RECONSTRUCTING THE PREHISTORIC LANDSCAPES OF THE LITTLEBROOK POWER STATION SITE, DARTFORD

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with contributions from
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Analysis of the thick Holocene sediment sequences at the site of Littlebrook Power station, Dartford, has revealed an archive of environmental change spanning much of the Holocene, from the Early Mesolithic to the historic period. Analysis of core samples from the site, along with modelling of stratigraphic data from nearby boreholes, has allowed the past environments of Littlebrook to be reconstructed. Whilst changing on-site depositional environments were largely driven by relative sea level rise, there was intensifying human influence on the surrounding landscape, beginning with the first evidence of cereal cultivation during the Neolithic and followed by a marked expansion of pastoralism from the Roman period onwards.

The Lower Thames Estuary, along with its adjoining swathes of flat marshland, dominates the landscape of north Kent, physically defining the county's border with Essex, and shaping much of the region's history. Given the well-documented relationship between the Estuary and the economic, social, and military history of the region (Addison 1954; Bowler 1969; VCH 1974; Bull 1996; Galloway 2009; Lichtenstein 2017), it is perhaps not surprising that there is a long tradition of enquiry into the natural history of the Estuary itself. Whilst in other parts of the country the landscape can sometimes be imagined as a constant, unchanging backdrop to the development of human civilisation (Muir 1999; Daniels 2009; Gammon and Elkington 2015), even the earliest studies of the Thames Estuary acknowledged the profound changes that the river and its margins have undergone over timescales commensurate with the human history of the region (*e.g.* Spurrell 1885).

The history of study of the sedimentary sequence of the Thames Estuary reaches back to the late 19th century with Flaxman C.J. Spurrell's (1889a) paper given at the Geologists' Association; even at this early stage, Spurrell was plainly aware of the importance of long-term changes in sea-level and the effects that these had on the archaeology of the region, both in terms of understanding where, and how deeply buried, archaeological remains might be found, and the changing environmental context of past human occupation (Spurrell 1885, 1889b).

In the 20th century, a series of landmark studies carried out by Devoy (1977, 1979, 1980, 1982, 2000), elucidated in detail a complex sequence of changes in relative sea level during the Holocene Epoch (the last 11,700 years, after the 'ice ages' of the Pleistocene Epoch). Through the application of pollen analysis and radiocarbon dating, Devoy (1980) was also able to understand in greater detail the complex interaction between phases of marine transgression and regression and patterns of human activity and vegetation change in the wider landscape, and thus begin to place these processes within the framework of climatic change during the Holocene. The importance of understanding these processes and patterns has taken on greater significance in the light of a new focus on 'sustainable development' enshrined in the *National Planning Policy Framework* (Ministry of Housing, Communities and Local Government 2018).

In 2014 and 2015, MOLA (Museum of London Archaeology) carried out a programme of geoarchaeological investigations at Littlebrook Power Station, Dartford, in advance of redevelopment.[1] The work involved multiple phases of borehole sampling, laboratory analysis and deposit modelling in order to explore the Holocene environmental history of the site and provide evidence for past human activity in that part of the Lower Thames Estuary.

The redevelopment site at Littlebrook (centred at NGR TQ 56000 76160) covers approximately 30ha in an area of reclaimed marshland, south-east of the present Dartford Marshes, and lies on the south bank of the River Thames, approximately 2.5km downstream from the confluence of the River Darent / Dartford Creek (**Fig. 1**).

The site is underlain by bedrock of the Late Cretaceous White Chalk Subgroup (BGS 1998), which is locally folded upwards (the 'Purfleet anticline'; Gibbard 1994; Schreve *et al.* 2002), forming east-west trending ridges within which the present course of the Thames is confined to a relatively narrow valley between Erith and Cliffe. Across the whole of the site and its vicinity the bedrock is overlain by a thick sequence of Holocene alluvial and intertidal silts and clays, capped by a thick raft of made ground upon which the former power station was constructed, whilst 400m further to the south-west the chalk is instead overlain by the Taplow Gravel terrace.

A total of nine boreholes (BH1-BH9; see Fig. 1) were put down across the site using a Comacchio dynamic drilling rig, in order to collect continuous sequences of core samples from the present ground surface to the top of the underlying Pleistocene gravel deposits. In the laboratory, the cores were opened and the sediments were described according to standard geological criteria (Tucker 1982; Jones *et al.* 1999). The sediment descriptions and surveyed positions of the nine geoarchaeological boreholes, along with information from nearby archaeological sites and open-source data available on the British Geological Survey (BGS) website, were entered into digital databases (RockWorks 15 and ArcGIS 10); these were then used to model the below-ground surfaces of key stratigraphic units. The cores containing the thickest and least disturbed sedimentary sequences (BH3 and BH9) were then subsampled for analysis of fossil pollen, plant macro-remains, insects, ostracods, and foraminifera, as well as radiocarbon dating. Samples for dating were submitted to BETA Analytic Inc., Miami, for AMS ^{14}C measurement; dates were calibrated and then converted to calendar dates (in years 'cal. BC' or 'cal. AD') using the IntCal13 calibration curve (Reimer *et al.* 2013).[2]

