Crossrail

CROSSRAIL ARCHAEOLOGY

A JOURNEY THROUGH TIME: CROSSRAIL IN THE LOWER THAMES FLOODPLAIN

Graham Spurr with Mary Nicholls and Virgil Yendell

MAYOR OF LONDON

Department for Transport

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A JOURNEY THROUGH TIME:
CROSSRAIL IN THE LOWER THAMES FLOODPLAIN

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Front cover: conjectural reconstruction of the Mesolithic seasonal encampment situated on high ground at North Woolwich Portal, overlooking the river to the south (Fig 25)
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CONTENTS

FIGURES

TABLES

SUMMARY

Geoarchaeology is a branch of archaeology that focuses on understanding archaeological sites and sediments from the perspective of earth sciences. This book demonstrates how geoarchaeological studies of sediments along the Crossrail south-east worksites help us to understand the evolving landscape and environment of the lower Thames using bespoke methods, such as deposit modelling, alongside more traditional palaeoenvironmental techniques, such as pollen analysis. The Crossrail south-east route diverts southward off the main line at Stepney Green in Tower Hamlets and tunnels underneath the Thames floodplain to terminate at Abbey Wood in Greenwich.

Employing current theories on the evolution of the lower Thames as a guide, the sediments that are repeatedly found across the floodplain are put into context in an attempt to outline the broader processes at work, how the river levels and environments have changed, and how these changes may have influenced the people of the London area over time.

Beginning the story with the river gravels that underlie the modern floodplain (roughly equivalent with the Mesolithic land surface, *c* 10,000 years ago), each of the three main deposits that subsequently accumulated have been examined. Each deposit has a story to tell about how the Thames changed from a once wide, freshwater system to the muddy, brackish one we know today. Along the way we envisage how these changes affect (or were affected by) the people who lived in the region, whether they were early farmers in the Neolithic or wealthy land owners in the post-medieval period.

The scale and scope of the Crossrail project provided a rare opportunity for MOLA (Museum of London Archaeology) not only to add to the study of the lower Thames but to introduce to a wider audience something of the multidisciplinary approach modern archaeology involves. This long-term view of river-level change provided by the sediments and the archaeology within them can inform current policy as well as our understanding of past change. Information such as this can feed into the future of landscape planning, particularly in a time of climatic change and population pressures within environmentally sensitive locations such as floodplains. We hope this work will not only add to an increasing awareness of the lessons of the past but lead to a greater understanding for the future of cities like London, whose histories have always been entwined with the rivers they lie beside, such as the Thames.

ACKNOWLEDGEMENTS

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FOREWORD

Jane Sidell, Inspector of Ancient Monuments for Greater London, Historic England

London has benefited from infrastructure projects since the early years of the Roman period, the second half of the 1st century AD. Initially, these were in the form of basic town planning, laying out the roads and forming the waterfront. But these schemes were followed by true infrastructure projects designed to improve the city and its society. These included schemes to bring in fresh water, to provide a defensive wall, to bridge the Thames and construct a major sewer system. Places of worship and public open spaces were also created as part of the operation of urban Roman society in the provinces.

Over the centuries this Roman infrastructure has been replaced many times, upgraded, modernised, with new roads, walls, bridges and sewers. But with the coming of the railways, a paradigm shift occurred. So began the daily commute, where people could live further than a walk from their employment. This totally changed housing patterns, creating suburbs and leading to new architectural spaces, realms and forms, with the tracks, viaducts and of course the majestic railway stations such as the recently restored King's Cross.

Crossrail thus forms part of a long tradition of improving London for Londoners and visitors that stretches back nearly 2000 years. Today, not all those who work in London can perhaps be classed as Londoners, coming from as far afield as Maidenhead and Shenfield on the Crossrail scheme. It is appropriate then, that the Crossrail project has allowed extensive examination of the lives of past Londoners, through the fragmentary traces left behind. The great benefit to urban archaeologists from infrastructure schemes such as rail and road building is the ability to allow this examination on a landscape scale. Previous examples include High Speed 1, the Jubilee line extension and the Heathrow expansion, where significant new information was generated.

This volume is an important new contribution in this tradition of major projects, allowing us to glimpse at the past and understand what London actually looked like before the Romans started laying out their roads. A geoarchaeological approach has permitted the authors to take away samples of the very landscape itself, and interrogate these samples at a microscopic scale, using individual grains of pollen and sediment to see how London has evolved. The book charts the south-eastern stretch of the Elizabeth line and has woven a picture of how the inhabitants would have perceived and used the river valley, and how the changing Thames has affected those societies.

The story begins shortly after the end of the last ice age, when settlement was very ephemeral and the traces left by Mesolithic society are slim indeed. We have so little evidence of how these people lived that new information, in new parts of London, is extremely valuable. The story is traced through to the creation and use of salt marsh grazing adjacent to the Thames in the later medieval period, and shows a landscape that until relatively recently has changed very little, with the slow but constant rising of the Thames a continual, and perhaps worrying, theme.

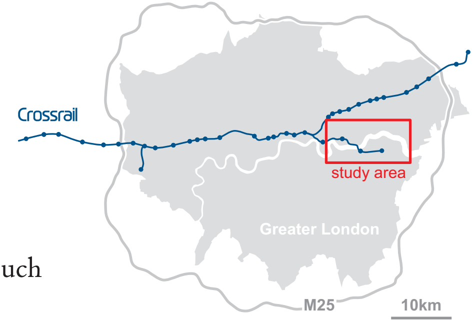
The authors have taken a refreshingly direct approach – placing themselves into the minds of the people living here, describing what they could actually see and examining their allegiances and anxieties. Consideration is, of course, given to the landform, with plenty of scientific data as to how the landscape morphed and evolved with the deforestation of the landscape and the introduction of farming, and how people would have travelled around south-east London in the millennia before rail travel. This is a valuable volume and one that I hope we shall see others emulate when London is next improved for the better operation of its society.

CHAPTER 1

CROSSRAIL SOUTH-EAST WORKSITES AND THE WIDER STUDY AREA

1.1 Introduction

The Crossrail project, the first complete new underground line in more than 30 years,[1] gave rise to a wealth of archaeological work that took place between 2008 and 2016. As a whole, the Crossrail route (which will be known as the Elizabeth line from December 2018) runs *c* 118km from Reading in Berkshire and Heathrow in the London Borough of Hillingdon (Middlesex) in the west to Shenfield in Essex and Abbey Wood in the Royal Borough of Greenwich (Kent) in the east (Fig 1). This book was initiated by geoarchaeological studies carried out along the south-easterly branch arm that diverts from the main west–east tunnel route at Stepney Green in Tower Hamlets and terminates at Abbey Wood.



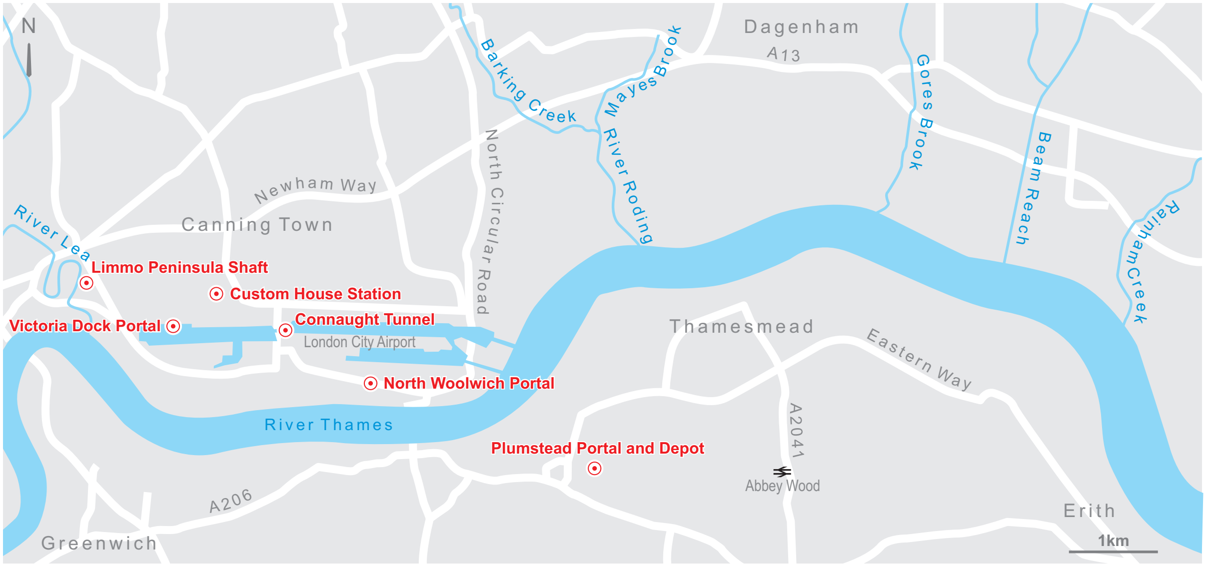


Fig 1 The Crossrail route showing the study area and the six sites (in red) (scale 1:85,000)

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Geoarchaeology is a way of understanding archaeological sites and deposits through earth science techniques and principles, such as those learnt from geology, geomorphology and environmental sciences. Geoarchaeology is particularly useful across the Crossrail south-east worksites because, in areas such as floodplains, the general lack of cultural indicators at these locations (ie artefacts) is often countered by the bounty of palaeoenvironmental (ancient environmental) evidence, including indirect indications of the effects of people on their surroundings. Furthermore, the depth of sediments across floodplains often physically exceeds access by traditional trenching techniques, thereby redefining the means by which archaeologists can access the information that these sites withhold. Essentially, by probing these alluvial sediments with boreholes, for example, geoarchaeologists can sample sediments at great depth safely, and scrutinise them off site under laboratory conditions for the information they contain. Across the Crossrail south-east work area, however, sampling of the sites was often undertaken by examining trench sections (Fig 2).

Six sites across the Crossrail south-east work area were targeted for geoarchaeological investigation where the tunnelling work surfaced, whether at stations, portals, or track lowering. In all, the sites included five locations on the northern side of the Thames – (from west to east) Limmo Peninsula Shaft (site code: XRW10), Victoria Dock Portal (XSX11), Custom House Station (XTI13), Connaught Tunnel (XSY11) and North Woolwich Portal (XSV11), all in Newham – and one on the southern bank of the Thames – Plumstead Portal and Depot (XSW11), in Greenwich (Fig 1). All these sites were analysed following excavation using standard geoarchaeological techniques studying the sediments, the dates of accumulation and the changing environments they reflect.

Fig 2 A geoarchaeologist sampling from a section through the organic complex and upper alluvial sequence at the North Woolwich Portal site, looking west

The area covered by the Crossrail south-east worksites was in the upper reaches of what is known as the lower Thames valley (from Blackfriars Bridge, which links the City of London and Southwark, to Shorne marshes in Kent). The study area was expanded to incorporate sites MOLA (Museum of London Archaeology) and other archaeological units have been involved with further to the east (the lower Thames mid estuary) in order to demonstrate geoarchaeological deposit modelling (the technique that geoarchaeologists use to map the changing environment of an area through time) across the valley's diverse terrain. In total the study area crossed six London boroughs stretching from Tower Hamlets, Newham and Greenwich in the west to Bexley and Havering in the east, and Barking and Dagenham in the north (Fig 3).

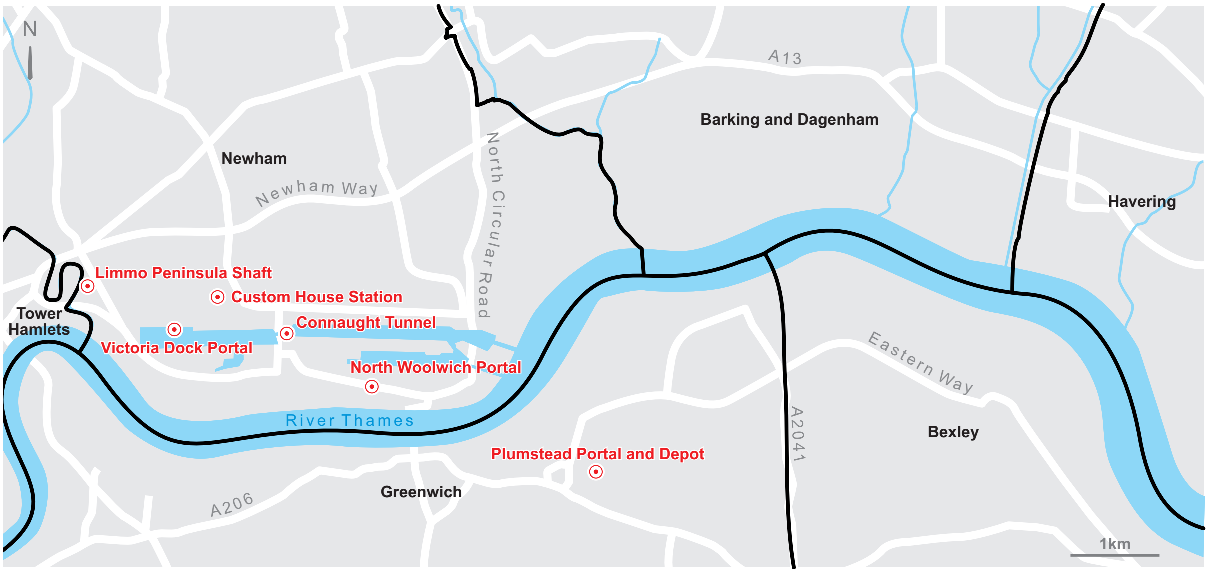

Fig 3 The study area showing the six London boroughs and the six Crossrail south-east worksites (scale 1:85,000)

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1.2 About this book

This book begins with the Thames *c* 10,000 years ago, shortly after the beginning of the Holocene, the most recent geological epoch, roughly equivalent with the beginning of the archaeological period known as the Mesolithic. At this time, the lower Thames valley was broad and expansive with clear running freshwater channels and lakes, markedly different from the essentially canalised, murky appearance of the Thames today. From this baseline we will look at how the area has changed over time up until the present day: from a freshwater to a brackish, tidal river, from a wide floodplain of gravel and sand to one of marsh and muds.

Along this journey, we will explore how this part of the Thames was affected by the people who were attracted to this area from the prehistoric to the post-medieval period and how, in turn, the physical environment may have affected them. This book, although drawing on a large amount of academic study, will not, however, be one of a deeply technical nature but more of a voyage through time, exploring how the environment of this part of the Thames has changed and is now being studied through geoarchaeology.

Following this introduction, Chapter 2 sets the scene looking at how the ice ages shaped the Thames valley in the run up to the Holocene and the nature of the archaeological timescales over these periods. Chapter 3 introduces the main themes of the book and the tripartite sequence of deposits that characterise the deposit sequence of the Thames and are the focus of this book. It also outlines the background work and models that are helping us to understand how the lower Thames area developed and, importantly, how this affected the people who lived there. Chapter 4 looks at the 'geoarchaeological toolbox' or the methods geoarchaeologists use to analyse the sediments of the past (including those across the Crossrail south-east work area), which range from palaeoenvironmental and sedimentological analyses to computer modelling of borehole data. Chapters 5, 6 and 7 look in detail at the tripartite sequence, discussing each in chronological order from the Mesolithic to the Neolithic and Bronze Age and, finally, from the late prehistoric through to the historic periods. Chapter 8 concludes the book with a look to the future. The appendices in Chapter 9 provide a glossary of geoarchaeological terms and details of the radiocarbon dating results.

The date ranges of the various cultural periods such as the Mesolithic are taken from *The archaeology of Greater London*.[2] County names in the text refer to historic counties.

The paper and digital archives, together with the finds from the sites are publicly accessible in the archive of Museum of London, where they are held under the site codes XRW10 (Limmo Peninsula Shaft), XSX11 (Victoria Dock Portal), XTI13 (Custom House Station), XSY11 (Connaught Tunnel), XSV11 (North Woolwich Portal) and XSW11 (Plumstead Portal and Depot). They can be consulted by prior arrangement at Museum of London's Archaeological Archive (LAA), Mortimer Wheeler House, 46 Eagle Wharf Road, London N1 7ED; the digital archive will also be deposited with the Archaeology Data Service (ADS).[3]

Notes to Chapter 1

1 Crossrail http://www.crossrail.co.uk

2 MoLAS 2000

3 LAA https://www.museumoflondon.org.uk/collections/other-collection-databases-and-libraries/museum-london-archaeological-archive; ADS https://archaeologydataservice.ac.uk

CHAPTER 2

SETTING THE SCENE

Human activity in Britain has taken place during the period of geological time known as the Quaternary period, which spans the last 2.6 million years and is characterised by the climatic oscillations commonly known as the ice ages. The Quaternary is broadly subdivided into the Pleistocene epoch *c* 2.6 million–*c* 11,500 years ago and the Holocene epoch (*c* 11,500 years ago to present).

