 28-Feb-2025
Location	1 Alfred's Way, Barking, London. Palaeoenvironmental Assessment Report NGR : TQ 46400 83600 LL : 51.532331711420866, 0.109268719166041 12 Fig : 546400,183600
Administrative Areas	Country : England County/Local Authority : Barking and Dagenham Local Authority District : Barking and Dagenham Parish : Barking and Dagenham, unparished area
Project Methodology	Wessex Archaeology was commissioned by Lok'n Store Limited to undertake a palaeoenvironmental assessment of sub-samples taken during a purposive geoarchaeological borehole survey of c. 0.6 hectares of land at 1 Alfred's Way, Barking, London Borough of Barking and Dagenham. This Site is centred on National Grid Reference 546400, 183600 (TQ 4640 8360) This report follows on from a purposive borehole survey, which identified a series of superficial deposits comprised Pleistocene sands and gravels, overlain by a Holocene alluvial sequence of minerogenic alluvium, organic alluvium and peat. The Pleistocene sands and gravels likely corresponded to the East Tilbury Marshes and/or Mucking Gravels to the north, and Shepperton Gravels in the south. Within borehole WA01, a fine-grained clay unit was encountered within the gravel sequence and was identified as high geoarchaeological potential. The series of organic alluvium and peat deposits have a high



	<p>geoarchaeological potential to provide information of the environment and vegetation history during deposition, and to contain in situ archaeology. A programme of targeted palaeoenvironmental assessment and scientific dating was recommended on boreholes WA01 and WA04.</p> <p>The principal aim of the palaeoenvironmental assessment is to determine the age, nature and depositional history of deposits recovered at the Site. The results will be used to assess the preservation potential of palaeoenvironmental remains, and to reconstruct past environments and landscapes change associated with local and regional archaeological records and settlement histories. The results will inform on the need for and scope of further analysis, where appropriate</p>
Project Results	<p>Radiocarbon dating of the peat places the deposition of the lowermost organic alluvium in the Early Neolithic (3425-3375 cal. BC), with peat formation spanning from the Middle Neolithic (3325-3250 cal. BC) to the Early/Middle Bronze Age (1615-1535 cal. BC). OSL dating of fine-grained deposits within the river terrace deposits to the north of the Site produced A date of 411±30 thousand years ago (Kya). However, the De values associated with this date are higher than the highest independently verified date, which suggests that there may have been reworking of older sediments, resulting in an older date. Within the fine-grained sediments within the terrace sequence, preservation of pollen was poor, with a high number of reworked grains, while diatoms and foraminifera/ostracods were absent. This poor preservation and concentration likely reflect aerobic conditions during deposition, allowing for microbial activity, and post-depositional activities, such as high water acidity/alkalinity. Within the lower organic alluvium, pollen and plant macroremains had good preservation and concentrations, likely reflecting anaerobic conditions of deposition. Within the peat preservation of plant macroremains and pollen was good, but diatom preservation was poor. This likely reflects aerobic conditions resulting in good preservation of pollen, but post-depositional conditions, such as high water alkalinity/acidity resulting in damage to diatom frustules.</p> <p>The sands and gravels across the Site represent two terraces, based on the elevation ranges, with the terrace subject to palaeoenvironmental assessment likely being the East Tilbury Marshes, deposited during Marine Isotope Stages 4-2. The fine-grained deposit may represent a warm-stage interglacial (MIS 3), as alder is present. However, pollen concentrations were very low, and this interpretation is tentative.</p> <p>Organic deposition occurred from the Early Neolithic to the Early/Middle Bronze Age, which is consistent with many peat deposits within the Thames Floodplain sequence. During the deposition of the early peat, the wetland environment would have been an alder carr environment with a sedge understory, with the dryland comprised of mixed deciduous woodland. Further up the peat sequence, there is a decline in sedge at the cost of bulrush,</p>



	<p>grasses and members of the goosefoot family, possibly due to a greater marine influence, but alder remains dominant. The dryland remains largely wooded, but there is some evidence of an increased number of clearings in the woodland. In the Early/Middle Bronze Age, there is a shift from peat deposition to that of organic alluvium. The wetland alder carr is replaced by a saltmarsh-like environment. The dryland woodland is replaced by more open environments, with grasses, daisies and plantains noted.</p> <p>Due to the poor preservation of palaeoenvironmental proxies within the river terrace deposits, there is limited interpretation available. However, this terrace is likely that of the East Tilbury Marsh terrace, which is associated with megafaunal remains and Mousterian-type archaeology.</p> <p>The peat deposits show some evidence of human activity, with microscopic charcoal occurring synchronously with a small increase in herbaceous taxa, which could reflect the development of small clearings within the woodland. Within the undated uppermost organic alluvium, there is evidence for widespread deforestation, with woodland being replaced by open, pastoral or arable environments. Taxa associated with disturbance become more frequent. Microscopic charcoal also becomes common, suggesting regular burning is occurring.</p> <p>Based on the results of this assessment, it is recommended that a programme of palaeoenvironmental analysis is undertaken, which would comprise pollen analysis targeting the periods with evidence for human activity, and dating of the uppermost organic alluvium associated with human activity.</p>
Keywords	
Funder	Private or public corporation Lok'n Store Ltd
HER	Greater London HER – unRev – STANDARD
Person Responsible for Work	Alex Brown
HER Identifiers	
Archives	Documentary Archive, Digital Archive – to be deposited with Archaeology Data Service Archive;