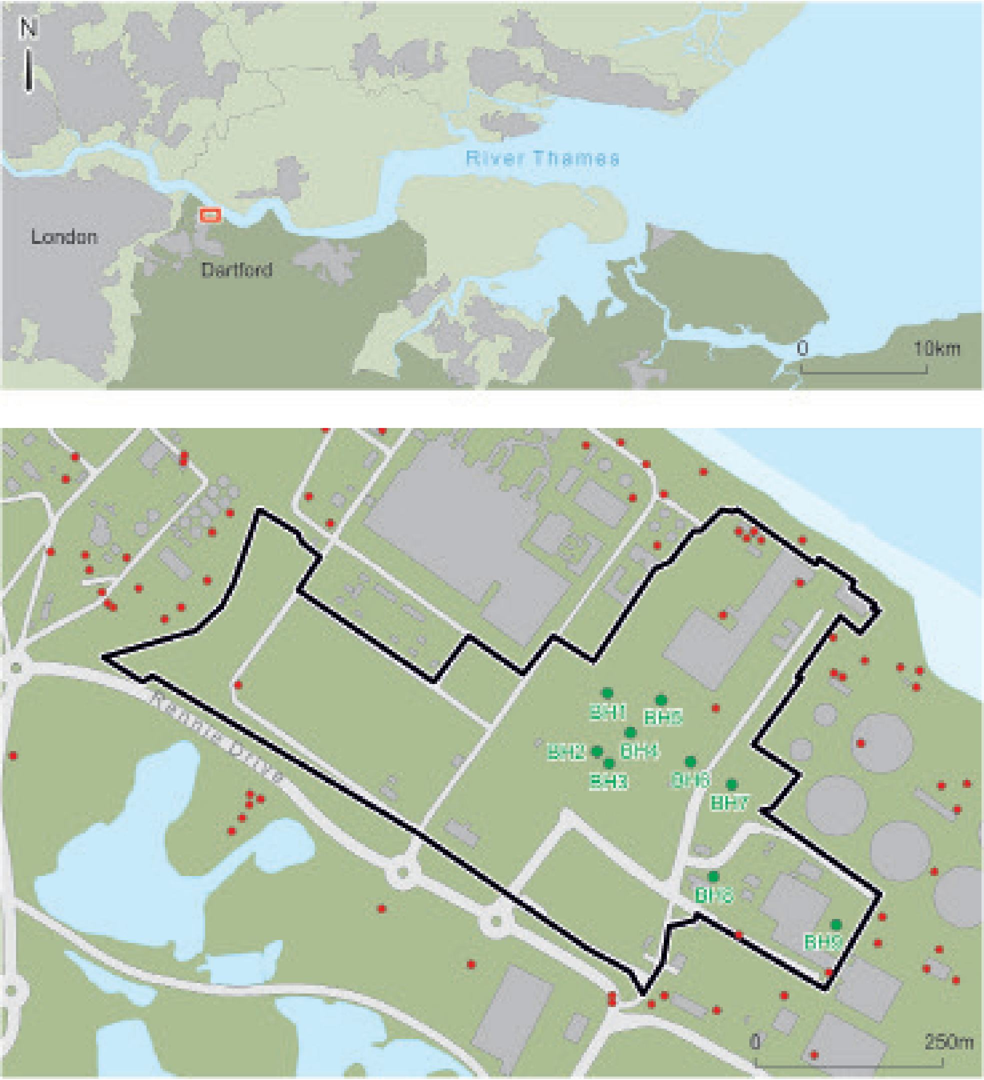

Fig. 1 Location of the site and boreholes (building arrangement as in 2014; since superseded by redevelopment).

The deposits

To facilitate their discussion, the deposits have been grouped into sets of broadly synchronous strata representing changing depositional environments at the site. These are described in turn, from earliest to latest.