The Thames valley, as we know it today, has been sculpted through the effects of ice advance and retreat, during glacial and interglacial periods of the Pleistocene, respectively. The greatest ice advance *c* 450,000 years ago in the latter part of the Pleistocene, known as the Anglian glaciation, had a profound effect on the Thames as it changed its route from one that ran through the vale of St Albans (Hertfordshire) into eastern Essex to the route we know today.[1] Indeed, the Anglian glaciation was so extensive that the ice front reached as far as Hornchurch in Havering (Essex), just within the limits of the study area (Fig 4).[2]

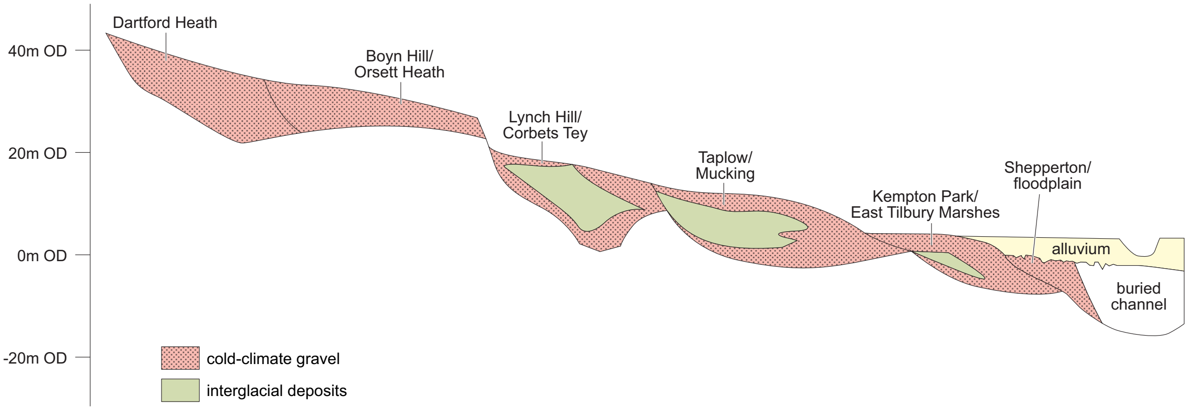
As the ice sheets thawed, meltwater swept down the river valleys of Britain, including the Thames, carving through their floodplains, leaving only a patchwork of evidence remaining.[3] Along the Thames, as along many rivers, the evidence of these climatic cycles largely survives as a downslope sequence or 'staircase' of older to younger river terraces lining valley sides (Fig 5).

The river terraces of the Thames have been subject to much study, not only as topographic remnants of the past but also as archaeologically important indicators.[4] Some of the river terraces contain faunal and Stone Age tool evidence from which we can build a picture of the past environments of the Pleistocene and the type of peoples who inhabited them.[5]

Toward the end of the Pleistocene, during the last great thawing of the ice sheets, sea levels worldwide began to rise again. Along the Thames, the high-energy ice-meltwaters deposited the gravels and coarse sands across the floodplain (known as Shepperton Gravel) drawing a line (and a level) to Pleistocene deposits within the study area. At this time the current warm period or interglacial known as the Holocene began. The Holocene means 'wholly new' and was coined in the 19th century to differentiate the period from the previous ice ages. The most important feature of the Holocene, which separates it from any other period, is, of course, the rapid cultural development of modern peoples (*Homo sapiens*).

Fig 4 Limits of the Devensian glaciation and the Anglian glaciation, the latter being the most extensive of all during the Pleistocene (arrows indicate direction of ice flow) (scale 1:10,000,000)

Fig 5 Schematic section through the lower Thames terrace sequence (after Bridgland 2006, fig 1)



The start of the Holocene approximately equates with the beginning of the Mesolithic (*c* 10,000 years ago/*c* 8000 BC), when hunter-gatherer groups came back to Britain from the refuge of Continental Europe. From the Late Mesolithic (*c* 7000–*c* 6000 years ago/*c* 5000–*c* 4000 BC) onwards, the Thames we know today formed, periodically depositing thick alluvium and influencing peat growth across the floodplain floor.

The following Neolithic period (*c* 4000–*c* 2000 BC) was the final stage in the long history of Stone Age culture. It is characterised not only by new techniques in tool making but by the adoption of agriculture, pottery, sedentary living and the construction of large ceremonial monuments like the first phases of Stonehenge. In terms of the ancient environment and our study, the clearance of woodland for hunting, pastoralism, agriculture and settlement occurred at a time when, due to natural changes in river levels, wide expanses of marshland developed across the Thames floodplain that continued throughout the following Bronze Age.

The Bronze Age (*c* 2000–*c* 800 BC) and subsequent Iron Age (*c* 800 BC–AD 43), when societies became more complex, metallurgy developed and agricultural practices became more widespread, was also a time of deteriorating (largely wetter) climatic conditions.[6] In Britain, the Iron Age also marks the end of the prehistoric period, with the Roman invasion in AD 43 demarcating the beginning of the historic period.

The historic period spans the last 2000 years or so and stretches from the Roman invasion through the Anglo-Saxon (and Viking) period (the early medieval period), the Norman invasion (beginning the medieval period – 1066) through to the post-medieval period which began with the Tudors (1485) and the Dissolution of the monasteries (1536–40/1), and takes us up to the present. Of course, the historic period is characterised by the written word documenting history. The environment, at this time within the study area at least, is reconfigured dramatically with the creation and expansion of London and changes in the Thames from a freshwater river to a brackish river with the migration of the tidal head upstream as far as around Teddington in Richmond upon Thames. During this time, the land along the Thames would have been flooded due to a sustained rise in relative sea level (RSL) and it would have remained largely uninhabitable, although utilised for its agriculturally valuable water meadows until modern development.

The archaeological timescale, charting the development of human activity in Britain through both the Pleistocene and the Holocene and referred to widely throughout this book, is shown in Table 1.

Table 1 Archaeological timescales

Period	Time period/date (years approximate)	Characteristics/events
The Pleistocene (prehistoric)		
Lower Palaeolithic	1,000,000–150,000 years ago	ancestral humans: hominins
Middle Palaeolithic	150,000–45,000 years ago	hominins
Upper Palaeolithic	45,000–10,000 years ago	*Homo sapiens*
The Holocene (prehistoric)		
Mesolithic	10,000–6000 years ago/8000–4000 BC	development in stone tool manufacture, hunter-gatherer foragers; later period woodland clearance; mobile groups, ephemeral remains
Neolithic	4000–2000 BC	the earliest farmers, settlement, first large communal tombs, earliest ceremonial monuments
Bronze Age	2000–800 BC	'Beaker' people; first substantial use of metals, advanced pottery-making techniques, and more sophisticated weapon making; more complex societies and religious monuments; development of trading and exchange contacts between Britain and mainland Europe
Iron Age	800 BC–AD 43	increasing development of metallurgy, agricultural intensification; political elites; international trade and technological innovation
The Holocene (historic)		
Roman	AD 43–410	improved agriculture, urban planning, industrial production, architecture, extensive road networks and the first written records
Anglo-Saxon/early medieval	AD 410–1066	emerging English national identity, language and literature, Christianisation, charters and law; invasion by the Vikings, establishment of Danelaw
Medieval	1066–1485	Norman Conquest; feudal system; crusades; plague and climatic deterioration; burgeoning nationalism; embryonic parliamentary developments; increasingly complex forms of art, literature, poetry, music and theatre
Post-medieval	1485–present	the Tudor monarchy; civil war; the Industrial Revolution and Victorian Britain, maritime dominance and empire; worldwide influence in art, literature, poetry, music and theatre

Notes to Chapter 2

1 Bridgland 1994, 3
2 Ibid, 176
3 Gibbard 1994, 2–3, fig 1
4 Ibid, 1–9
5 Ibid, 162–73
6 Barber et al 2004

CHAPTER 3

GEOARCHAEOLOGICAL RESEARCH

Much of the story of the lower Thames is that of relative sea-level (RSL) change. Towards the end of the Pleistocene, *c* 18,000 years ago, sea level was as much as 120m lower than it is today only reaching modern levels by about 6000 years ago.[1] However, as a result of isostatic rebound (the seesaw effect caused by the release of the weight of ice over northern Britain) in relative terms, the level of the sea around southern England has continued to rise with respect to that of the land, flooding the low-lying river valleys.

The effect of RSL within the lower Thames valley over the last 6000 years is echoed in the floodplain deposits. It is a pattern which is repeated again and again in boreholes across the floodplain, and in essence tells a story of three main periods and associated phases of deposition. Firstly, toward the end of the Mesolithic (Table 1), as the sea began to filter into the estuary, the Thames and its tributaries were ponded back and waterlogging of previously dry land surfaces started to occur, flooding increased and sandy clay alluvium was deposited. Secondly, during the Neolithic and Bronze Age periods, because RSL stabilised or fell, widespread peat and organic clay deposits developed across the floodplain. Finally, during the late prehistoric and historic periods, marine incursion occurred again in earnest and the lower Thames was drowned under increasingly brackish conditions depositing more alluvium in salt marsh and mudflat environments which, over time, stretched up past London as far as Teddington weir.

This 'tripartite sequence' of deposits was acknowledged in research in the early 2000s[2] and since employed across the region,[3] and will be employed throughout the text. The first stage is termed the 'lower alluvium', the second the 'organic complex' and the final stage the 'upper alluvium' (Fig 6; Table 2). Quaternary scientists and geographers are interested in the alluvial sequence for the information it provides on the pattern of local RSL change and its implications for Holocene sea-level fluctuations and climate change at a wider scale.[4] Archaeologically, the significance of the interbedded peats and clays within the floodplain lies in the information they provide about past fluctuations in the environment and thus the changing landscape available to be exploited and inhabited by people in the past.

3.1 Background research

The sediments of the lower Thames have been investigated since the late 19th century in order to understand and classify them in terms of their geomorphology,

Fig 6 Sections from the Connaught Tunnel site indicative of the sedimentary sequence typical of the Thames floodplain, showing organic complex overlain by upper alluvium and finally made ground, looking east (1m scale)

formation (ie the landscape processes at work in the valley) and age. Initial studies concentrated on the gravel terraces,[5] and it became clear that they are the result of aggradation by the river in earlier times and, importantly, formed in synchrony with the large-scale climatic changes of the Pleistocene.[6]

During excavation of docks such as Tilbury (Essex), early researchers were also able to observe the soft alluvium and peat infilling the gravel valley, replete with buried forests, fauna remains and artefacts.[7] The interleaving layers of peats and silts within the alluvium introduced terms such as 'regressive and transgressive events' to describe and interpret changes in sea level, and even named horizons that represented specific episodes (eg 'Tilbury Stage'[8]).

It was not until Devoy's seminal work[9] was published, however, that a stratigraphic framework was developed (substantiated with palaeoenvironmental analysis and radiocarbon dating) that established a narrative between former environments, landscapes and RSL fluctuations across an extensive area of the Thames estuary. Following Devoy, particularly over the last 20 years, highly influential books and papers have advanced these arguments investigating RSL, palaeoenvironments and archaeology in this part of the Thames, four of which are referred to widely in this study and are recommended to the reader for further detail.[10]

For the purposes of this study, however, much will be made of the lower Thames modelling by Bates and Whittaker,[11] as this is central to understanding the nature of how the Thames has evolved and developed throughout the Late Pleistocene and Holocene.

The model (known as the cultural landscape model or CLM) draws upon previous investigations (including Devoy's) to suggest a history of landscape change that can be summarised in six different stages (CLM stages) of lower Thames sedimentation (Table 2). Importantly, the CLM stages outline how changes in RSL affected the landscape and people throughout the prehistoric and historic periods; we will refer to these stages throughout this text.

It is important to note, as pointed out by Sidell,[12] that these geoarchaeological and palaeoenvironmental models tracking RSL changes in the Thames estuary tend to focus more heavily on the prehistoric, primarily because of the lack of easily dated organic sediments in the CLM stage 5 deposits and later. As a counterbalance to this, archaeologists are increasingly providing RSL data through structural

Table 2 The cultural landscape model (CLM) stages of lower Thames sedimentation and environment (after Bates and Whittaker 2004)

CLM stage	Time period (years ago approximately)	Archaeological period	Characteristics
1: Lateglacial	a: 30,000–15,000	Upper Palaeolithic	Lateglacial period; low sea level; reworking of river terraces under periglacial conditions; downcutting by river greatest at Glacial Maximum (height of cold period) 18,000 years ago
	b: 15,000–10,000	Upper Palaeolithic	valley infilling and deposition of Shepperton Gravel; Lateglacial braided channel system; high fluvial energy
2: Early Holocene	10,000–7000/6000	Mesolithic; Early Neolithic	early period of landscape stability across floodplain; low fluvial energy; complex vegetation mosaics; sedimentation largely sand bodies within river channels and areas of localised peat growth
3: Middle Holocene	7000/6000–5000	Neolithic	major landscape instability; sea-level rise associated with extensive flooding (initially freshwater then brackish); expansion of wetland environments across previously dryland areas; mainly minerogenic sedimentation (clay/silts); numerous temporary and ephemeral land surfaces existing within flooded zone
4: Late Holocene	5000–3000	Neolithic/Bronze Age	apparent sea-level fall or stabilisation and associated reduction of tidal influence; period of organic sedimentation under brackish conditions (alder carr peat development) equating with Devoy's (1979) Tilbury III; expansion of wetland environments inland; topographic variation lost
5: later Holocene	3000–1000	Late Bronze Age; Iron Age; Roman; early medieval	final submergence of floodplain with minerogenic (clay/silt) sedimentation dominating; no organic sedimentation; brackish tidal conditions as tidal head moves up lower Thames
6: later Holocene	1000–present	medieval; post-medieval	human manipulation of floodplain (flood defences and drainage channels); sedimentation rates reduce

remains and their relationship to the river throughout the historic period from the Roman through to the post-medieval periods.[13] An often quoted example was an archaeological excavation at Regis House[14] in the City of London, next to London Bridge, where a sequence of progressively lower waterfront structures dating to the Roman period indicated that sea levels dropped by as much as 1.5m throughout the Roman occupation from 1st-century AD levels of *c* 0m OD until reversing in the Anglo-Saxon period (*c* AD 600) (Fig 7).[15]

Fig 7 Model of the Roman waterfront adjacent to the first London Bridge, showing extension of the waterfront following receding water levels in the Thames, looking north-north-east (Museum of London)

3.2 Site-specific studies

In terms of more site- or area-specific work across the lower Thames over the years, a growing corpus of published and unpublished (grey literature) work across the region has developed in a largely sporadic fashion, determined by commercial development and the need for infrastructure (not least that associated with the Crossrail development). The study area, therefore, encapsulates much of what the lower Thames has to offer in terms of its stratigraphy, depths of deposits, palaeotopography, palaeoenvironments and, of course, archaeology (Fig 8; Table 3).

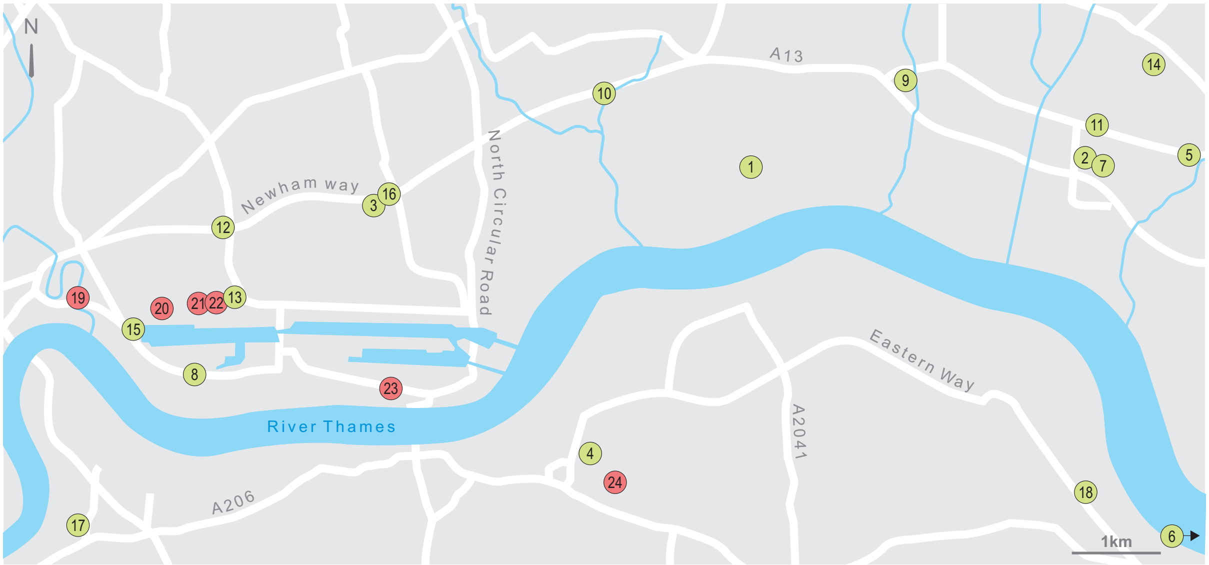


Fig 8 Sites within the study area mentioned in the text (for key to sites see Table 3; Crossrail south-east worksites shown in red circles) (scale 1:85,000)

Table 3 Details of sites within the study area shown on Figs 8 and 26

Site no.	Site name/address	Site code	NGR	Reference
1	Barking Riverside Penwick Road, Barking, Barking and Dagenham, IG11 0XF*	RWC10	547000 182500	Green et al 2014
2	Beam Reach Industrial Park, Marsh Way, Rainham, Havering, RM13	BMR11	550714 182512	Spurr 2012
3	Beckton nursery, Newham Way, Beckton, Newham, E6*	HE-BN94	542600 182000	Meddens 1996
4	HMP Belmarsh West, Western Way, Thamesmead, Greenwich, SE28 0EB*	BWQ08	545194 179293	Hart 2010
5	Bridge Road, Rainham, Havering, RM13*	RA-BR89	552045 182498	Meddens 1996
6	Erith Forest, Erith, Bexley*	-	553467 178121	Seel 2002
7	Ford Park Road, Canning Town, Newham, E16	FDP07	551056 182443	Nicholls et al 2013
8	Fort Street, Silvertown, Newham, E16*	HW-FO94	540815 180151	Crockett et al 2002
9	Hays Storage Services Ltd, Pooles Lane, Ripple Road, Dagenham, Barking and Dagenham, RM9*	DA-HS93	548716 183419	Meddens 1996
10	Movers Lane, Barking, Barking and Dagenham*	ML group	545255 183330	Stafford 2012
11	105–109 New Road, Rainham, Havering, RM13	NEU09	550870 182917	Bull 2014
12	Prince Regent Lane, Newham, E16*	PRL group	541000 181800	Stafford 2012
13	Royal Docks Community School, Prince Regent Lane, Newham, E16	PRG97	541323 181084	Holder 1998
14	South Hornchurch, Havering*	SH	551500 183500	Guttmann and Last 2000
15	Urban Sustainability Centre, Silvertown Way, Newham, E16	USC10	540020 180640	Nicholls and Halsey in prep
16	Woolwich Manor Way, Newham*	WMW group	542850 182200	Stafford 2012

Table 3 *(continued)*

Site no.	Site name/address	Site code	NGR	Reference
17	Bellot Street, Greenwich, SE10*	GBL05	539350 178490	Hawkins 2005
18	Bronze Age Way, Belvedere, Erith, Bexley*	BAW	550800 178700	Bennell 1998
19	Limmo Peninsula Shaft, Lower Lea Crossing, Newham, E16 1DN	XRW10	539495 180982	Spurr 2015
20	Victoria Dock Portal, Seagul Lane, Newham	XSX11	540402 180908	Spurr 2015
21	Custom House Station, Victoria Dock Road, Newham, E16 3BU	XTI13	540880 180948	Spurr 2015
22	Connaught Tunnel, Newham, E1	XSY11	541103 180945	Spurr 2015
23	North Woolwich Portal, Albert Road, Factory Road, Newham, E16	XSV11	542879 179972	Spurr 2015
24	Plumstead Portal and Depot, Woolwich New Road, Greenwich, SE18	XSW11	545528 178897	Spurr 2015

*non-MOLA sites discussed in this volume

Notes to Chapter 3

1 Sidell et al 2000, 15–16; Gornitz 2007
2 Bates and Whittaker 2004
3 Stafford 2012; Green et al 2014
4 Eg Long et al 2000
5 Eg Spurrell 1885; Whitaker 1889
6 Gibbard 1994, 9; Bridgland 1994, 9–10
7 Spurrell 1885; Whitaker 1889
8 Wilkinson et al 2000
9 Devoy 1979
10 Sidell et al 2000; Sidell 2003; Bates and Whittaker 2004; Corcoran et al 2011
11 Bates and Whittaker 2004
12 Sidell et al 2000, 16
13 Eg Milne 1985
14 Brigham et al 1996
15 Sidell et al 2000, 16

CHAPTER 4

RECONSTRUCTING THE EVOLVING ENVIRONMENT

4.1 Introduction

Geoarchaeologists have a variety of tools at their disposal for understanding how and why an archaeological site came to exist through cultural and natural site formation processes. These range from looking at the properties of the sediment (sedimentology) and analysing semi-fossilised plant and animal remains (palaeoenvironmental analyses), to computer modelling using data from boreholes. These techniques are particularly useful for thick and deeply buried alluvial deposits, as their application can characterise the environment as well as look for evidence of human activity in areas too deep for traditional trenching, like river valleys. Even where little direct archaeological evidence survives, a story can be told that often has meaning for sites in the wider landscape.