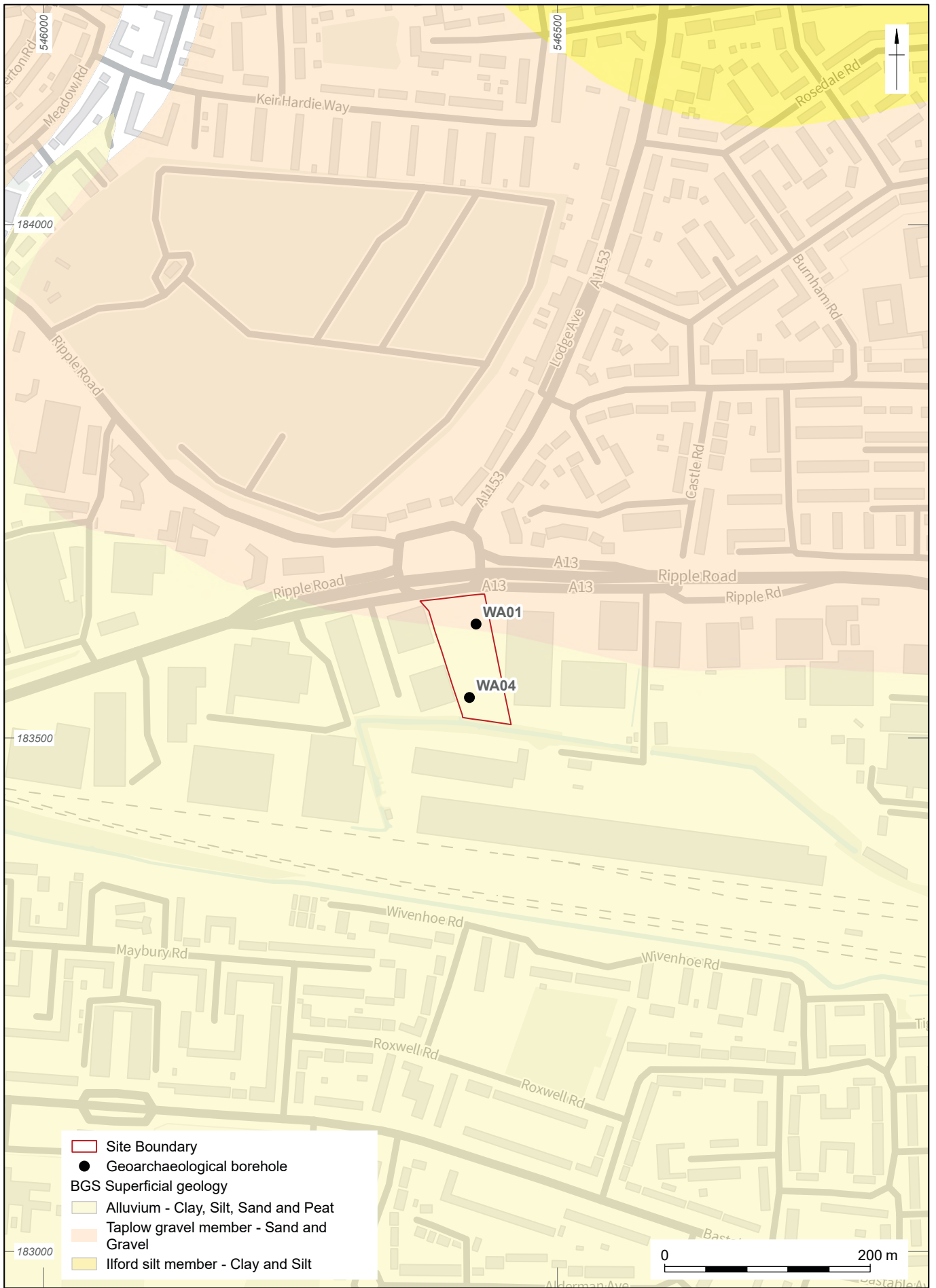


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Figure 1. Site location and bedrock geology