Chalk bedrock and terrace gravels: to the south-west of the site, the surface of the chalk is overlain by deposits of dense sandy flint gravels up to 10m thick, creating a more or less horizontal terrace at around 5m OD. The surface of these

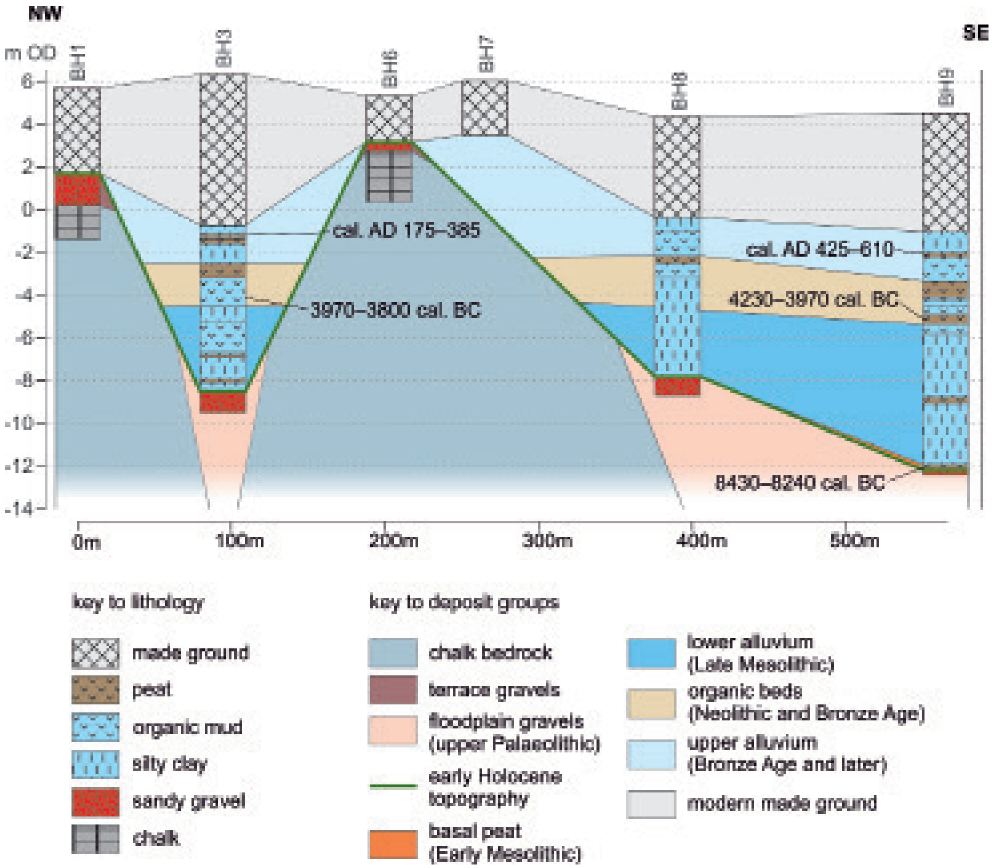

Fig. 2 Borehole transect across the site.

gravels represents the remains of a river braid plain, laid down by the forerunner to the present Thames during the Late Pleistocene, now forming a raised terrace (relative to the modern river level) as a result of progressive tectonic uplift combined with subsequent river incision. The older terrace gravels are generally absent within the site, having been removed by subsequent downcutting of the Thames during the latest (Devensian) Stage of the Pleistocene, when the river incised down to -15m OD (**Fig. 2**).

Two boreholes within the site, however, encountered chalk bedrock outcropping at elevations of 0m and 2m OD (BH1 and BH6, respectively; see Fig. 2). During the Late Devensian (or, archaeologically, during the Late Upper Palaeolithic), at *c.*10,000 BC, these localised highpoints would have been prominent features in the landscape, standing more than 10m above the rest of the river valley and remaining prominent features in the landscape for several millennia.

Floodplain gravels (Upper Palaeolithic): following the most recent phase of river downcutting, which occurred in the Devensian Stage, *c.*80,000-11,650 years before present (BP), deposits of sand and gravel began to accumulate on the valley floor. These gravels were typically laid down in a cold-climate, high-energy braid plain environment similar to that in which the older, higher, gravel terraces had formed earlier in the Pleistocene. Large seasonal variations in river output and high sediment loads from the sparsely-vegetated tundra-type landscape resulted in a characteristic topography of multiple braided river channels separated by shifting sand bars and gravel islands that today underlies the whole of the present floodplain of the Thames.

The Early Holocene surface model is shown in **Fig. 3**, which illustrates the topography around the site at the beginning of the present interglacial. The modelled relief can be considered the template onto which subsequent depositional environments were overlaid. As shown in Fig. 3, the site occupies part of the southern edge of the former Thames braid plain, the buried surface of which typically lies at between -15m and -8m OD, rising in the south and west of the site towards the edge of the higher and older terrace gravel. Within the site limits, there are two conspicuous high points representing the chalk outcrops described above.