4.2 Palaeoenvironmental reconstruction

As we have seen, the Quaternary is a unique time in earth history for its rapidly oscillating climate (in geological terms) and the evolution of humans. We know about how the environment changed because of an important tool in the tool kit: palaeoecology. Since the late 19th century and the pioneering work of Clement Reid, palaeoecology has emerged as a powerful discipline that brings together geology, stratigraphy, vegetation and faunal history.[1] Palaeoecology, or palaeoenvironmental research, uses the microscopic remains of plants and animals that survive within sediment to explore past environments. If the relationship between past organisms and the environment in which they lived can be understood, we can learn about the evolution of ecosystems, landscape and climate. The sorts of microscopic remains that are durable and can be extracted from sediment include pollen, diatoms and ostracods – the methods for these will be sketched out here, although many other techniques are available.[2]

Palaeoenvironmental work typically involves in-tandem laboratory analyses of micro- and macrofossils – both floral and faunal – coupled with radiocarbon dating. Pollen analysis, for example, works well with an analysis of larger (macro) plant remains (eg twigs and seeds) in helping to build up a picture of the vegetation on and around a site, and how that changes over time. Radiocarbon dating of organic materials will provide a time frame or chronostratigraphy for a sequence of deposits. Detailed sedimentological analysis can include soil micromorphology (thin section analysis), soil chemistry (loss-on ignition and carbonates analysis) and magnetic susceptibility – all of which can reveal evidence within the sediments too small to see with the naked eye. What follows is a selection of those used across the Crossrail south-east worksites. For a more detailed overview of these and other environmental techniques see the Historic England guide.[3]

Fig 9 Pollen grain from the lime tree (*Tilia* sp), one of the dominant species of the deciduous woodland in the prehistoric period (actual size, diameter just under 0.05mm) (R Scaife)

Pollen analysis, or palynology, is the analysis of the range of plant pollen types present in sedimentary layers, such as evidence of lime trees (or *Tilia* sp) (Fig 9). Pollen is released by plants year on year (as every hay fever sufferer knows), some of which becomes buried in the sediments as they accumulate. By taking small samples of sediment throughout the sedimentary profile (from which pollen is extracted), palynologists can tell us what the vegetation was like locally when a layer was deposited. Hence, if samples are taken from the bottom to the top of a borehole or trench sequence of deposits we can see how the vegetation changes through time. This is particularly relevant to archaeology, as pollen reflective of woodland clearance activities and crop production, for example, is a good indicator of the presence of people in the area (particularly during the Neolithic and later).

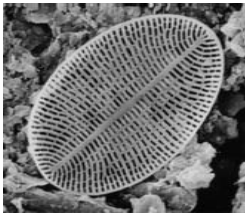


Fig 10 Electron micrograph of *Cocconeis placentula*, a very widely distributed diatom, found in mostly freshwater, benthic habitats; it is a fast-growing, pioneer species able to colonise quickly bare substrates (actual size, length *c* 25μm)

Plant macrofossils are larger, visible plant remains such as wood, seeds, fruit and leaves that have been preserved by charring, waterlogging or mineralisation. Like pollen, they can be good indicators of the environment at the time of deposition, as well as indicators of human activity. Plant macrofossils can shed light on such things as diet, agriculture and, particularly in the post-medieval period with the introduction of non-indigenous species from across the world, changing socio-economic circumstances.

Diatoms are algae which have hard external layers or frustules made of silica (Fig 10). These frustules survive within deposits and can be identified to species level by their distinctive shapes and patterns. They survive particularly well in waterlain deposits from alluvium (flood deposits) through to ditch deposits, and can be used to track changes in the water body such as salinity as well as levels of pollution. In relation to this study, diatoms are a very good way of tracking the effects of sea-level change within the Thames, as the river changed from a predominantly freshwater to a brackish one over time.

Ostracods are small crustaceans (like a shrimp) but encased in a calcareous shell of two valves (like a mollusc) (Fig 11). Their shells can be studied and discerned by their unique shapes and sculpturing. Like diatoms they exist in a wide variety of aquatic habitats from freshwater to marine. They are good indicators of salinity, water depth, temperature, water acidity or alkalinity (pH) and other environmental conditions that help discern not only the nature of Holocene environments they inhabited but those of the Pleistocene (Ice Age) environments as well.

In contrast to the above, sedimentological techniques including soil micromorphology, chemical analysis and magnetic susceptibility are commonly used in geoarchaeology. Soil micromorphology, for example (Fig 12), involves microscopic analysis of selected blocks of sediments where microstructures, soil particles, root traces and microscopic evidence of human activity can be seen.

Fig 11 Ostracod *Cyprideis torosa* originally described from Grays (Essex) on the old course of the River Thames – about 320,000 years ago when the estuary was further to the north of the present one; this species has bumps or nodes on its shell indicating that the Thames at Grays was brackish and tidal, albeit with a very low salinity (actual size, length 1mm)

(J E Whittaker, Natural History Museum)

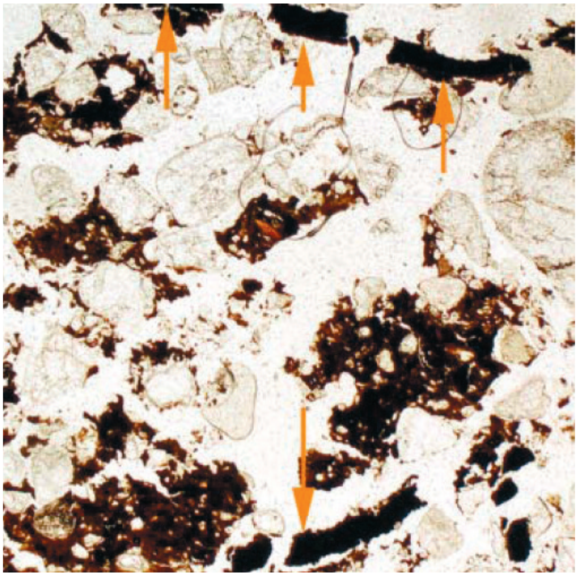


Fig 12 Photomicrograph of sediment sample from the North Woolwich Portal site; a peaty sandy soil with charred material (arrowed) was noted, evidence amongst other things of a midden site (actual frame width 4.62mm)

(Richard MacPhail)

4.3 Deposit modelling

Increasingly, and particularly in relation to this study, geoarchaeological deposit models are being used as predictive and interpretative tools in archaeological study.[4] A deposit model generally uses logs of deposit sequences (eg borehole and trench logs) to construct cross sections (transects) and two-dimensional (2D) or three-dimensional (3D) topographic models. Using these techniques, geoarchaeologists can preliminarily reconstruct the sequence of changing environments and landscapes that the deposits represent, layer on layer, in order to identify important archaeological and environmental features.

The first stage of deposit modelling involves gathering the data. These data can take the form of geotechnical or archaeological borehole logs, test pits or trench data. Some of this information is provided by the site contractor or previous archaeological investigations, for example, although many borehole logs can be obtained as freely available 'open source' data from the British Geological Survey (BGS).[5]

The data set for this book consists of 2310 data points, representing deposit logs, over *c* 84 square km. A regular distribution of these data points over the area would provide an expected average distance between data points of 66m, whereas the observed average distance between the data points is 16m, suggesting some clustering which will affect extrapolation of the data across such a wide area, not untypical of computer modelling as a whole. The majority of the deposit logs themselves were directly recorded by MOLA geoarchaeologists, but 531 (23%) are historic logs from BGS records (Fig 13).

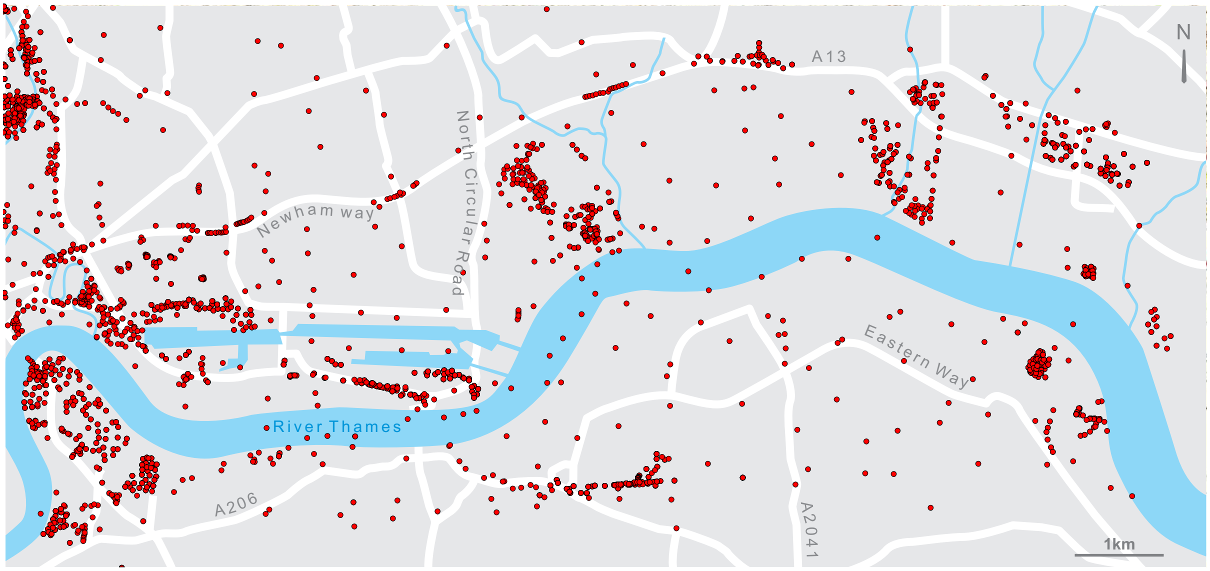


Fig 13 Locations of boreholes across the study area; the clusters centre on Crossrail and other major archaeological sites, notably at the western edge of the study area; despite clustering, data are present at least every kilometre; coverage becomes sparse towards the fringes of the study area where the limits of the alluvial floodplain and the gravel terraces are evident (scale 1:85,000)

Once the data are assembled, the next step is to enter the heights, nature and thicknesses of the different deposits into a digital database (commonly RockWorks[6]) through which each deposit component can be linked with similar deposits across the site. From these correlations a series of working cross sections (or transects) are constructed. Linking similar deposits between boreholes across transects produces a series of site-wide deposits, or 'facies', which are representative of certain environments (Fig 14). Thus a sequence of environments both laterally and through time can be reconstructed for a site or, indeed, a study area.

Transects drawn through the sedimentary (mainly borehole) profiles form the primary means of illustrating the buried stratigraphy in any geoarchaeological report; five transects were selected across the study area to illustrate the general stratigraphic sequence and distribution of deposits (Fig 15).

Fig 14 Boreholes being grouped together by linking similar deposits between them in RockWorks

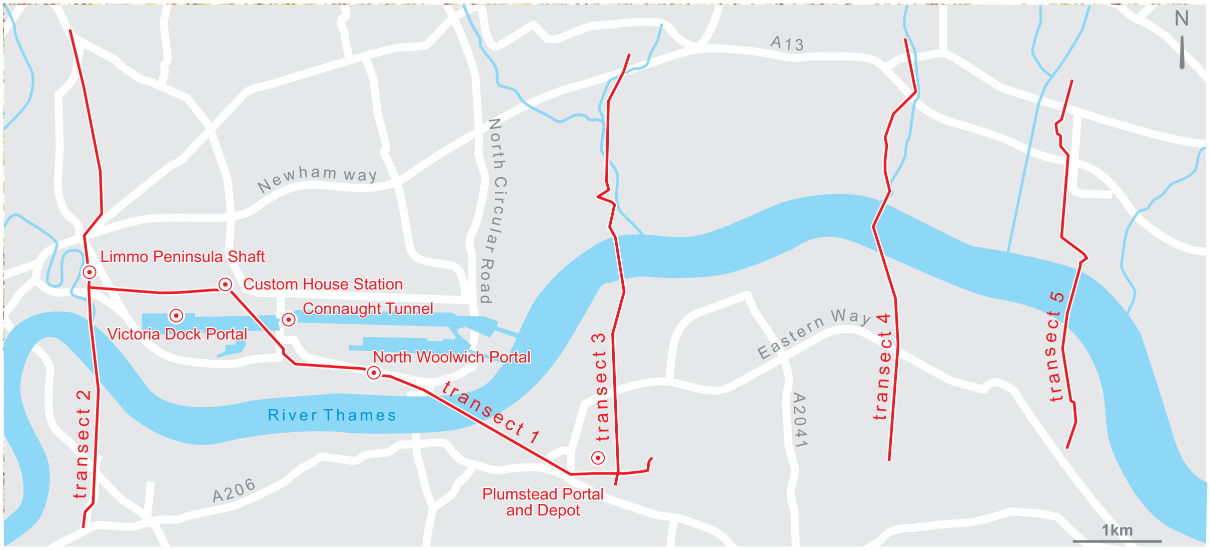


Fig 15 Locations of transects 1–5 across the study area; the only east–west transect (transect 1) links the Crossrail south-east worksites with selected borehole or trench data and some other significant data combined along the route; transect 1 is illustrated along with four other transects along north–south axes across the study area to show similarities (and differences) of the deposit sequences (scale 1:85,000)

4.4 The Early Holocene surface

After mapping the deposits in transects, a topographic marker that signifies the base of archaeologically important deposits is chosen; in the case of the Thames floodplain, this is the surface of the underlying Pleistocene gravels.

The gravels are chosen because of their ubiquity and because they formed the last major deposit laid down by the Thames prior to the Holocene. As such, the gravels form an approximation of the topography of the floodplain at the start of the Holocene when Mesolithic hunter-gatherers returned to the region, about 10,000 years ago. This surface is termed the 'Early Holocene surface' or EHS (Fig 16).

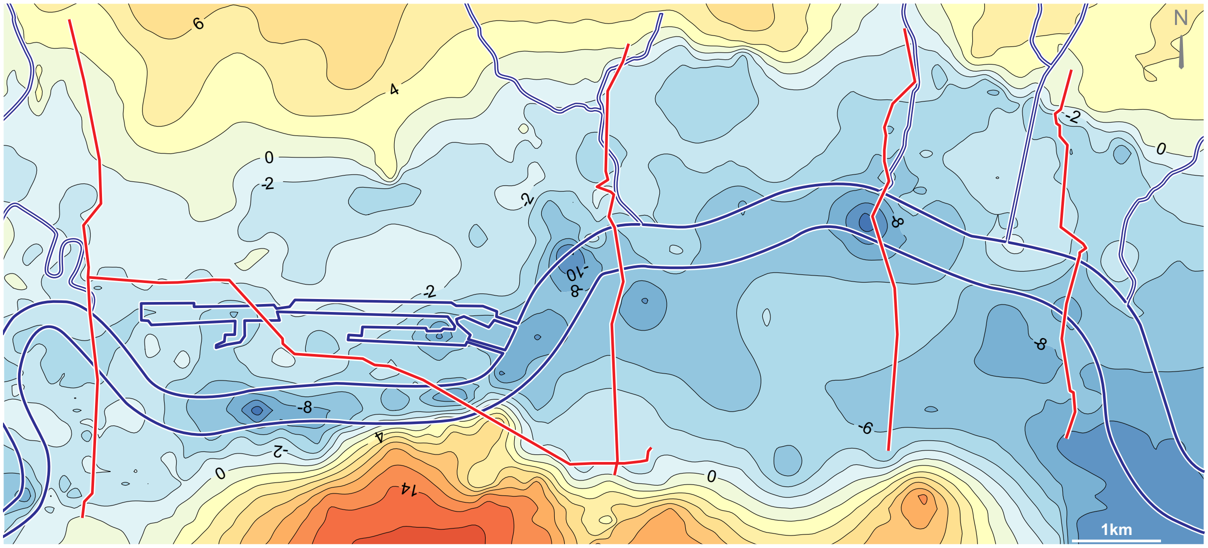


Fig 16 Contour map of the Early Holocene surface of the study area, with transects (in red) and lines of modern Thames and major tributaries (in dark blue) superimposed for reference (scale 1:85,000)

Not only does the EHS act as the bottom line for archaeological potential in this area, but it describes an undulating topography that would have influenced how later environments developed, particularly through prehistory. As an example, low-lying areas will tend to dictate the course of later channels and some high points will form islands of dry land within the wetlands. The different and changing environments that the EHS has put in train will also, of course, have a direct impact on human activity and settlement across the region, as we shall see.