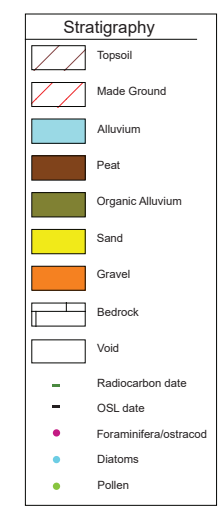
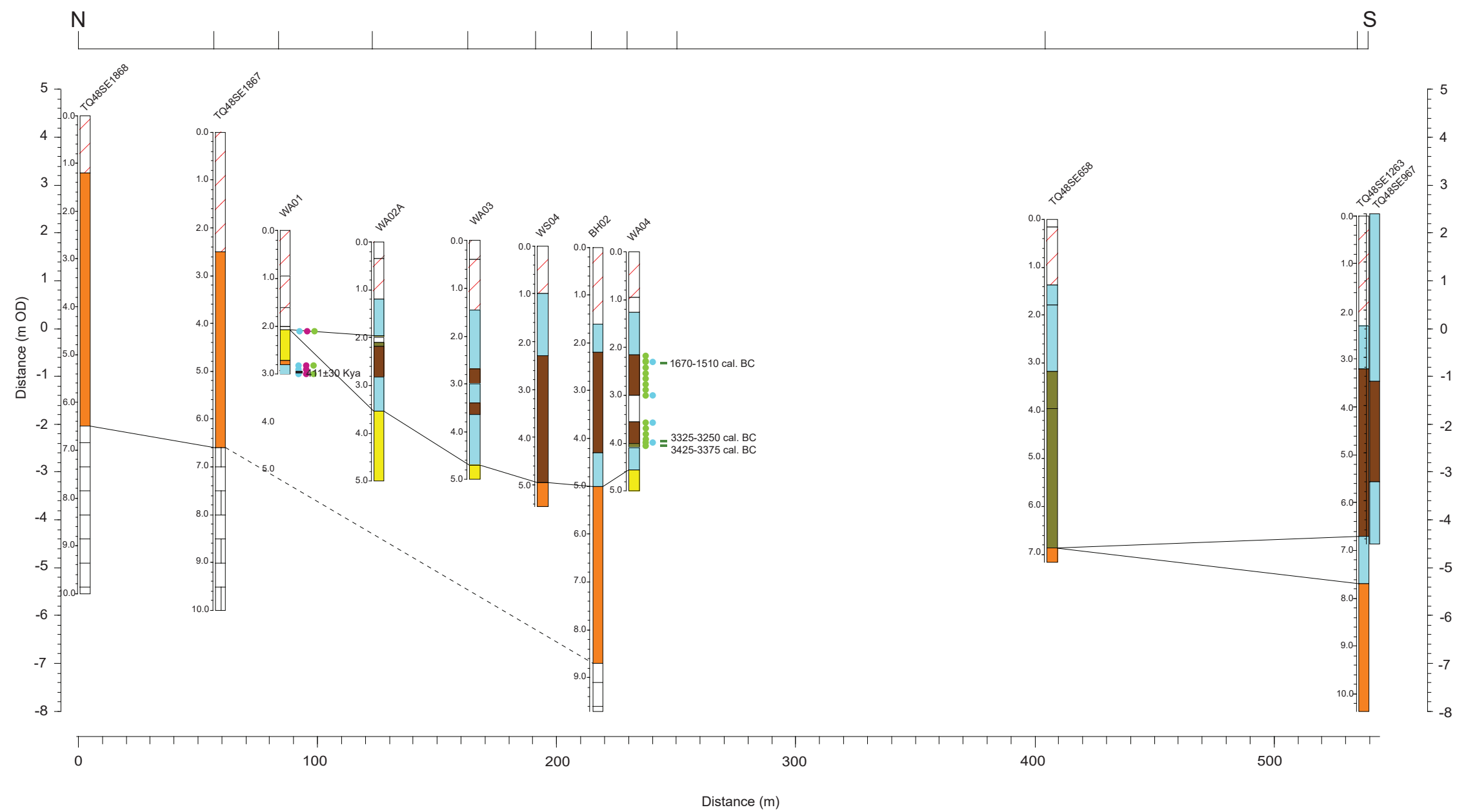
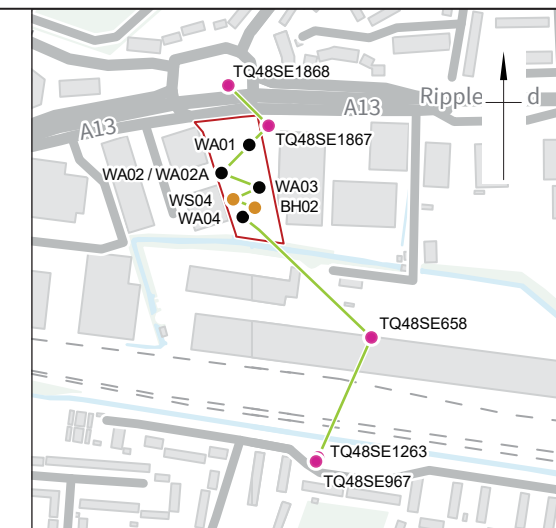


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Figure 2. Site location and superficial geology



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Figure 3. Transect 1 and sample locations



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