Basal peat (Early Mesolithic): the beginning of the Holocene at 11,650 BP (9700 BC) (Walker *et al.* 2009), coincident with the beginning of the Mesolithic, was characterised by rapidly warming climatic conditions and accompanied by large-scale changes in local flora and fauna. As a result of melting of the ice sheets that once covered much of the northern hemisphere, sea levels, estimated to be at approximately -30m OD at the start of the Holocene (Devoy 1982), began to rise rapidly. As the climate became more temperate, the seasonal fluctuations in river discharge became less pronounced and, in response to the rising sea levels, finer-grained alluvium typical of lower-energy deposition began to accumulate within parts of the floodplain.

At the beginning of this phase, any alluvial deposition would have been concentrated towards the centre of the floodplain, with the more marginal parts of the valley, such as the present [Littlebrook] site, being covered by woodland and marginal riparian wetlands. These environments are represented by a 0.16m-thick layer of woody peat, radiocarbon dated to 8430-8240 cal. BC,[3] overlying the floodplain gravels in BH9 at -12.12m OD. This basal peat layer contained a typical Early Holocene 'Boreal' pollen assemblage, indicating local woodland cover dominated by pine with smaller amounts of hazel and oak, with some birch possibly representing local remnants of the earliest post-glacial pioneer woodland (Birks 1989).

Lower alluvium (Late Mesolithic): during the Middle Holocene, broadly coincident with the late Mesolithic, continued inundation of the floodplain led to the deposition of a series of silty clays interspersed with occasional beds of silty peat. Pollen assemblages from these sediments indicate a change to mixed broadleaf woodland, dominated by elm, oak, hazel, and with some lime, on the surrounding drylands, whilst alder carr began to colonise the floodplain. Based on comparisons with other nearby sites (Devoy 1979), the pollen evidence suggests a Middle Holocene date for these deposits, indicating that a gap,