Notes to Chapter 4

1 West 2014, 13–16

2 English Heritage 2011, 8; Lowe and Walker 1997, 162–236

3 English Heritage 2011

4 Corcoran et al 2011, 29; Powell 2012, 349; Stafford 2012, 15

5 *BGS*

6 RockWorks15 was used in this study

CHAPTER 5

THE EARLY HOLOCENE SURFACE AND THE MESOLITHIC (*c* 8000–*c* 4000 BC)

5.1 Introduction

This chapter discusses the nature of the topography, sediments and environments that characterised the study area during the Late Pleistocene and Early Holocene, and the evidence for the peoples that inhabited it. As mentioned (Chapter 4.4), the deposit model of the Early Holocene surface (EHS) developed for this exercise will broadly equate with the floodplain topography at the Upper Palaeolithic and Mesolithic interface, which is considered to have largely dictated the nature of the subsequent sedimentation throughout most of the prehistoric period.

5.2 The Upper Palaeolithic environment

Toward the end of the Late Pleistocene glacial period (CLM stage 1b; Table 2), with the amelioration of climatic conditions at around 18,000 years ago, the Upper Palaeolithic and Mesolithic landscape that underlie the present-day Thames alluvial sequences began to form.

According to the Bates and Whittaker model,[1] over the next 3000 years or so until *c* 15,000 years ago a high-energy fluvial system fuelled by ice-melt waters eroded (downcut) the river channel under periglacial conditions. Following this period (*c* 15,000–*c* 10,000 years ago/*c* 8000 BC) the floodplain (Shepperton) gravels were laid down, sculpted by a braided channel system. As is often mentioned by other writers on this subject,[2] the Thames, during the latter part of this period, would have appeared like one of the rivers commonly seen in the higher latitudes today (eg Alaska or Siberia) with numerous, braided channels interweaving across a wide floodplain dominated by gravels (Fig 17).

The amelioration of the climate was rapid but not continuous as the warm period (the Windermere Interstadial), post-dating the initial ice melt, came to an abrupt halt during the Upper Palaeolithic as cold arctic conditions returned for *c* 1300 years. This cold snap is called the Loch Lomond readvance (ie the resurgence of the Scottish ice cap) and only at the end of this readvance did our current interglacial (the Holocene) begin about 11,500 years ago.[3]

Fig 17 The early Thames would have looked like many of the rivers from higher latitude areas today with numerous braided channels; example shown is Tanana River, Fairbanks (Alaska, USA) (Wikimedia Commons: United States Army Corps of Engineers)

Given the cooler temperatures (even in an ameliorating climate), coupled with the tumult following the end of the last glaciation, it is not surprising that archaeological remains from the Upper Palaeolithic are scarce. Nevertheless, the East Tilbury Marshes Gravel Terrace (or 'Kempton Park Gravel' as mapped by the BGS), that borders the study area (Fig 5), has yielded some of the best known Middle Pleistocene mammal fossil discoveries. A prime example of these are the remains of hippopotamus (*Hippopotamus amphibius*) and other warmth-loving species found in gravels directly under Trafalgar Square, at a time when humans were absent from Britain.[4] Upper Palaeolithic artefacts are not recorded in the Crossrail study area, historically tending to be found west of London. One exemplary site with flint scatters characterised by Lateglacial 'long blades' associated with animal bones over 10,000 years old (*c* 8000 BC) is Three Ways Wharf on the Colne in Uxbridge, Hillingdon (Middlesex).[5]

5.3 The Early Holocene surface

The EHS replicates the Mesolithic terrain, a period in which hunter-gatherer groups recolonised Britain from the Continent (CLM stage 2; Table 2). At this time, people could have crossed a land bridge still existent in an area now lying beneath the southern part of the North Sea (Fig 18).[6]

At first glance of the EHS (in 3D; Fig 19), it is apparent that the floodplain would have appeared much wider than it is today (some 4.5km in places) and the topography was more irregular, giving rise to a mosaic of microhabitats.

On the higher ground to the north and south of the floodplain we can approximate the river terraces to be around and above the 0m OD contour.[7]

Fig 18 Map showing the land bridge that existed between Britain and Europe around 9500 years ago (after Sturt et al 2013) (scale 1:10,000,000)

To the north the gradient of the terraces is gentle, rising from 0m to 6m OD over a 2km stretch across Newham, whereas on the southern bank the gradient of the terrace is much more pronounced, rising from the river to over 30m in places within a kilometre, particularly where the Thames abuts outcropping basal geology (Thanet sands, chalk and head deposits).

Across the floodplain in the northern part of the study area, the gravel surface dips towards the river from the terrace to about -8m OD, close to the river itself. Importantly, within this gentle trend, undulations across the gravelly floodplain occur, varying by as much as 5m in places representing the relict surface of the old Pleistocene braided river channel environment. As a consequence, gravel 'highs' and 'lows' characterised the terrain on the now, largely dry floodplain, across which Mesolithic hunters would have walked.

By this time the Thames had largely reduced to a single main thread, adopting the route of the old Lateglacial channel[8] commonly incised to between -10m OD and more across the study area (cf Fig 15; Fig 20). Abandoned channels, which might be recognised by areas of low gravel, have potential to preserve

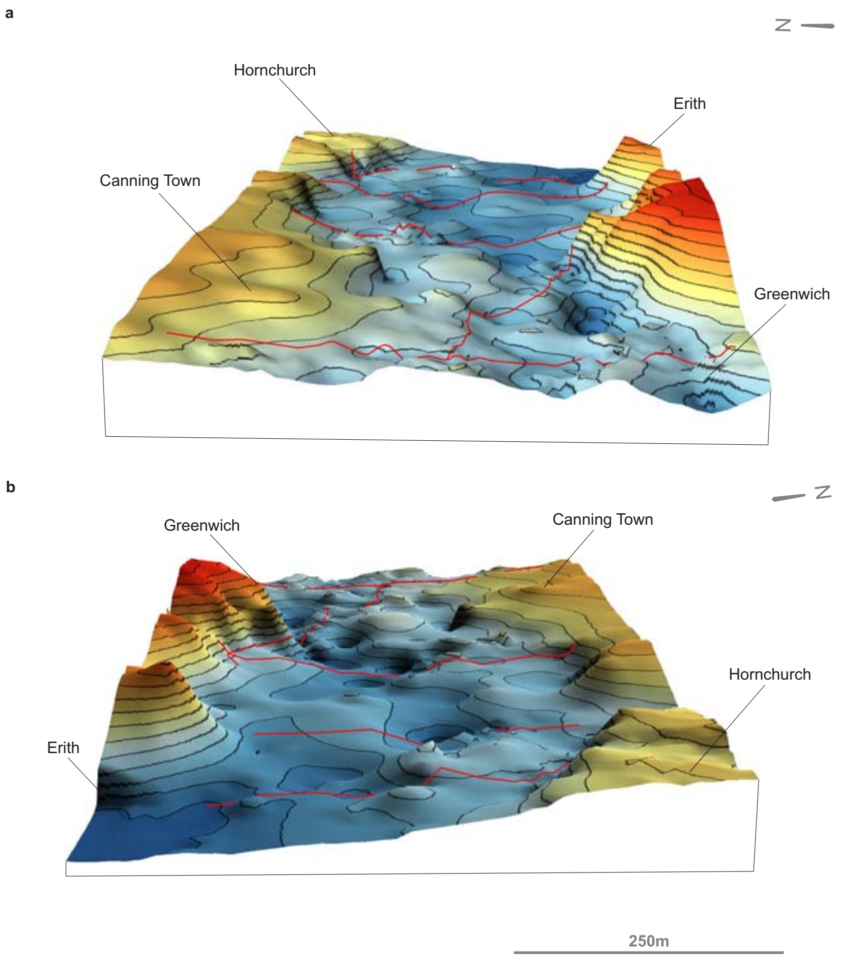
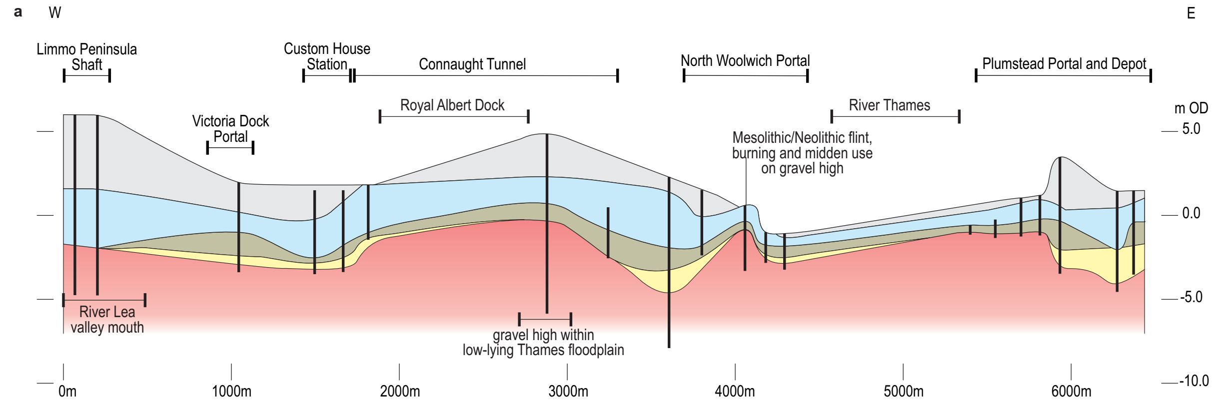


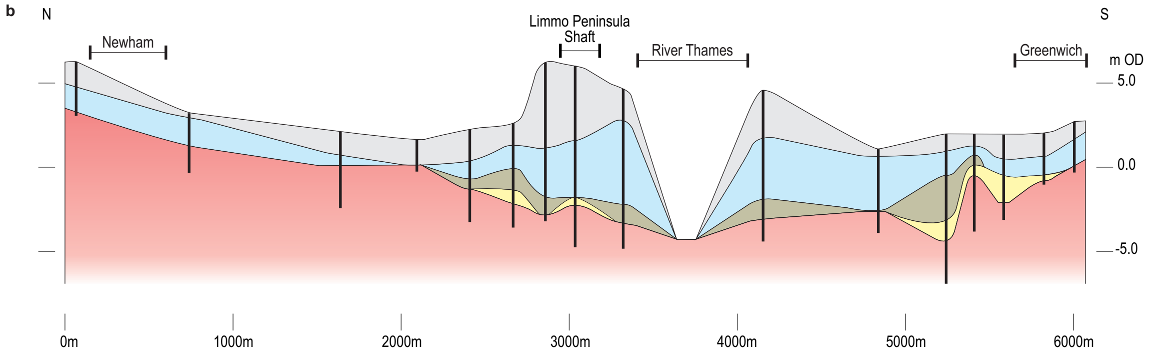
Fig 19 Two views of the Early Holocene surface of the study area in 3D, with transects superimposed (in red): a, looking east and b, looking west; note both the width and the undulating nature of the floodplain formed by the Thames when a braided channel system (coloured blue below 0m OD) and the relatively gentle slope of the ground from the river terraces in the north as opposed to the southern edge of the floodplain (coloured yellow to red above 0m OD) (scale 1:7000)

fine-grained and organic sediments typically dating from the Lateglacial and Early Holocene. Within such sediments biological remains may exist that have potential for reconstructing the environment of the late Upper Palaeolithic and Mesolithic periods.

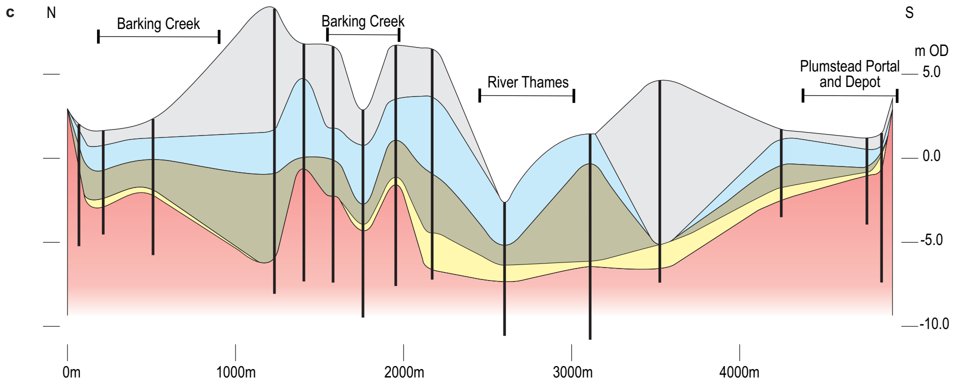
A good example of how the morphology of the floodplain can undulate within a short distance and influence the potential for archaeological recovery comes from two trenches *c* 0.5km apart at the Connaught Tunnel site. Radiocarbon dating on peats that accumulated in a redundant channel (at approximately -3m OD) from the most easterly trench (trench 3, not illustrated), returned a Late Mesolithic date of 4320–4040 cal BC (BETA-407283, 5340±30 BP; Table 4), the earliest for the whole of the Crossrail south-east work area.[9] In contrast, trench 1 to the west (not illustrated) revealed a high area of sand and gravel (at approximately -1.25m OD) which radiocarbon dating revealed remained dry until the Mid Neolithic (3090–2900 cal BC: BETA-407280, 4360±30 BP; Table 4).[10]



Transect 1 (Crossrail route)



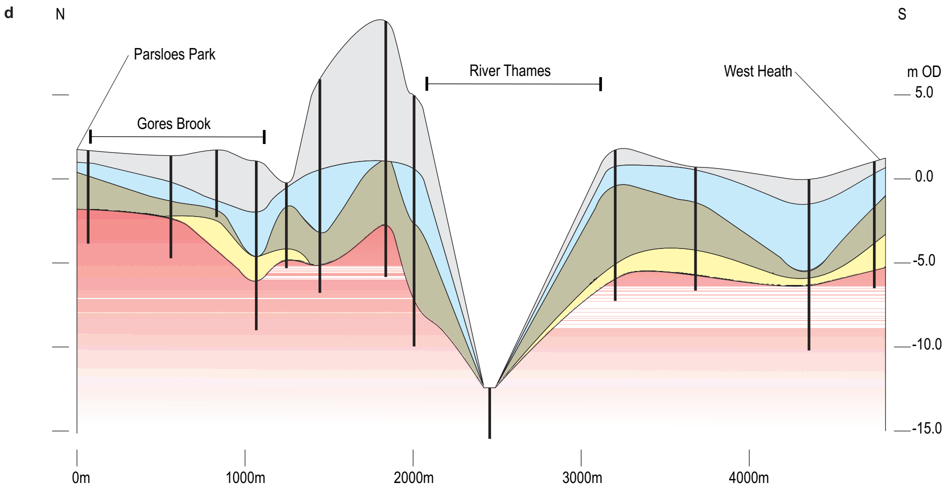
Transect 2 (539500)



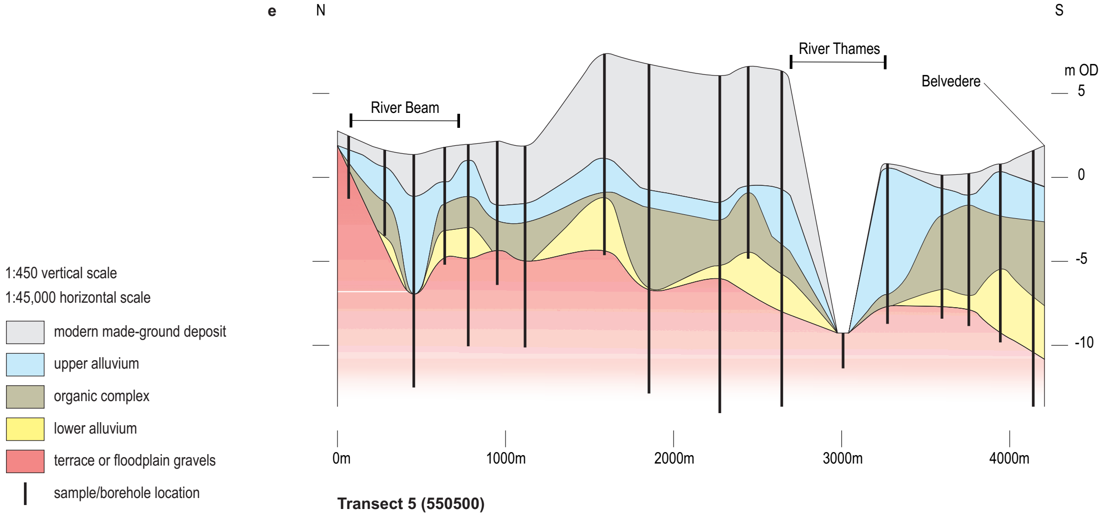
Transect 3 (545500)

Fig 20 (above and overleaf) Schematic cross sections of transects 1–5 showing the tripartite sequence of deposition across the study area; key overleaf; for location of transects refer to Fig 15 (vertical scale 1:450; horizontal scale 1:45,000)

Fig 20 *(continued)*



Transect 4 (548500)



Transect 5 (550500)

Key point

An important feature of the Thames floodplain in the Early Holocene, Early Mesolithic period (CLM stage 2, *c* 10,000–*c* 6000 years ago/*c* 8000–*c* 4000 BC; Table 2), was the stability of the environment relative to the turmoil of the Late Pleistocene, Upper Palaeolithic. Indeed, gravel high areas, sometimes overlain by sand, are likely to have remained as dry land during the whole of the prehistoric period (and occasionally even into the historic period) when the surrounding land was becoming waterlogged and buried beneath peat and alluvium. In contrast, areas of low gravel (once the main threads of water flow of the Late Pleistocene braided channels) frequently became abandoned and clogged up with peat or filled with water, forming lakes.