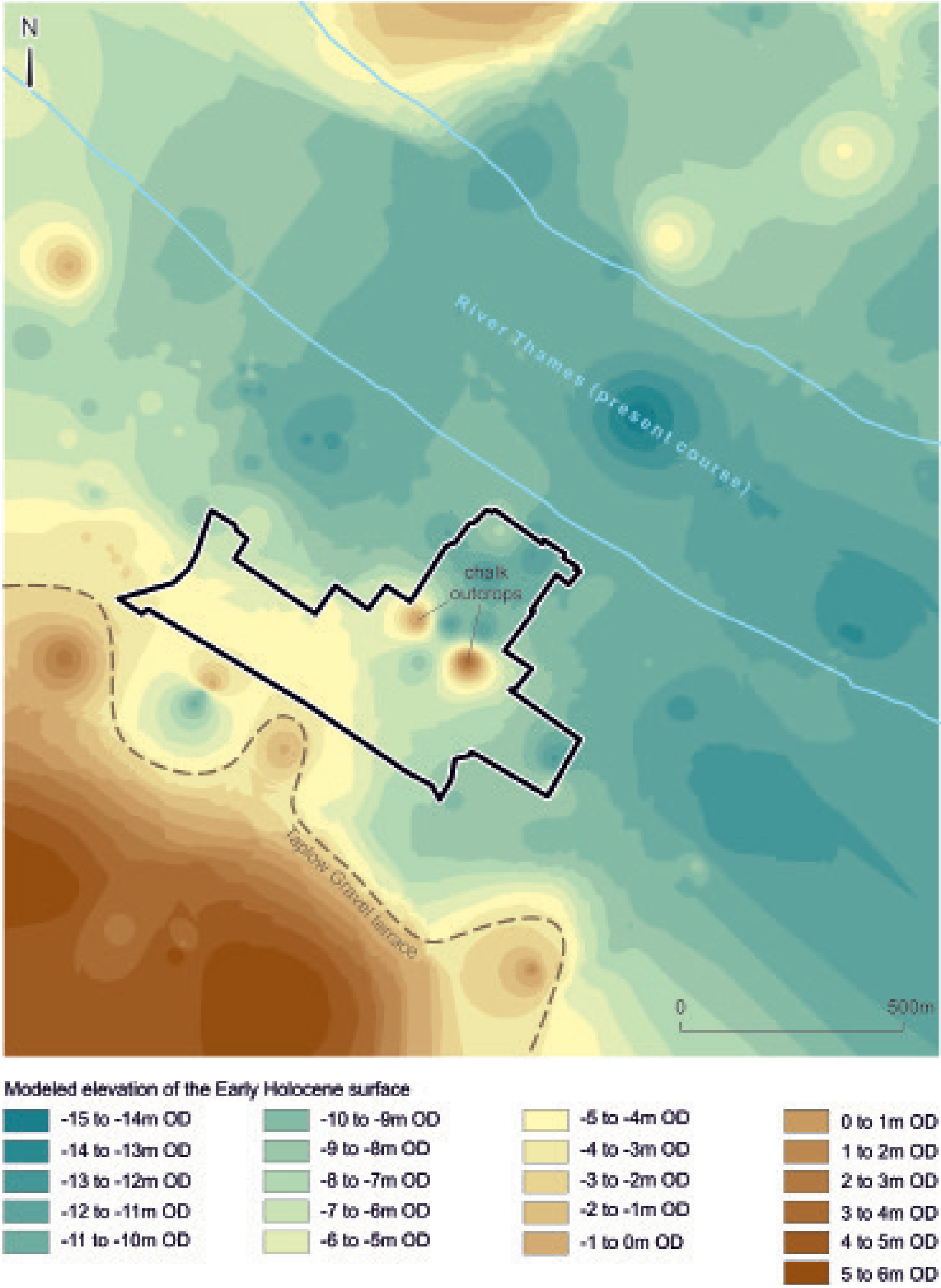

Fig. 3 Palaeotopographical model of the Early Holocene land surface.

perhaps of 1,000 to 2,000 years, may have separated the formation of the basal peat and its later inundation and burial.

The presence of brackish-water ostracods and foraminifera throughout these late Mesolithic alluvial deposits indicates some estuarine influence, although salinity was initially very low, as shown by the dominance of freshwater ostracods[4] and the presence of testate amoebae[5] in the deposits below -10m OD. Above this level, species typical of brackish conditions[6] dominated, indicating encroachment of tidal mudflats and high saltmarsh (*i.e.*, above mean high water) in this part of the floodplain during this time. The pattern of increasing estuarine influence is interrupted at the end of the Mesolithic period, however, with the disappearance of all brackish indicators, and the return of freshwater ostracods at -6.3m OD.[7]

The lower alluvial deposits are assigned to the Late Mesolithic on stratigraphic grounds, since strata securely dated to the Early Mesolithic and to the early Neolithic were found above and below. Pieces of roundwood from within the lower alluvium of both BH3 and BH9 were submitted for radiocarbon dating, but the resultant Neolithic dates – with ranges between *c.*3650 and 3350 cal. BC[8] – are taken to be unacceptably young. The somewhat earlier Neolithic dates from the overlying peats are deemed the more secure, whilst the dates on these roundwood fragments are thought to pertain not to the (older) sediment they are within, but instead to the later colonisation of the floodplain by woodland during the Neolithic.

Organic beds (Neolithic to Bronze Age): at -5.37m OD, the freshwater alluvium in BH9 was overlain by a dark reddish-brown wood peat, dated to 4230-3970 cal. BC[11] (at -5.19m OD). Similar peats, often interbedded with organic silty clays, were widespread across the site. Closer to the edge of the floodplain, in BH3, these strata returned a date of 3970-3800 cal. BC[12] at -4.20m OD. Collectively these strata represent a mosaic of freshwater environments: mainly alder carr, but with some marginal areas of reedswamp and alluvial floodplain. Ostracods and foraminifera were entirely absent in these strata, although beetle and bug assemblages indicative of freshwater muddy streams in wooded environments were found in both BH3 and BH9.[13]

Pollen assemblages in BH9 generally indicated the dominance of alder carr within the floodplain and, initially, the persistence of the Middle Holocene mixed deciduous woodland on the surrounding dry land, although abundances of elm pollen began to decline permanently at -5.12m OD. BH3 contained a similar record of vegetation cover, albeit with slightly greater representation of herbaceous plants and, above -4.20m OD, intermittent presence of small amounts of cereal pollen; these small differences in pollen content are due to the position of BH3 on the edge of the densely vegetated floodplain at this time.

Upper alluvium (Bronze Age onwards): the organic-rich deposits across the site were overlain by 2-3m of predominantly minerogenic alluvium, marking a return to sediment deposition on an open estuarine floodplain environment in response to rising relative sea level. The base of the upper alluvium was at -3.39m OD in BH9 and -2.74m OD in BH3. Although not directly dated, linear interpolation of the age vs. depth models for the two cores suggest a Middle to Late Bronze Age date (*i.e.*, between *c.*1500 and 800 BC) is likely for the return to estuarine conditions at the site, which accords well with regional models for sedimentation in the Lower Thames (Bates and Whittaker 2004; Stafford *et al.* 2012). In the lower part of these estuarine deposits, high saltmarsh conditions are indicated, both by the presence of agglutinating foraminifera[14] and by occasional thin discontinuous beds of fibrous peat, the uppermost of which were dated to cal. AD 175-385[15] and AD 425-610[16] in BH3 and BH9, respectively. Above these organic beds, foraminifera indicative of low saltmarsh and tidal flats[17] become dominant, indicating ever increasing marine influence from the early medieval period onwards.