5.4 The Mesolithic environment

The stable topography of the floodplain during the Early Mesolithic largely dictated the environment and sedimentation patterns across the area. It appears that peat growth was isolated to places of hindered drainage whilst sand accumulated in and about river channels.[11] Evidence for soil formation both on the higher areas of gravel and, importantly, within sands adjacent to the river channels suggests that the valley was relatively dry with vegetation dominated increasingly by deciduous forests stabilising the higher ground (whether stretching up from the river's edge or on islands within or between the channels or interfluves).[12]

As the Mesolithic progressed, the climate became warmer and, as sea level began to rise, the floodplain became less stable (water levels rose and flooding increased). Alluvial deposits of silt, clay and sandy clay accumulated particularly toward the end of the Mesolithic/Early Neolithic (*c* 7000–*c* 6000 years ago). These minerogenic, lower alluvium deposits (CLM stage 3; Table 2) form the first deposits of the tripartite sequence lying on top of the EHS and can be seen occurring within the transects at several locations across the Crossrail south-east work area (Fig 20), thickening toward the mouth of the estuary.[13]

Importantly, during this time, the dynamics of the floodplain change and, particularly toward the end of the Mesolithic, change rapidly. Wetland environments expand across previously dry ground and flooding frequently overwhelms areas of high ground. According to the cultural landscape model (CLM), radiocarbon dates returned from organic material directly over gravels in the lower Thames area (indicative of wetland expansion during the prehistoric) indicate that, in the mid Mesolithic, only the ground above -8m OD was dryland rising 2m higher to -6m OD toward the end of the Mesolithic. However, from this point, over a period of *c* 700 years, river levels rose rapidly, pushing back dryland areas to above *c* -3m OD by the start of the Neolithic.[14]

Using the CLM as a guide, these three stages of what might be termed the 'flood front' have been conjectured using the EHS as a template (Fig 21). The sequence clearly indicates how the Thames expands from its main channel (roughly the course of the Thames today), flooding the low areas over time. Initially (Fig 21a; representing the -8m OD levels), for much of the Mesolithic, the floodplain was largely dry with the waters of the Thames occupying the main channel thread. By the Late Mesolithic (*c* 7000–*c* 6000 years ago), according to the second projection (Fig 21b), when the ground at about -6m OD becomes wet, about 50% of the floodplain becomes subject to inundation – although large swathes of the floodplain, including the Crossrail south-east worksites, remain dryland (albeit pockmarked with pools and lakes). Finally, however, by the final projection (Fig 21c), illustrating the nature of the Thames

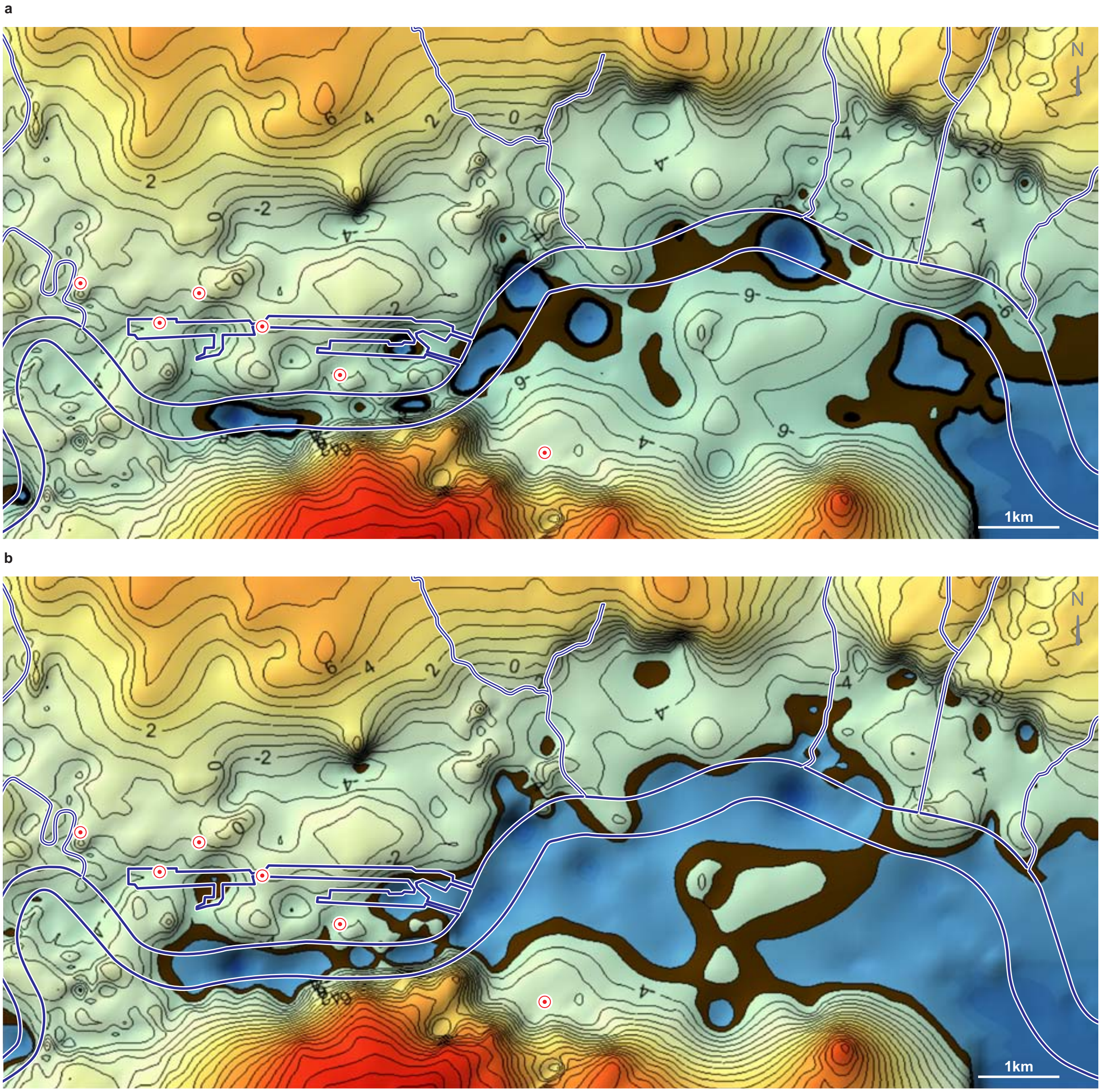
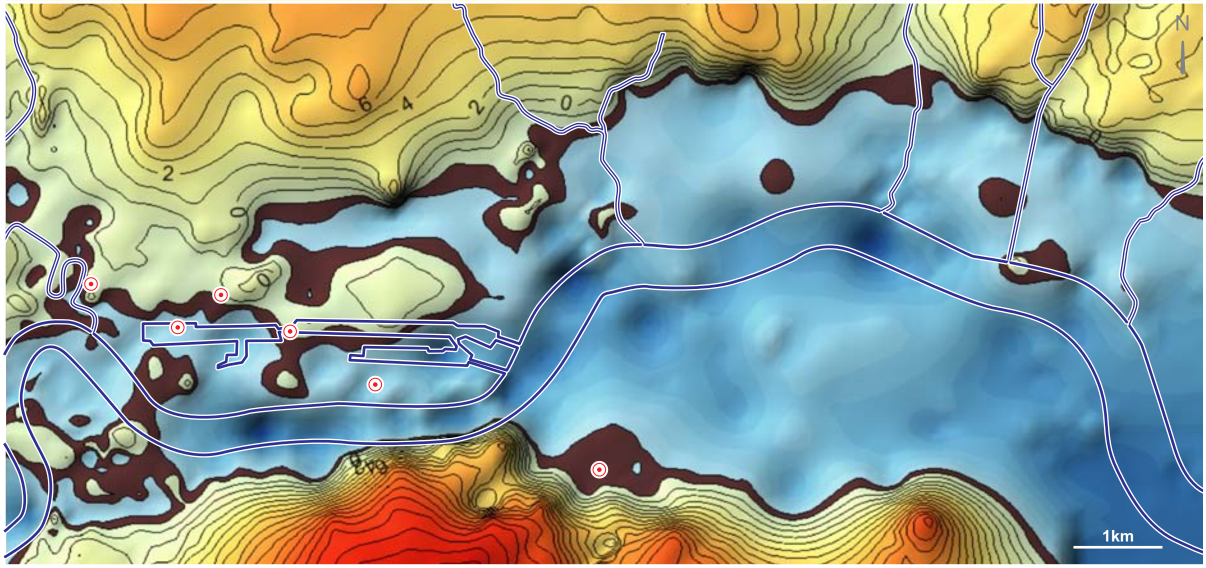


Fig 21 (above and facing) Three conjectural projections of the flood front (the areas coloured blue) throughout the Mesolithic across the study area (following the CLM): a, mid Mesolithic at -8m OD; b, Late Mesolithic at -6m OD; and c, at the Mesolithic/Neolithic period boundary at -3m OD; lines of modern Thames and major tributaries (in dark blue) and Crossrail south-east worksites (in red) are superimposed for reference (scale 1:85,000)



flood front at the Mesolithic/Neolithic boundary (*c* 4000 BC), almost 75% of the floodplain seems under threat, with the remaining dry ground largely isolated to the west away from the advancing flood front.

5.5 The archaeology and evidence of human interaction

Mesolithic people appear to have used the rivers such as the Thames and its tributaries as routeways through the increasingly densely wooded landscapes of Britain as well as, of course, a rich resource of food and fresh water.

Direct evidence of Mesolithic occupation (typically scatters of flint and animal bone/antlers) is infrequently recovered from the Thames floodplain region because of their ephemeral nature (being often temporary encampments or hunting sites) and probably because of the depth of the Mesolithic land surface.[15] Where found on the Thames floodplain, Mesolithic sites tend to be located on higher areas of ground typically upon sandy eyots (eg site 7; Fig 8)[16] although, coupled with notable exceptions,[17] evidence from sites located along tributary valleys such as the Colne[18] and Lea[19] indicate Mesolithic peoples tended also to utilise key ecotonal areas, such as those adjacent to a main river channel, as well as the higher ground.

Consistent with the bulk of Mesolithic finds along the Thames, however, within the Crossrail south-east work area at the North Woolwich Portal site, rich deposits of Mesolithic flint debitage within the sands overlying an area of higher ground were recovered close to the main channel. Soil micromorphology (and associated tests) indicated remnant ancient soils with evidence of burning (burnt flint and charcoal) indicative of midden deposits on a land surface intermittently occupied throughout the Mesolithic. Notably, these once humic sandy deposits became heavily leached (due to their antiquity and sandy nature) so that barely any evidence of any other proxy environmental indicators remains, although, fascinatingly, fish bone within the same context suggested the possibility of hunter/fisher activity.

The Mesolithic flints

Jon Cotton

North Woolwich Portal was the only site across the Crossrail south-east work area to produce direct evidence for human activity. This comprised small scatters of struck and burnt flint lying within leached sandy soils at the bottom of the recorded sequence in trenches 3 and 4 (Fig 1; Fig 22), and a deposit of burnt flint buried in a pit cut into the soil horizon in trench 2.

Fig 22 Trench 4 at the North Woolwich Portal site, with the Mesolithic flint scatter in the foreground, looking north-east

These soils had developed on one of a number of local high points or sand and gravel islands across the floodplain floor and they were sealed by humic peats dated to the Early Neolithic.

Stone tools were made by skilfully fracturing a flint nodule in a process known as knapping. In all, 183 pieces of struck flint were retrieved, with the bulk coming from trench 4. Most of the flints were excavated by hand, although a small number were found during the subsequent wet-sieving of soil samples (Fig 23).

The raw flint material comprises medium-sized cobbles of reasonable quality for working. The rolled and water-worn natural surfaces of these cobbles are thin and smooth, and buff or off-white in colour, which suggests that they were collected from secondary sources such as the terrace gravels and/or the beds of local river channels.

When freshly split, the flint is a semi-translucent, smoky grey-brown colour, with occasional bands of lighter, cherty inclusions. However, most of the pieces in the present assemblage have faint milky-blue surfaces brought about by chemical changes that have affected them during their burial in the soil. A majority of the worked pieces have sharp edges, suggesting that they have suffered little during the time they have been in the ground.

Dating and significance of the flint scatters

Both flint scatters are dominated by fresh flakes with plain, faceted and occasionally carefully prepared platforms – the latter an indication of skill on the part of the flint knapper. Flakes within the second scatter are noticeably larger in size, and their prominent bulbs of percussion (caused by the force of a blow) suggest that they were struck with a stone hammer, rather than with a soft antler or bone hammer. True blades are few in either scatter, though there are a number of narrow flakes/blades. Diagnostically, two microliths (small, carefully-shaped points) suggest that elements of both assemblages are likely to be of later Mesolithic date (*c* 8500–*c* 6000 years ago).

Fig 23 A selection of flints from trench 4 at North Woolwich Portal (scale *c* 1:2)

The fresh condition and tight distribution of the larger of the two scatters in particular suggests that it represents a single, short-lived, possibly task-specific and more or less undisturbed episode of human activity. The presence of the butt end of a small adze or axe, coupled with the large size and distinctive form of many of the hard hammer flakes, in particular, further suggests that the location was principally used for the initial working of one or more river cobbles into axes/adzes subsequently carried elsewhere for final shaping.[20] The dominance of axe-preparation and axe-thinning flakes amongst the assemblage can be matched locally elsewhere, as at Erith, in Bexley, and Purfleet (Essex) further downstream.[21] Moreover, a number of finished axes/adzes have been reported from the locality, as at Poplar in Tower Hamlets, Beckton Gas Works and the King George V Dock, both in Newham, and from local stretches of the Thames at Woolwich in Greenwich and Erith (Fig 24).[22] Such tools would have been mounted on wooden hafts and used for tree felling and carpentry (cf Fig 38).

The episodes of flint working at North Woolwich Portal indicate that later Mesolithic human communities were engaged in a range of foraging tasks,

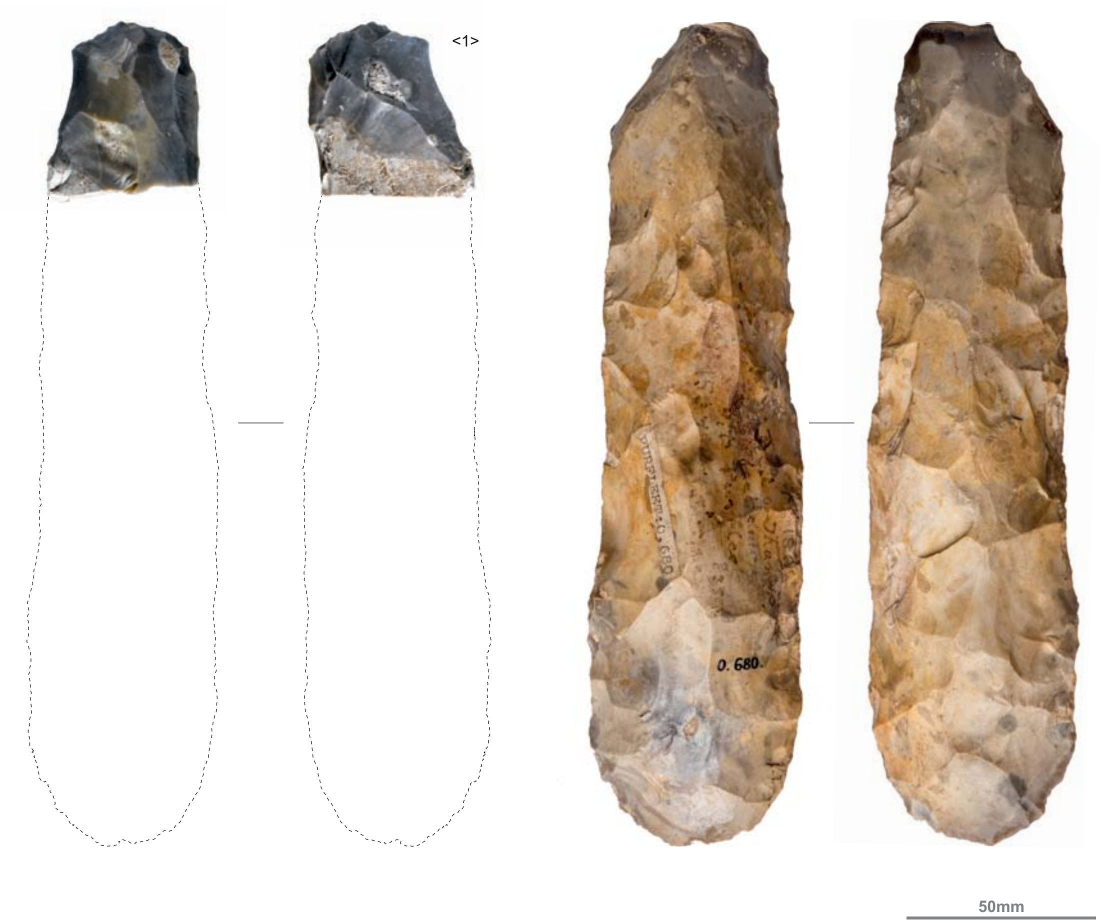


Fig 24 (left) The butt of a small adze found at North Woolwich Portal (XSV11 <1> [15]) compared with (right) a similar complete adze from nearby Purfleet (MOL acc no. 0.680) (scale *c* 1:2)

encompassing hunting and woodcraft. Furthermore, the worked flints are loosely associated with traces of unworked burnt flint and charcoal suggestive of the former presence of hearths, around which a number of these activities are likely to have taken place. Apart from a number of fish bones in the soil samples, however, no animal bones survived, though it is possible that elements of the flint assemblages were deployed on large terrestrial fauna such as deer and aurochs (a species of large indigenous cattle, now extinct). The North Woolwich Portal finds form part of a complex mosaic of intermittent and perhaps seasonal human exploitation of the lower Thames floodplain in the Early to Mid Holocene.

5.6 Following the Elizabeth line to the south-east

To conclude this chapter on the Mesolithic environment of the lower Thames, let us imagine what it would be like walking the surface of the route during this period, say approaching from the north bank during the mid Mesolithic (*c* 8000 years ago) (western part, Fig 21a).

Walking with the clear flowing fresh water of the Lea to the west around the Limmo Peninsula Shaft site, the underlying gravel topography would slope gently in front of you southward and eastward for a kilometre or so near the Victoria Dock Portal and Custom House Station sites. The ground would undulate slightly but at this contour level you could strike eastward, along a route staying north of the more heavily dissected topography near the main channel's edge, through modern-day Silvertown, in Newham. The environment would be one of lime and elm forests with some pine stands dotted around across areas of well-drained gravelly ground. Oak and hazel would be common too. Perhaps there are favoured locations along this route where hazel grows thickly and is good for seasonal harvest, or areas of scrub that you occasionally burn back to clear the ground for hunting.

Closer to the main channel and perhaps in lower areas along the route, grass and sedge grow thickly, providing clear access to the waterholes and, for example, the herds of deer that could drink there – although you may not be the only predator here, as animals such as bears could be targeting this area too. Rivulets and channels frequently block your path, however, flowing off the gravels into the main channel. Boggy areas hinder you as well, not only here but within the forests. At the river's edge you know a favoured site where the high ground around the North Woolwich Portal site provides an excellent vantage point over the river. Here you could safely establish a seasonal encampment, knapping flint and exploiting the rich resources of the freshwater Thames (Fig 25).

Fig 25 Conjectural reconstruction of the Mesolithic encampment on high ground at North Woolwich Portal

(artist Faith Vardy)

Notes to Chapter 5

1 Bates and Whittaker 2004

2 Eg Stafford 2012, 19

3 Sidell et al 2000, 12–14

4 Franks 1960

5 Lewis et al 1992

6 Sturt et al 2013

7 Stafford 2012, fig 8.1

8 Ibid, 100

9 One sample from Victoria Dock Portal produced an earlier date of 6670–3100 cal BC (BETA-407277, 4540±30 BP), but the date range is too wide to be considered here.

10 Spurr 2015

11 Bates and Whittaker 2004

12 Scaife 2000

13 Devoy 1979

14 Stafford 2012, 106, fig 807

15 Bates and Barham 1995

16 Holder 1998; Powell and Leivers 2012; Nicholls et al 2013

17 Thomas and Rackham 1996

18 Lewis 2011

19 Corcoran et al 2011

20 For a full description of the technology see Ashton 1988.

21 Taylor 1996; Leivers et al 2007, 21

22 Eg Wymer 1977, 183, 187, 192 and 198; Cotton and Green 2004, 125–6

CHAPTER 6

NEOLITHIC TO BRONZE AGE (*c* 4000–*c* 800 BC)

6.1 Introduction

Across the majority of the lower Thames area, large swathes of woody, humified peats and peaty organic clays can be seen overlying the Mesolithic deposits (Fig 20). These, predominantly organic, deposits are termed the 'organic complex' for the purposes of this study, and relate to around 5000 to 3000 years ago (CLM stage 4; Table 2) and Devoy's Tilbury III and IV peats.[1] These deposits developed in swampy environments during periods of fluctuating relative sea level (RSL) and have been radiocarbon-dated to the Neolithic, continuing through to the Late Bronze Age.[2]

6.2 The Neolithic to Bronze Age environment

Modelling the environment using the CLM as a guide, the extent of the organic complex can be conjectured across the study area (Fig 26). The boreholes with organic deposits within them that correlate with this period by altitude at their surface (lying between +0.5m and -3m OD) are coloured red in the map. Not only do these boreholes indicate the spread of the organic complex, but the thickness of these deposits as well. To correlate with contemporary archaeology, the sites on the map are a selection of those that revealed trackways/timber structures within the peat (Fig 26).

The transects (Fig 20) and the heat map (Fig 26) reveal that the organic deposits of this period were widespread, thickening to approximately 6m in certain areas. This is particularly apparent on the southern side of the Roding/Barking Creek confluence with the Thames and at Erith where the EHS indicates the Mesolithic floodplain was wide and deep (transects 3 and 4; Fig 15; Fig 19; Fig 20; Fig 26). Conversely, the sites with trackways tend to lie in areas where the organic complex (mainly consisting of peats) is between 1m and 3m thick toward the fringes of the floodplain and areas of relatively higher ground. Through the process of paludification, the organic complex deposits (particularly the peats) would, in general, have spread out across the floodplain from the deeper pockets to the higher areas, although erosion (eg along the Lea and the Beam) would have had an attritional effect, reducing or inhibiting the peats at these locations (Fig 26).

Undeniably, however, the organic deposits would have formed a distinct regional deposit marking significant changes in the landscape and environment that would have directly affected the perception and use of the landscape by prehistoric groups. Pollen evidence from the Early to Mid Holocene, Mesolithic period painted a picture of a floodplain that was forested by species-rich deciduous woodland which, by the Late Mesolithic, became ousted by alder (*Alnus glutinosa*).[3] Throughout the period increasing wetness was driven by rises in RSL, causing ponding back of freshwater systems which alder, as a species, is perfectly suited to exploit, as it can survive up to three months inundation typical of seasonal flood events.[4] By the Neolithic, alder formed very dense woodland or alder carr in the ecotonal zone between the river and higher dryer ground (to the extent that some consider it actually inhibited changes in channel morphology during this period).[5] The deciduous woodland continued to dominate the fully terrestrial environment (ie the higher, dryer ground) and typically consisted of oak (*Quercus* sp), hazel (*Corylus avellana* sp) and lime as well as elm (*Ulmus* sp). Interestingly, over time, the swampy areas began to dry out to a certain degree, allowing these deciduous woodlands to develop across a substratum of organic complex deposits (below).

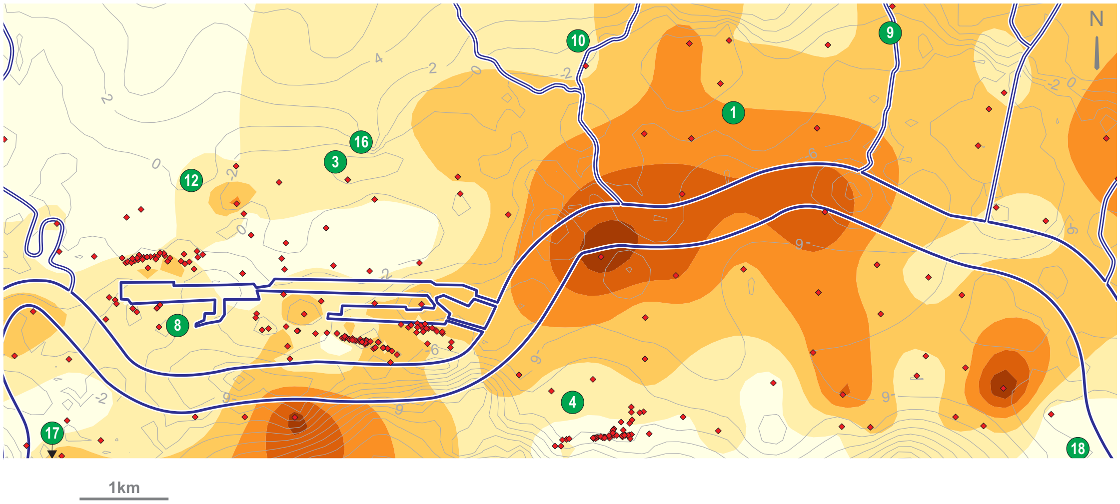


Fig 26 A ‘heat map’ conjecturing the extent and thicknesses of the organic complex across the study area during the Neolithic and Bronze Age periods, superimposed over the Early Holocene surface contours; lines of modern Thames and major tributaries shown for reference (for key to sites see Table 3) (scale 1:85,000)

Notably, because of its high acidity, peat provides an excellent environment for organic remains of archaeological interest, which rarely survive on dryland sites. These range from microfossils such as pollen through to so-called ‘bog bodies’, such as Lindow man discovered at Lindow Moss in Cheshire.[6] Across the lower Thames area, the peats have preserved not only evidence of a changing vegetational environment but also direct evidence of people and their interaction with the environment, particularly through the survival of timber structures such as trackways across the peat. The highly organic nature of the peat also allows radiocarbon dating of organic materials preserved within it, providing a time frame for a sedimentary profile as a whole.

6.3 Evidence from the Crossrail south-east worksites and the wider study area

Extensive areas of organic complex deposits were recorded across the Crossrail south-east worksites and across the lower Thames region. Particularly large swathes of peat were recorded across the northern floodplain in Barking and Dagenham across to the Hornchurch marshes in Havering, where tributaries fed the dryland with continuous supplies of fresh water (transects 3–5; Fig 15; Fig 20; Fig 26). Typical levels of the organic deposits across the Crossrail south-east worksites range from approximately -3m OD to 0m OD, although later erosion, whether by tidal creeks or flooding, has blurred the upper deposit boundary (transect 1; Fig 15; Fig 20).

As mentioned above, radiocarbon dates from the organic complex deposits place their accumulation within the Neolithic to Bronze Age periods, and this has been mirrored across the Crossrail south-east worksites[7] (although much can depend on the site location relative to the Thames or one of its tributaries). The radiocarbon dates returned for Custom House Station, for example, provided a good, sequential chronostratigraphy for the peat deposit at this location, roughly in the middle of the floodplain between the terrace and the river (Fig 1; Table 4). The lowest date, from approximately -2.7m OD at the initiation of the peats, returned an Early Neolithic date of 3505–3425 cal BC (BETA-396254, 4630±30 BP). The middle of the peat around -2.50m OD returned a date relating to the Middle Neolithic of 3030–2890 cal BC (BETA 396253, 4340±30 BP) and the uppermost sample at approximately -2.10m OD, dating the cessation of the peat at Custom House Station, returned a date relating to the Late Neolithic of 2570–2340 cal BC (BETA 396252, 3950±30 BP). In contrast, toward the edge of the floodplain at Plumstead Portal and Depot (Fig 1), samples from the peat deposit lying across the site at around 0m OD dated to the Early Bronze Age (2020–1770 cal BC: BETA-407272, 3560±30 BP; 1900–1690 cal BC: BETA-407273, 3480±30 BP; 1920–1700 cal BC: BETA-407274, 3500±30 BP; Table 4).

As time progressed the floodplain became unstable and flooding increased again, drowning areas of once established woodland, downing trees across the ancient, formerly dryland surface (Fig 27). Remains of prehistoric forests are revealed on the lowest parts of the modern foreshore at Erith at low tide, west of

Fig 27 Fallen trees on the higher ground at North Woolwich Portal, looking east; as waterlogging of the floodplain increased throughout the Late Neolithic and Early Bronze Age periods, trees intolerant of the wetter conditions died out

Crayford Ness also in Bexley (site 6; Fig 8),[8] where tree species examination and radiocarbon dating has been used to reconstruct the changing composition of the prehistoric floodplain woodland through time. This study has shown that, although alder was the major component of the Neolithic floodplain woodland, there was a higher proportion of dryland species in comparison to the Late Bronze Age (*c* 1000–*c* 800 BC), reflecting the progressive waterlogging of the floodplain in the Late Neolithic/Early Bronze Age (*c* 2000 BC). Furthermore, the composition of the woodland was sometimes markedly different to today. At sites across Barking and Dagenham and Havering (eg sites 1, 2; Fig 8),[9] the woodlands consisted principally of yew (*Taxus bacata*) (of which there is no modern analogue in a lowland river valley in the United Kingdom).[10]

6.4 The archaeological evidence and human interaction

As wetlands submerged the Late Mesolithic/Early Neolithic floodplain floor, human activity would have been pushed back on to the higher eyots and river terraces. Interestingly, at these locations archaeological finds of multiple periods are often concatenated (linked together), because these areas have been used for millennia as favoured locations for prehistoric peoples. Examples of terrace occupation are numerous, including those along the A13 road route (Prince Regent Lane, Woolwich Manor Way, Movers Lane; sites 10, 12, 16; Fig 8),[11] the Bronze Age to Iron Age settlements at Rainham (site 11; Fig 8)[12] and in South Hornchurch (site 14; Fig 8),[13] both in Havering. Examples across the floodplain include eyots that have been found within the floodplain at Canning Town, Newham, within the study area (sites 7, 13; Fig 8).[14]

Fig 28 Bronze Age trackway being excavated at Beckton; such trackways provided routes through the densely vegetated marshlands
(Pam Greenwood)

Conversely, archaeological evidence found within the peat, such as trackways to access and traverse the wetlands (from the river terraces), demonstrates that prehistoric populations were exploiting this wetland landscape for its rich subsistence resources. A number of timber structures have been recovered from the peats, again across the A13 sites (given their edge of terrace locations), across Beckton, Newham (site 3; Fig 8; Fig 28),[15] Rainham and Dagenham on the north bank (eg sites 5, 9; Fig 8),[16] as well as across Thamesmead[17] in Greenwich, the Greenwich Peninsula[18] and Erith[19] in Bexley in the south (sites 4, 17, 18; Fig 8). Other

Fig 29 Worked wood within the peats and gravels at Plumstead Portal and Depot, looking south

analogous Neolithic timber structures in the London region are represented by examples from both within and in the vicinity of the Crossrail south-east work area at Fort Street, Silvertown (site 8; Fig 8),[20] and Belmarsh in Greenwich (site 4; Fig 8).[21]

Indeed, remnants of timbers considered to be of Bronze Age date and likely to have been used in a trackway or platform were discovered at Plumstead Portal and Depot (Fig 29). One piece of timber had one neatly bevelled end left from either cross-cutting or felling with a metal axe. The timber appeared to have been the end of a log deliberately split in half after being axe-cut to length.

In contrast to the above wooden structures or trackways, a wooden 'Dagenham idol', dated to the Late Neolithic,[22] was found alongside the skeleton of a large animal, perhaps a deer, in the vicinity of Beckton Reaches in 1922 (Fig 30).[23] This is an extremely rare find and possibly a votive offering associated with the deer, and similar to others found in deep peat sequences across Europe.[24]

The Neolithic was a pivotal period in the human story within Britain as hunter-gatherers began to farm, clearing forests for crop production and animal fodder. Interestingly, cereal pollen and plant macrofossil analysis of charred seeds and wood in the peat at Plumstead Portal and Depot provide evidence of cultivation on the terraces.[25] Certainly, however, other pollen records from sites across the central Crossrail south-east work area (around Silvertown), such as Fort Street,[26] and ard marks at Wolseley Street, Southwark,[27] record clear evidence of agriculture on the floodplain at this time, taking place on increasingly isolated higher ground and eyots (Fig 31).

Fig 30 The Dagenham idol (height 495mm)

Fig 31 (left) The criss-cross pattern of ard marks found on the higher ground in Southwark (site code WOY94) and (right) conjectural reconstruction of a view of Late Neolithic/Early Bronze Age ploughing techniques which would have produced such marks; draft animals drag a point or ard to cut a shallow furrow (rather than turn the soil) to clear weeds and plant cereals (artist Derek Lucas)

Key point

During the Neolithic and Bronze Age periods, wetlands expanded because freshwater rivers flowing from the terraces backed up against pressure from sea-level rise. Water saturated the floodplain, and the wetland spread, supporting an assortment of freshwater and brackish environments. The growth of the marshlands inevitably resulted in the loss of dry land, and would have had significant influence on the plants and animals of the study area, including humans. Settlement areas were forced to higher ground and access to the floodplain was limited.

6.5 Following the Elizabeth line to the south-east

In conclusion, what would the floodplain in the Neolithic and Bronze Age look like to someone navigating the route? At Limmo Peninsula Shaft around the Lea, the freshwater river would be winding its way through the thick alder woodland that dominated the floodplain. The marshy areas would be extensive as, unbeknown to you, the relentless rise of RSL has faltered and allowed once inundated land to dry out somewhat and heavily wooded marshland to develop (Fig 32). Here, at Limmo Peninsula Shaft, as at the mouths of other tributaries in the lower Thames, the rivers probably offered the only respite from the dense forests and year-round access to the main river and the resources it provided. Using a boat to access the tributaries and Thames would be wise, avoiding the exertions of negotiating the woodland.

The marshy banks and rivers would be rich in terms of wildlife with fish and fowl aplenty, particularly at the confluences.

Going south and eastward, traversing the peatlands by foot would be a different matter entirely. Circumnavigating swampy backwaters and minor channels recorded around the North Woolwich Portal area would be challenging, not least because of the hindrance of the alder. Areas of higher ground would be well known and offer some relief, with deciduous species standing tall amid the surrounding wooded wetlands. Perhaps of course, particularly in the Silvertown area where at other sites we have seen evidence of these, you can utilise trackways, perhaps branch-lain, perhaps more substantial in nature, linking these areas of high ground. The trackways would be old, well-known routes, maintained throughout the generations to access the marshes and the Thames from your village or farmstead on the terrace. Perhaps, indeed, some of the higher ground within the marsh has been cleared, with the lime, elm and oaks felled, allowing a little plot of land to be farmed. Heavy work with the stone axes of the Neolithic and burning back would always be needed to prevent regrowth. Notably, these areas, unlike the river terrace, would only be accessible in the summer when it was relatively dry, unlike the long months of winter when the lower areas of alder woodland stood submerged in cold waters.