Pollen from both BH3 and BH9 indicate open conditions, both on the floodplain and on the surrounding dry land. Pollen of herbaceous plants and grasses becomes increasingly abundant into the historic period. Although cereal pollen continued to be present in small amounts in BH3, the general opening of the landscape evident from the Roman period onwards was not associated with any significant increase in evidence for cereal cultivation; instead the appearance of pollen associated with pastoral habitats[18] illustrates the greater importance of livestock farming over arable agriculture into the historic period.

Evidence for Neolithic agriculture

The first evidence for human disturbance of the natural vegetation cover around Littlebrook occurs during the early Neolithic in the form of a reduction in elm (*Ulmus*) pollen at -5.12m OD in BH9. Given that this is associated with an increase in ash (*Fraxinus*) and a reduction in lime (*Tilia*) pollen, this may be indicative of the 'Elm Decline' – a widespread event in north-western Europe commonly associated with early agriculture during the Neolithic (Scaife 1988; Parker *et al.* 2002; Batchelor *et al.* 2014). In BH3, closer to the margins of the floodplain, evidence for some cultivation in the surrounding landscape is provided in the form of the intermittent presence of cereal pollen above -4.20m OD. Cereal pollen was absent in BH9, although cultivated cereals do not tend to disperse large volumes of pollen across the surrounding landscape, so this apparent absence is almost certainly due to the dense alder carr vegetation drowning out any faint traces of cereal cultivation in that sampling location.

The decline in elm pollen in BH9 occurs just above the horizon dated to 4230-3970 cal. BC,[19] and age vs. depth modelling provides an age estimate for the onset of the event of *c.4195-3850 cal. BC* (95% confidence),[20] which is within the typical range observed elsewhere in the British Isles (Parker *et al.* 2002). The two most common explanations put forward for the elm decline are either deliberate human deforestation, which (due to preference for particular soils favoured by elm or some other factor) disproportionately affected elm over other types of tree, or a widespread outbreak of Dutch elm disease. The main vectors for Dutch elm disease are the two species of European elm bark beetle (*Scolytus scolytus* and *S. multistriatus*) and remains of these insects have been found in direct association with evidence for an unusually early[21] decline in elm at Horton Kirby, 8km south of the site (Batchelor *et al.* 2014). There was no evidence for the presence of

Scolytus at the Littlebrook site, but the first positive evidence for cereal cultivation near the site is dated to soon after the local elm decline, at 3970-3800 cal. BC.[22] This evidence suggests that, at least in this part of the Thames Estuary, human activity associated with early Neolithic agriculture may have been the principal driver of the decline in elm woodland at the beginning of the Late Holocene. The small increase in ash coincident with the elm decline is typically interpreted as the result of secondary woodland recolonizing clearings left by the removal of elm, and elsewhere in the British Isles this is often put forward as evidence for a pattern of cultivation in shifting clearances ('landnam'; Iversen 1941; Scaife 1988; Caseldine and Fyfe 2006).

Reconstructing lost landscapes

Geoarchaeological deposit models are increasingly recognised as important tools to help understand and visualise complex sedimentary sequences, and are of particular use when assessing the archaeological and palaeo-environmental potential of sites in alluvial floodplain environments such as the Lower Thames Estuary (Howard and Macklin 1999; Carey *et al.* 2018). Fig. 3 is an example of such an approach, and illustrates how it can be used to better understand the buried topography of a site; the Early Holocene surface represents the initial topographic 'template' onto which all subsequent sedimentation at Littlebrook has been superimposed, and shows a clear distinction between areas of higher terrace gravels and the deeper Thames floodplain. By combining this model with radiocarbon-based age vs depth models, and interpretation of the sedimentary and palaeo-environmental evidence obtained from the samples, it has been possible to produce interpretative palaeo-geographic reconstructions, shown in **Fig. 4**. These reconstructions were generated for six discreet 'time slices' to illustrate the patterns of environmental change at Littlebrook, and provide valuable insights that may inform future archaeological research in the region.

The reconstruction maps show that the greatest magnitude of environmental change occurred during the Mesolithic period. The map for *c.*8500 BC shows the relict braid plain, inherited from the Pleistocene Thames, still defining the topography of the river valley, potentially still with multiple braided streams, and the characteristic Boreal pine forest on the surrounding drylands. By *c.*7000 BC, as a result of a rapidly warming climate and rising sea levels, the pine forests had been replaced by warmth-loving mixed broadleaf woodland (Birks 1989), the floodplain began to be colonised by alder carr, and alluvial sedimentation began across some parts of the site. A thousand years later, by *c.*6000 BC, further sea level rise led to expansion of the active floodplain, and increasingly brackish estuarine conditions.