At North Woolwich Portal, close to the main channel, you could be reaching favoured high spots in the landscape for fishing or accessing the river by boat. Again, these areas have probably been known for generations, as waste

Fig 32 Alder-dominated woodlands make for hard going close to the water's edge

material spread about provides evidence of an unwritten history from the dim and distant past. Across the water? Well that's another matter. Other people live there. Smoke rising from farmsteads on the steeper banks around the Plumstead Portal and Depot site attests to well-established communities. Farm animals and cereal production are clearly visible on the slopes (Fig 33). Time to turn back and return to your own people.

Fig 33 Artist's impression of Bronze Age Thames-side farming on the Greenwich peninsula (artist Faith Vardy)

Notes to Chapter 6

1 Devoy 1979
2 Sidell et al 2000, 19
3 Brown 1997, 10
4 Scaife 2000
5 Brown 1997, 10
6 Brothwell 1986
7 Spurr 2015
8 Seel 2002
9 Green et al 2014; Spurr 2012
10 Sidell 2002
11 Stafford 2012
12 Bull 2014
13 Guttmann and Last 2000
14 Holder 1998; Nicholls et al 2013
15 Meddens 1996, 327–9
16 Ibid
17 Hart 2010
18 Hawkins 2005
19 Bennell 1998
20 Crockett et al 2002
21 Hart 2010
22 Coles 1990, 326
23 Wright 1923; Coles 1990, 320 pl 29a, b
24 Menotti 2012, 193–4
25 A Davis, K Stewart and R Scaife in Spurr 2015
26 Crockett et al 2002
27 Drummond-Murray et al 1994, 253

CHAPTER 7

THE LATE PREHISTORIC TO POST-MEDIEVAL PERIOD (*c* 800 BC–*c* 1800)

7.1 Introduction

This chapter examines the upper silt and clay horizons of the lower Thames area that blanketed the prehistoric peaty marshes, concealing and burying relict channels and often archaeology too (upper alluvium of CLM stages 5 and 6; Table 2; *c* 3000 years ago to present). This sediment can appear as a uniform block, but hides a complex history of landscape and economic change. If the landscape can be read, it tells a story of human enterprise in the face of evolving climatic conditions.

At the end of the Bronze Age (*c* 800 BC), there is a change from organic peats to essentially bluish grey silts and clays of the upper alluvium (albeit with some local variation). This marks the Iron Age transition, when the landscape opened up and forested marsh gradually turned into tidal mudflats and salt marsh. This characteristic change in sediment type is seen not only across the Thames floodplain, but in fact across the coastal wetlands of north-west Europe, where silt clay deposits accumulate through the next *c* 2000 years, from the Iron Age to the post-medieval period.[1]

7.2 The late prehistoric to post-medieval environment

Although actual sea-level rise finished *c* 6000 years ago, southern Britain continued to sink, which brought tidal conditions up the Thames estuary into London.[2] Consequently, by the Iron Age, the Thames began to erode the former peatlands, flood new areas and, eventually, blanket the floodplain in alluvium (Fig 34). Across the zone, upper surfaces of the prehistoric peats are radiocarbon-dated to between the Neolithic and the Middle Bronze Age (*c* 4000–*c* 1000 BC). This broad spread of dates, rather than reflecting the date at which the peat was drowned, shows that each site was affected differentially (largely because of its landscape position and to what degree the peat surface was eroded). Nevertheless, the dates do provide an approximate date for clay alluviation, which we know began toward the end of the Bronze Age and Early Iron Age.

The rise in river levels was not entirely due to RSL rise, however. At this time conditions became wetter, rainfall increased, and river and lake levels across

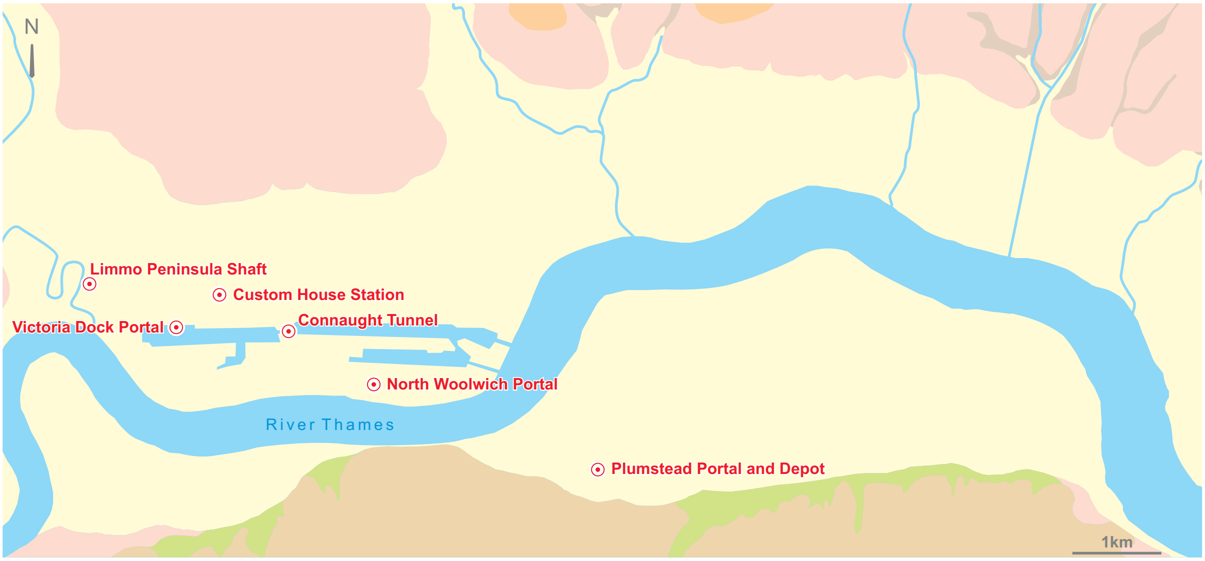


Fig 34 Map showing the spread of (upper) river alluvium across the lower Thames within the study area using current British Geological Survey data (scale 1:85,000)

north-west Europe rose.[3] The climate is understood through various studies (such as upon ice cores, ocean cores and tree-ring data), but the most dependable terrestrial climate indicators for archaeology come from raised peat bogs in upland areas (not across river floodplains). These records suggest a wetter phase at the end of the Bronze Age and beginning of the Iron Age.[4]

This wetter climatic phase coupled with the upward RSL trend was at least partly responsible for the initial change to alluvial clay sedimentation that continued through the historic period. Again RSL rise was not continuous but variable, with river levels falling during the Roman period (*c* 1st–5th century AD), for example, but recovering from the downturn and continuing their inexorable rise, reaching and exceeding their former height by the end of the Early Anglo-Saxon period (7th century AD).[5]

The Roman and early medieval periods were warmer, but the later medieval period saw the climate cool (with some short-lived disruptions) into the ‘Little Ice Age’. This deterioration particularly affected northern and western Europe between the 13th and 15th centuries, and was characterised by increased storminess.[6] Damaging storm surges broke through flood defences of countries around the southern shores of the North Sea, including those on the Thames estuary.[7] Storms would have created surges of tidal water and these extreme events would have had a powerful impact on the deposit sequence, both by scouring away sediment (and with it evidence of environmental change) and depositing large volumes of mud on the floodplain. Therefore, while storms are likely to have had an overarching influence on deposit build-up, sedimentary evidence of specific events is often reworked by subsequent tides or weathered away.

7.3 Evidence from the Crossrail south-east worksites and the wider study area

The transects across the Crossrail south-east worksites and the wider study area clearly show how deep deposits of upper alluvium accumulated across the floodplain – in places up to 4m in thickness (Fig 20).

Diatom and ostracod analyses show that, across the Crossrail south-east worksites, the clays were deposited under brackish or estuarine conditions and probably formed as tidal mudflats and salt marsh.[8] At every site, pollen and plant macrofossil analyses indicated that the onset of alluviation led to a decline in alder and deciduous tree species, alongside a prevalence of grasses and a rise in cereal pollen.[9]

The thick alluvium at Limmo Peninsula Shaft contained part of a clinker boat preserved within tidal sediments, which lay on the outside of the mud wall that protected adjacent farmland (Fig 35). The date of the boat of cal AD 1220–90 provides a later, medieval date for the accumulation of the muds here.[10]

Fig 35 Fragment of a medieval clinker boat provides a date for the muds at Limmo Peninsula Shaft near the mouth of the River Lea (1.0m scale)

To some degree throughout but particularly toward the end of their deposition, all the Crossrail south-east worksites indicate that the alluvial clays became increasingly exposed to the elements.[11] Near the top of almost every sequence their rusted and weathered appearance and blocky structure shows that the clays dried out and soils formed. This points toward seasonal flooding rather than permanent or even daily tidal inundation, and there was supporting evidence from the microfossils at Victoria Dock Portal, Connaught Tunnel and Plumstead Portal and Depot, such as earthworm granules, plant debris, ostracod and diatom data, indicating a semi-terrestrial (not entirely wet) environment.[12]

During the Roman period sea levels fluctuated as did river levels (Chapter 3.1),[13] but by the later medieval period (ie the Little Ice Age) flooding was catastrophic, breaching many river walls and covering reclaimed farmland. Flooding directly downstream of London may have actually been exacerbated by the presence of the narrow spans between the arches of London Bridge (completed *c* 1200[14]) as certainly, across the Crossrail south-east work area, livestock, fishing structures and mills were lost and arable land and pasture were damaged. Despite repeated attempts to reclaim the land (not helped by the coincidence of recurring outbreaks of plague through the 14th century that depleted the population), embankments could not be repaired and in many areas reclaimed marshland permanently returned to its former wetland state.[15] For example, on the once arable Barking marshes (Barking and Dagenham), from the late 14th century, a lake formed and fisheries were established.[16] This had the unintended consequence of easing upstream flooding, much like managed retreat today. If the upper part of Crossrail profiles had survived modern truncation, as was the case at the nearby Urban Sustainability Centre site (USC10) in Newham (site 15; Fig 8),[17] we might see renewed alluvial clay sedimentation burying the medieval soil layers (Fig 36).

Maps show extensive (saltwater) marsh across the Crossrail south-east work zone which can give clues to the landscape history. By the late 18th century the Crossrail south-east worksites on the north bank of the Thames lie on the enclosed ‘levels’ of the ‘Abbey Marsh’ (Essex), ‘Plaistow Level’ and ‘Barking Level’. These were flat zones irrigated as water meadows and grazing marshlands, divided according to jurisdiction but also subject to flooding (Fig 37).[18]

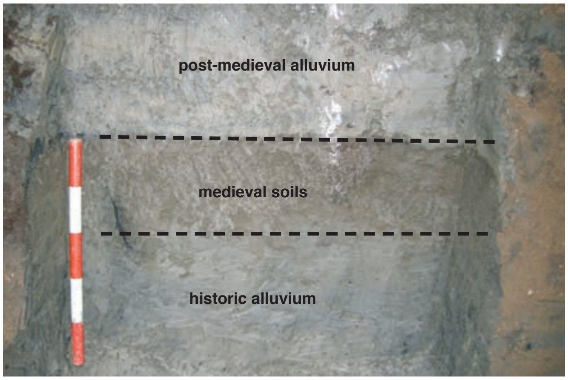


Fig 36 Upper alluvium containing a soil profile from Urban Sustainability Centre at the western end of Royal Victoria Docks (0.5m scale)

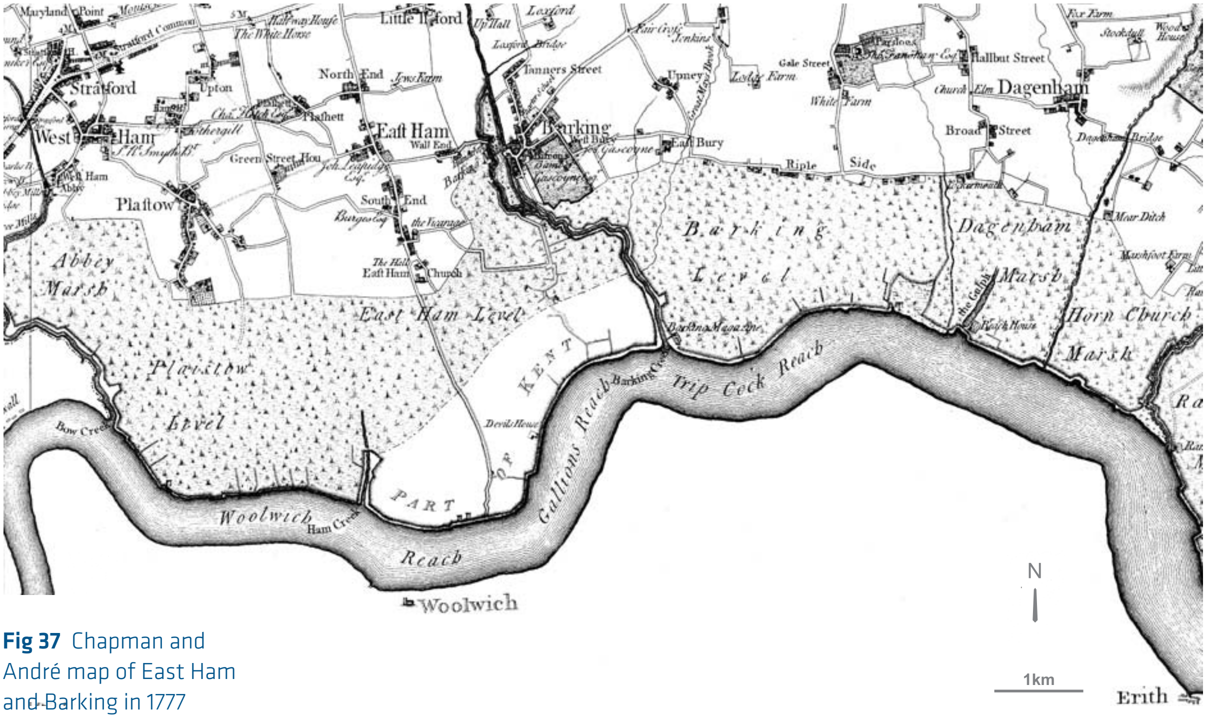


Fig 37 Chapman and André map of East Ham and Barking in 1777 showing some of the ‘levels’ and marshes, and the location of Dagenham Breach (House) where the river wall was breached in a flood of 1707 (scale *c* 1:85,000)

In contrast, on the south side of the river at Plumstead Portal and Depot, the presence of conifer pollen indicates 17th-century plantations with a series of soil layers containing plant remains reflecting woodland rather than open fen.[19] The area had dried out and woodland developed as local river defences protected the area from flooding.

7.4 The archaeological evidence and human interaction

Up until this point, climate and sea levels are the main drivers of change in this geoarchaeological story, but from the start of the historic period the impact that humans had on the landscape becomes overwhelming and irreversible. As we have seen in previous chapters (Chapter 5; Chapter 6), from early prehistory communities were drawn to the wetlands because of the fresh water, wealth of plant and animal life, and the good transport links of the waterways. From the Iron Age onwards, however, settlement expanded significantly, industry began to develop and the Thames wetland was exploited in a different way. Human modification of the environment became a major force for change, and by the medieval period (*c* 1000–*c* 1500) this part of the floodplain was one of the most economically advanced areas in the country, being highly urbanised and a commercial farming centre (Table 1).[20] Below we shall look at three main drivers of change across the study area, introduced in the medieval and post-medieval periods in particular: deforestation, drainage and reclamation, and agriculture.

Deforestation

Clearance activity had been taking place on a growing scale through the Neolithic and Bronze Age (Chapter 6), but by the Iron Age the Thames banks and interfluves were comparatively treeless (Fig 38). This process destabilised the river's banks, resulting in more sediment being washed into the system. Greater run-off led to the river swelling and carrying sediment that was then dumped on the floodplain. As a consequence, over the late prehistoric period, groundwater tables rose, which in turn impeded drainage, aggravated flood episodes and led to a dwindling of the floodplain woodland.

The pattern of woodland decline is seen in pollen diagrams across the Crossrail sites and the region. Across the floodplain, from Limmo Peninsula Shaft to

Fig 38 Experimental archaeology in action – woodland clearance with stone tools

Plumstead Portal and Depot, as conditions become wetter tree species reduce in number, grasses flourish and an open grass-sedge fen develops. The pollen record from North Woolwich Portal provides an example typical of the Crossrail south-east work area, where declines in oak, hazel and lime were accompanied by the expansion of plants typical of disturbed ground.[21] Similarly, the pollen record from Barking suggests the initial flooding episodes (and subsequent waterlogging) were widespread, leading to a decrease in a loss of woodland habitat both on the peat and on the higher, dryer land surface. Ironically, an increased input of sediment into the river system through clearance activities probably led to an increase in the severity of the flooding episodes that hastened the abandonment of the floodplain by Bronze Age peoples.[22] Indeed, through the succeeding centuries, the fens and tidal mudflats would be reworked and overprinted, time and again, by anthropogenic activity and the river, with new layers superimposing or effacing those before, much like a medieval palimpsest.

Drainage and reclamation

During this period the floodplain in the Crossrail south-east work area was unsuitable for permanent settlement and this is reflected in the fact that structural archaeology is scarce – but it did not mean the floodplain was not of value. The advantages of grazing and cultivating wetland and salt marsh were certainly recognised by prehistoric people, but management became increasingly necessary to mitigate the risks of flooding.[23]

Drainage and reclamation are the first steps to using the wetland, and in some areas small-scale drainage was taking place as early as the Iron Age. Ditches and local drainage would have been easy to maintain, starting the process of organised exploitation of the wetland. Seasonal embankment would have followed to reduce the risk of floods. These engineering works were taken to a new level in the Roman and medieval periods, as embankment and reclamation transformed the landscape.