A further environmental shift occurred at the beginning of the Neolithic period, as the riverine environment shifted back to freshwater conditions, leading to a re-expansion of alder carr woodland across much of the floodplain, as shown in the reconstruction *c.*3500 BC. Based on current evidence it is not clear if this return to freshwater conditions was caused by a 'regression' phase of falling sea levels (Devoy 1982), merely a slowing down in the rate of sea level rise (Bates and Whittaker 2004; Stafford *et al.* 2012), or alternatively, if this was a localised

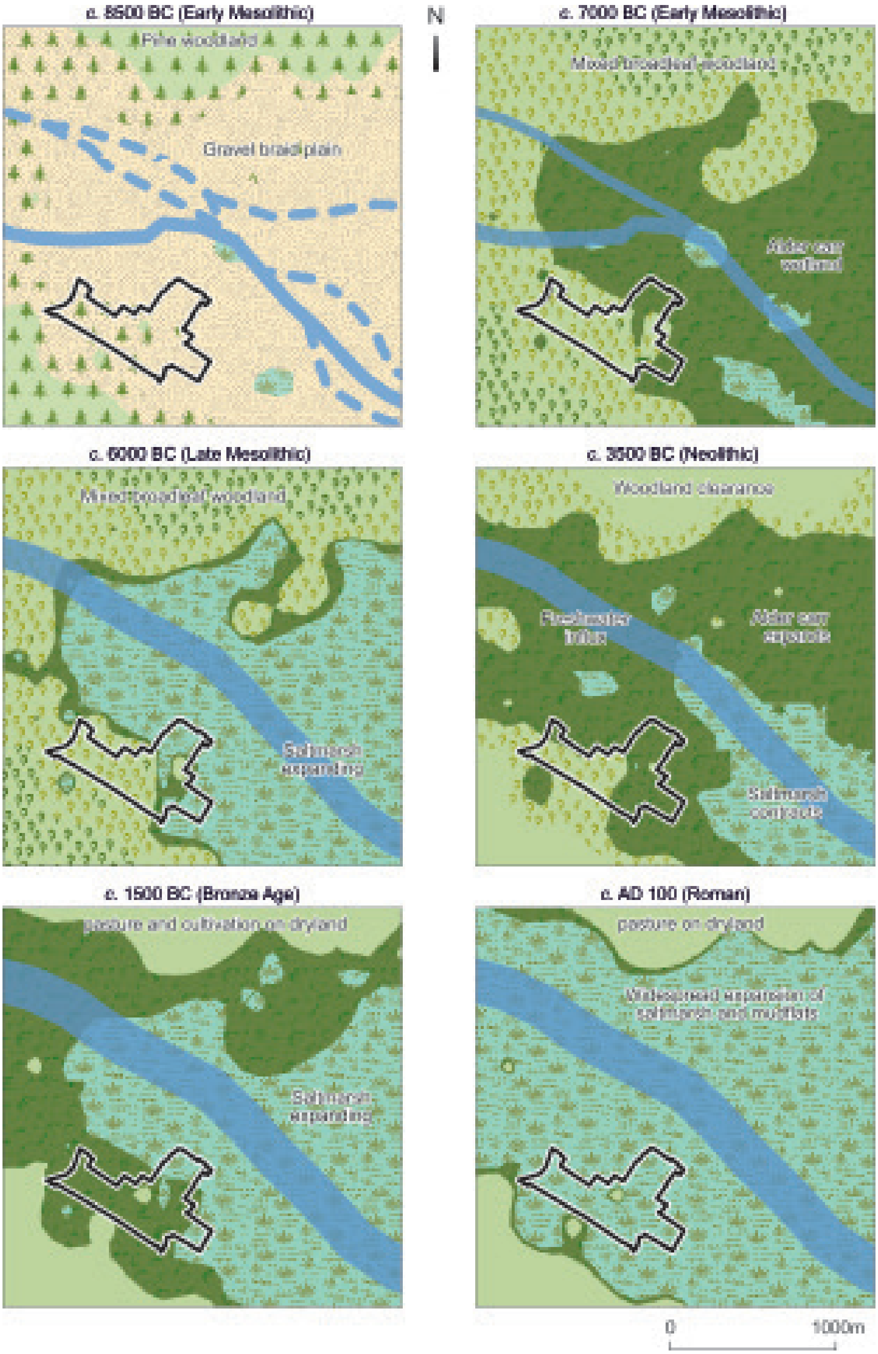

Fig. 4 Landscape reconstructions: Early Mesolithic to c.AD 100.

phenomenon related to the hydrology of the Darent and Mardyke streams that are both confluent with the Thames immediately upstream of the site. Whatever the cause, the change in salinity had a significant effect on the local landscape during this time. As discussed above, this period is also coincident with the first clear evidence for human impact on the landscape, in the form of small woodland clearances and small-scale cereal cultivation.

During the Bronze Age, brackish conditions once again became established at the site in response to rising sea levels. At this stage, as illustrated in the reconstruction for *c.*1500 BC, there was a diverse range of wetland habitats on site, with mudflats, saltmarsh and alder carr all represented locally. The deposit modelling also suggests that it is during this period that the distinctive outcrops of chalk bedrock at the site began to be submerged; for some time during later prehistory, these would have formed small islands of drier ground within the growing marshland.

Finally, as shown in the reconstruction for *c.*AD 100, continued sea level rise led to further expansion of mudflats and saltmarsh. During the Roman period, the ongoing accumulation of estuarine sediments finally buried all traces of the former Early Holocene topography of the site. From the beginning of the historic period onwards, the familiar uniform marshland of the Lower Thames Estuary became established, a landscape that largely persisted until reclamation and development in the twentieth century.

Conclusions

The geoarchaeological and palaeo-environmental work at Littlebrook Power Station has allowed the reconstruction of a complex story of changing landscapes and environments spanning the last 10,000 years. These environmental changes show a range of influences: global climatic conditions, changes in relative sea level, and the impacts of human activity. Pollen from the site has shown evidence for cereal cultivation dating from 3970-3800 cal. BC onwards, and this occurs soon after a decrease in elm, suggesting a probable human cause for the elm decline in this area.

Other insights provided by the data from Littlebrook also pose new questions to be answered by future research. The evidence for a return to freshwater conditions during the Neolithic is striking but as yet not fully understood: data from other nearby sites, including well dated 'sea level index points' (Shennan and Horton 2002; Edwards 2006),[23] are needed to determine if this is related to regionally-significant changes in relative sea level or a more localised phenomenon related to local tributary streams.

Finally, the work at Littlebrook has illustrated the use of geoarchaeological deposit modelling as a tool for revealing deeply buried topography and hidden landscapes, and, when combined with other palaeo-environmental information, as a means of illustrating and visualising past landscapes.

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ENDNOTES

[1] The investigation and its archive have been assigned archaeological site code KT-LPS14.

[2] Using the Clam software package (Blaauw 2010); the age vs. depth models were developed using the Bacon software package (Blaauw and Christen 2011).

[3] BETA-418111, 9100±40 bp, δ13C -26.5‰, woody plant remains, 8430-8240 cal. bc (95% confidence).

[4] Especially *Candona neglecta*, with other species including *Cyclocypris ovum* and *Ilocypris gibba*.

[5] Testate amoebae are usually present only in the very highest parts of saltmarshes but are more usually associated with freshwater habitats (Barnett *et al.* 2017).

[6] Brackish foraminifera *Jadammina macrescens*, *Arenoparrella maxicana*, *Ammonia* sp., and the brackish ostracod *Leptocythere porcellanea*.

[7] *Cryptocandona vavrai* and *Cyclocypris ovum*.

[8] BH3 -5.5m od: BETA-439234, 4640±30 bp, δ^{13}C -26.9‰, roundwood, 3520-3350 cal. bc (95% confidence); BH3 -6.8m od: BETA-418109, 4720±30 bp, δ^{13}C -27.8‰, roundwood, 3635-3375 cal. bc (95% confidence); BH9 -8.8m od: BETA-439236, 4790±30 bp, δ^{13}C -29.0‰, roundwood, 3645-3520 cal. bc (95% confidence).

[11] BETA-439235, 5250±30 bp, δ^{13}C -26.8‰, woody plant remains, 4230-3970 cal. bc (95% confidence).

[12] BETA-439233, 5100±30 bp, δ^{13}C -23.8‰, woody plant remains, 3970-3800 cal. bc (95% confidence).

[13] *Hydraena nigrita* and *H. tesacea*, both species typical of still or slowing flowing water, and the birch catkin bug *Kleidocerys resedae*, and red-legged shield bug *Penatoma rufipe*, both indicative of woodland.

[14] *Jadammina macrescens*.

[15] BH3 -1.2m od: BETA-418108, 1760±30, δ^{13}C -26.2‰, *c.f. Phragmites*, cal. ad 175-385 (95% confidence).

[16] BH9 -2.13m od: BETA-418110, 1520±30, δ^{13}C -27.1‰, *c.f. Phragmites*, cal. ad 425-610 (95% confidence).

[17] *Ammonia* sp., *Haynesina germanica* and *Elphidium williamsoni*.

[18] Dandelion type (Lactuoideae), ribwort plantain (*Plantago lanceolata*), clovers/vetches (*Trifolium* type) and docks (*Rumex* spp.).

[19] BETA-439235 – see note 11 above for details.

[20] Age estimates derived from the age vs. depth model are given in italics.

[21] 7329-7240 cal. bp = 5379-5290 cal. bc.

[22] BETA-439233, see note 12 above for details.

[23]. Sea level index points are ‘known points’ used to reconstruct past sea level changes. Shennan and Horton (2002) have proposed a set of criteria for defining valid index points.