For the late prehistoric, Roman and Anglo-Saxon periods there is no direct evidence to suggest that drainage took place on the Crossrail south-east worksites. There are, however, examples of prehistoric drainage in Tanner Street, Southwark,[24] and other examples from the United Kingdom coastal zone,[25] demonstrating that wetland management was undoubtedly happening both nearby and further afield from as early as the Bronze Age.

It was not until the medieval period that drainage became more systematic and embankment began, the Church being one of the main instigators of reclamation programmes. Large tracts of the coastal wetlands such as the East Anglian fenlands were drained, mud walls built and the floodplain marsh was reclaimed, cultivated and managed on an unparalleled scale.[26] Even though structural evidence for management of the Thames floodplain in the Crossrail south-east work area is not forthcoming, the clays do show evidence of drying out.[27] This could have been due to the formation of natural barriers, but it is more likely that the area was embanked or 'inned'.

Interestingly, enclosing intertidal wetlands in this way leads to freshening of the soil behind the wall, as the salts are washed away by the rain.[28] This may in part explain the lack of salt-loving plant species recovered from the clays at the Crossrail south-east worksites, as saltwater vegetation would be replaced by freshwater plants.[29]

Agriculture

For thousands of years, intertidal mudflats and salt marsh have been essential for fishing, fowling and grazing of sheep flocks on a seasonal basis,[30] but what can the sediments tell us about exploitation of the wetlands in the Crossrail south-east work area and the shift from simple-scale adaptations to reclamation?

Agriculture would have been the main form of landscape modification from the Neolithic, but with Iron Age settlement expansion, farming practices intensified.[31] Drainage allowed what would have been marginal land to be farmed and perhaps cultivated. The evidence, as we have seen above, is indirect, with a series of soils reflecting stabilisation of the landscape through drainage and other water management practices.

The scale of agricultural land management can be seen to be transformed in the medieval period, and historic records illustrate the importance of agriculture on the lower Thames floodplain at this time.[32] Within the Victoria Dock Portal site, charred rye (*Secale cereale*) grains in the upper alluvial deposits show agricultural activity was taking place in the historic period nearby.[33]

As agriculture burgeoned, the salt industry also flourished in Iron Age and Roman times.[34] Even though briquetage (coarse ceramic material used to make evaporation vessels used in extracting salt from seawater) has been found near the Plumstead Portal and Depot site at Charlton,[35] salterns would not be expected this far up the Thames estuary.

7.5 Following the Elizabeth line to the south-east

In this period we have seen the environment of the lower Thames and Crossrail south-east work areas change from a prehistoric wooded marsh to a tidal mudflat and salt marsh. These environments, represented by a thick swathe of alluvium, endure through Roman and Anglo-Saxon times to the medieval and post-medieval periods.

The switch in sediment type resulted from the combined effects of climate change, river-level rise (as a knock-on effect of RSL rise) and human activity. If you were travelling this area at any time say within the early medieval period (11th–12th century), you would definitely need a boat. The gravel contours of days gone by are now completely submerged below shifting muds.

Within the Crossrail south-east work corridor, lying as it did within the intertidal zone, the environment would now be a treacherous one of muds and tidal channels. It would still be a rich environment though, providing bounteous fish and oyster supplies, for example, particularly around the mouths of tributary rivers. The banks would be dense thickets of reeds and salt marsh communities (Fig 39) still good for wildfowling and, away from the lower ground, good for seasonal pasture, especially in the summer months when the risk of flooding, sometimes violent in the winter, had abated.

Increasingly, and particularly with the serious, widespread drainage and reclamation in the later medieval period (13th–15th century), most of the marginal land would be taken under the ownership of the Church or the wealthy. Access to the land for the first time would be limited. Only in the modern day would this land be fully reclaimed, however, confining the Thames back, close to its original Lateglacial channel route once again.

Fig 39 Salt marsh environments of the lower Thames at Rainham marshes

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Notes to Chapter 7

1 Rippon 2000
2 Sidell 2003, 257–378
3 Brown 2008
4 Barber 2006
5 Milne 1985; Brigham 1990
6 Galloway 2009, 173
7 Ibid
8 N Cameron and J E Whittaker in Spurr 2015
9 A Davis, K Stewart and R Scaife in Spurr 2015
10 Goodburn in prep, UBA-21608, 743±31 BP
11 Spurr 2015
12 N Cameron and J E Whittaker in Spurr 2015
13 Brigham 1990
14 Watson et al 2001
15 Galloway 2009
16 Ibid, 183
17 Nicholls and Halsey in prep
18 Chapman and André 1977
19 R Scaife in Spurr 2015
20 Galloway 2009
21 R Scaife in Spurr 2015
22 Green et al 2014
23 Rippon 2000
24 Drummond-Murray et al 1994
25 Rippon 2000
26 Menotti and O'Sullivan 2012
27 Spurr 2015
28 Gascoyne and Medlycott 2014
29 Spurr 2015
30 Rippon 2000
31 Brown 1996
32 Galloway 2009
33 A Davis and K Stewart in Spurr 2015
34 Biddulph et al 2012
35 Rippon 2006, 61

CHAPTER 8

CONCLUSIONS AND A LOOK TO THE FUTURE

The Thames is a dynamic river. Through the Crossrail investigations and others, we have seen it change over the last 10,000 years from a wide, gravel-bed river to one thick in peat and muds. At one stage, thick woodland and marsh filled the valley alongside a freshwater river. Later on, as southern Britain continued to sink slowly into the sea, the salty waters of the estuary pushed up along the Thames past London, changing the floodplain landscape in its wake and drowning the valley.

Archaeological discoveries have revealed, and will continue to do so, evidence for some of the earliest local communities to occupy the floodplain through which the Elizabeth line will run. Mesolithic people set up camp in carefully chosen locations and engaged in foraging, hunting and woodcraft (Chapter 5). As people moved to a sedentary lifestyle in the Neolithic and Bronze Age, they began cultivating the river terraces (Chapter 6). The intensity of agriculture and floodplain drainage grew through the historic period, hand in hand with river-level rise (Chapter 7), bringing about challenges with parallels in the present day. This long view of river-level change, which the sediments and archaeology within it provides, has provided essential information for researchers studying the past and modelling the future, as instrumental records only cover the last 60 years.[1]

As the population swelled from prehistoric to modern times, the impact humans have had on their surroundings has changed in scale from local to global. As a result, environmental change is undoubtedly the biggest threat we face today. One significant issue, as in the medieval period and arguably a trend emerging as early as the Iron Age, is the escalation in the regularity and extent of flooding. Today the rate of sea-level rise is estimated at around 3mm per year,[2] and likely to increase. This is a pressing and current problem affecting housing, infrastructure, industry and the natural environment in river valleys and lowlands across the country.[3] Although the Thames is now contained with high embankments and protected in London by the Thames barrier (Fig 40), areas upstream[4] and along the estuary[5] still remain subject to flooding, particularly when high tides coincide with high rainfall. Since it opened in 1984, the Thames barrier has closed over 170 times, a third of these in the winter of 2015/16.[6]

Considering the Thames barrier currently protects approximately 125 square km of Greater London from flooding, including an estimated 1.25 million

Fig 40 The Thames barrier, completed in 1984, is being utilised with increasing frequency

people, £200 billion worth of property and infrastructure, a large proportion of the London tube and rail network (not to mention many historic buildings, power supplies, hospitals and schools),[7] much depends on understanding how the Thames responds to flooding. As the deposit modelling of the past has shown, the intricate interplay of the geomorphology and topography of the floodplain and, increasingly, the bathymetry of the channel itself, will play an important part in understanding the Thames into the future.

The geoarchaeological work MOLA has undertaken for Crossrail points the way towards the future of landscape reconstruction. As we move forward, computing power will increase, geographic information system (GIS) modelling online will enable data sharing and technology will allow realistic visualisation of the past landscape. It is hoped that the work we do can be shared and accessible to archaeologists, curators, project designers and the public. This will enable a move towards creating an overarching and integrated view of the past across the capital, lead to a greater understanding of the potential and type of archaeological remains that may be hidden within the floodplain and provide a platform for future research.

The Crossrail project has been immensely beneficial in raising the profile of archaeology and what geoarchaeology can tell us about the history of the landscape and environment. The outlook for this work is bright, with potential not only to act as a foundation for developing new ways of understanding the changing landscapes of the past but those of the future too, as London expands and develops in the 21st century.

Notes to Chapter 8

1 Records were established after violent storms and flooding in 1953 (*National Tidal*).

2 This value is based on calculations based on satellite data collated since 1992 (*NASA*).

3 Eg flood events at Boscastle, Cornwall, in 2004 (*Met Office*), on the Somerset Levels, Somerset, in 2013–14 (*Gov.UK*) and Cockermouth, Cumberland, in 2009 and 2015 (*Cockermouth*)

4 *BBC News [10 February 2014]*

5 Gani 2016

6 *BBC News [5 March 2014]*

7 *21st century*

CHAPTER 9

APPENDICES

9.1 Geoarchaeological glossary

Alluvium: a broad term referring to material deposited in a river channel or floodplain. Alluvial sediments are usually fine-grained and well-sorted, although there is no diagnostic particle size as deposition depends on the energy of the water transport (ie from sands and gravels deposited by fast flowing water to clays that settle out of suspension during overbank flooding). Alluvium is frequently laminated or exhibits bedding structures, will often oxidise and change colour following exposure, and may be rich in environmental remains such as molluscs or pollen.

Braided channel: river channel pattern with multiple channels separated by shoals, bars and unstable islands that migrate and change frequently. Braided channels have high sediment loads and are typical of arctic regions today.

Cal BC: calibrated radiocarbon years before the year 0. Radiocarbon measurements are usually calibrated to (2σ error) (below, 9.2).

Carr: a north European wetland, a fen overgrown with trees.

Devensian: the last glacial complex in Britain.

Diatoms: microscopic siliceous algae sensitive to environmental conditions (such as salinity and temperature) used in palaeoenvironmental reconstruction.

Ecotone/ecotonal: a transition area between two adjacent ecological communities (ecosystems). Changes in the physical environment may produce a sharp boundary, as in the example of a shoreline or the interface between areas of forest and cleared land, or a more gradually blended interface area where species from each community will be found together, as well as unique local species. Mountain ranges often create such ecotones, due to the wide variety of climatic conditions experienced on their slopes.

Eyot: small braid bars within the network of small channels of a braided river that form temporary islands.

Facies: Reading's definition follows 'A *facies* is a body of rock with specified characteristic. ... A facies should ideally be a distinctive rock that forms under certain conditions of sedimentation, reflecting a particular process or environment.'[1] In sedimentology, lithofacies are defined, based on characteristics such as grain size and mineralogy that reflect depositional processes.

Fen: a type of wetland often marshy and low-lying, deriving most of its water from groundwater rich in calcium and magnesium, and characterised by a distinctive flora. Fens will ultimately become a terrestrial community, such as woodland, through the process of ecological succession. Fens are often confused with bogs, which are fed primarily by rainwater and often inhabited by sphagnum moss (*Sphagnum* sp), making them acidic.

Holocene: or 'Postglacial' is the most recent epoch (part) of the Quaternary, covering the past 11,500 years approximately, characterised by an interglacial climate. The Holocene in Britain is often referred to as the 'Flandrian'.

Hominin: Any member of the zoological 'tribe' Hominini, including humans or human ancestors. The taxonomic family Hominidae (order Primates) includes four extant genera: chimpanzees, gorillas, orang-utans and only one human/hominin species: *Homo sapiens*.

Kempton Park Terrace: (previously 'Upper Floodplain Terrace') comprises river gravels mapped at approximately +5m OD (Fig 5). Kempton Park Gravels are thought to have been deposited during the Devensian.

Loch Lomond Stadial/Readvance or Younger Dryas: Devensian Lateglacial, the period following the Last Glacial Maximum in which local ice readvance occurred lasting until the start of the Holocene. This period follows a warm interstadial episode (called the Windermere Interstadial in Britain).

Last Glacial Maximum: the peak of the most recent glaciation (Devensian), from between approximately 22,000 and 18,000 years ago. In Britain this is referred to as the Dimlington Stadial.

Lateglacial Interstadial: an episode of climatic improvement, called the Windermere Interstadial in Britain, that occurred during the Devensian from *c* 13,500 to *c* 11,000 years BP (equivalent to the European Bølling/Allerød).

Ostracods: bivalve crustacea common to almost all fresh and marine aquatic environments, including semi-terrestrial settings, living within the water column on and in the substrate.

Periglacial: characteristic of a region close to an ice sheet but not covered in ice. In such a region, the ground may be frozen all year, thawing and waterlogging the surface in summer because it cannot drain away through the subsurface ice. Geomorphological and sedimentological features characteristic of periglacial environments include tors, patterned ground and involutions.

Pleistocene: referring to the part of the Quaternary pre-dating the climatic amelioration at the start of the Holocene (approximately 2.6 million years ago to *c* 10,000 years ago). The epoch is divided into Early (*c* 2,600,000–*c* 450,000 years ago), Middle (*c* 450,000–*c* 120,000 years ago) and Late (*c* 120,000–*c* 10,000 years ago) Pleistocene.

Quaternary: the most recent major subdivision (series) of the geological record, extending from around 2.6 million years ago to the present day and characterised by climatic oscillations from full glacial to warm episodes (interglacial), when the climate was as warm as, if not warmer, than today. The observed pattern is of long glacial stages with cold and warm perturbations (stadials and interstadials) and short interglacials (usually less than 10,000 years). Human evolution has largely taken place within the Quaternary period.

Shepperton Gravel: or 'buried channel' infill (previously 'Lower Floodplain Terrace') on the floodplain of the Thames deposited during glacial outwash following the Last Glacial Maximum (*c* 18,000–*c* 10,000 years ago) (Fig 5).

9.2 Radiocarbon dates

A series of 19 samples was taken for radiocarbon dating from all the Crossrail south-east worksite sequences. The dates were obtained from a variety of plant macrofossils and, where this was not possible, unidentifiable plant material. All samples were pretreated, combusted, graphitised and measured by accelerator mass spectrometry by Beta Analytic.[2] The results have been calibrated from the conventional radiocarbon ages[3] and are quoted in accordance with the international standard known as the Trondheim convention.[4] The calibrations were calculated according to the maximum intercept method using the datasets published by Reimer et al[5] and the computer program OxCal v4.2.[6] End points have been rounded out to ten years.[7]

Notes to Chapter 9

1 Reading 1996, 3

2 The samples were processed as outlined at www.radiocarbon.com

3 Stuiver and Polach 1977

4 Stuiver and Kra 1986

5 Reimer et al 2013

6 Bronk Ramsey 1995; 1998; 2001; 2009

7 As recommended by Mook 1986

Table 4 Radiocarbon results on plant macrofossils and unidentified plant material from Custom House Station (XTI13), North Woolwich Portal (XSV11), Plumstead Portal and Depot (XSW11), Victoria Dock Portal (XSX11) and Connaught Tunnel (XSY11) sites, listed in sample number order

Laboratory no.	Sample reference (site code/trench or borehole no./monolith tin/context no.)	Material	$\delta^{13}C$ (‰)	Pre-treatment	Radiocarbon age before present (BP)	Calibrated date (95% confidence)
Custom House Station						
BETA-396252	XTI13/WS1-202	plant	-27.5	acid/alkali/acid	3950±30	2570–2340 cal BC
BETA-396253	XTI13/WS1-240	plant	-28.8	acid/alkali/acid	4340±30	3030–2890 cal BC
BETA-396254	XTI13/WS1-265	plant	-26.8	acid/alkali/acid	4630±30	3505–3425 cal BC
North Woolwich Portal						
BETA-407268	XSV11/2/59/32	plant	-25.6	acid/alkali/acid	3470±30	1890–1690 cal BC
BETA-407269	XSV11/3/5/3	seeds	-28.7	acid/alkali/acid	3040±30	1410–1210 cal BC
BETA-407270	XSV11/3/15/9	plant	-28.6	acid/alkali/acid	3830±30	2460–2150 cal BC
BETA-407271	XSV11/3/17/8	seeds	-27.1	acid/alkali/acid	3750±30	2280–2040 cal BC
Plumstead Portal and Depot						
BETA-407272	XSW11/1a/3/2	seeds	-27.8	acid/alkali/acid	3560±30	2020–1770 cal BC
BETA-407273	XSW11/1a/4/2	seeds	-24.0	acid/alkali/acid	3480±30	1900–1690 cal BC
BETA-407274	XSW11/1b/16/7	seeds	-25.7	acid/alkali/acid	3500±30	1920–1700 cal BC
Victoria Dock Portal						
BETA-407275	XSX11/2/29/11	plant	Na	acid/alkali/acid	3150±30	1500–1320 cal BC
BETA-407276	XSX11/2/40/13	plant	-28.4	acid/alkali/acid	5020±30	3950–3710 cal BC
BETA-407277	XSX11/2/44/12	plant	Na	acid/alkali/acid	4540±30	6670–3100 cal BC
Connaught Tunnel						
BETA-407278	XSY11/1/6/11	plant	-25.7	acid/alkali/acid	3580±30	2030–1880 cal BC
BETA-407279	XSY11/1/6/12	plant	-30.1	acid/alkali/acid	3250±30	1620–1440 cal BC
BETA-407280	XSY11/1/7/12	plant	-27.4	acid/alkali/acid	4360±30	3090–2900 cal BC
BETA-407281	XSY11/3/57/27	seeds	-27.4	acid/alkali/acid	2900±30	1210–1000 cal BC
BETA-407283	XSY11/3/68/30	seeds	-28.2	acid/alkali/acid	5340±30	4320–4040 cal BC
BETA-408194	XSY11/3/61/28	plant	-26.4	acid/alkali/acid	3770±30	2290–2050 cal BC

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