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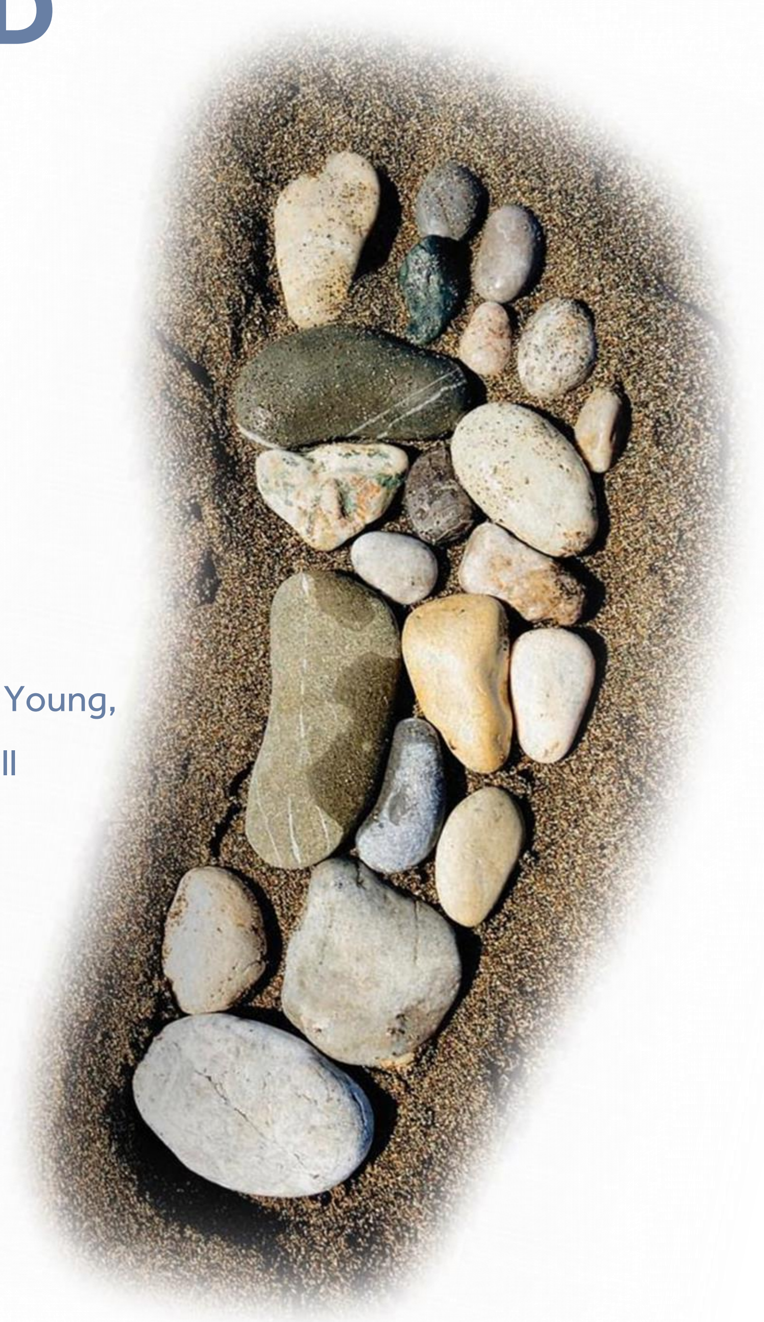
GORESBROOK PARK, LONDON BOROUGH OF BARKING AND DAGENHAM

Geoarchaeological and Palaeoenvironmental Analysis Report



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1. NON-TECHNICAL SUMMARY

Geoarchaeological and palaeoenvironmental analysis was carried out by Quaternary Scientific (University of Reading) in connection with the proposed development of at the Goresbrook Park site. The work was commissioned by CgMs Heritage. The aim of the investigation was to provide a detailed reconstruction of the stratigraphic, hydrological and vegetation history (including evidence of human activity). In order to carry out the work, a program of radiocarbon dating and an assessment of the palaeobotanical (pollen, seeds, wood, charcoal, diatoms) and palaeofaunal (insects, molluscs, ostracods and foraminifera) remains was undertaken.

The results of the geoarchaeological and palaeoenvironmental analysis have built upon the previous fieldwork, deposit modelling and assessment exercises indicating that the sediments present beneath the site are similar to those recorded elsewhere in the Lower Thames Valley. The surface of the Shepperton Gravel generally rests between -3 and -4.5m OD across the majority of the site, rising to 2m OD on the northern most part of the site, representative of the Taplow Gravel terrace and floodplain edge. The Shepperton Gravel (and occasional sand) at the site is overlain by a tripartite sequence of Lower Alluvium, Peat and Upper Alluvium. The Peat generally ranges between 1 and 2m in thickness, and lies at elevations of between *ca*. -1 and -5m OD. The results of the radiocarbon dating indicate that peat accumulation began towards the southeast of the site during the Early to Middle Neolithic, and towards the northwest, from at least the Late Neolithic. Peat accumulation continued at the site until the Iron Age, and towards the southeast, the Roman period.

The results of the palaeoenvironmental analysis indicate that from the Neolithic to at least the Bronze Age, the floodplain environment was dominated by alder and willow swamp carr woodland and sedge fen. Despite the absence of prehistoric remains found during the archaeological evaluation and watching brief (PCA, 2017), alder charcoal and microcharcoal was recorded between 5500 and 5000 cal BP indicating at least one episode of burning during this period on the peat surface. Whether this is of natural or anthropogenic origin cannot be ascertained with certainty however. During the later Neolithic and Bronze Age, drier peat surface conditions are indicated by the development of a more mature fen carr woodland dominated by alder with yew. Oak, hazel and birch may have occupied the peat surface during the late Mesolithic and Neolithic, but more likely formed mixed deciduous woodland on the dryland with lime. Sometime during or after the late Bronze Age (from *ca*. 3000 cal BP), woodland declined on both the peat surface and dryland to be replaced by herbaceous communities, most likely in response to a combination of clearance and an increased marine influence.

2. INTRODUCTION

2.1 Site context

This report summarises the findings arising out of the geoarchaeological and palaeoenvironmental investigations undertaken by Quaternary Scientific (University of Reading) in connection with the proposed development of land at Goresbrook Park, London Borough of Barking and Dagenham (National Grid Reference: centred on TQ 48432 83233; Figures 1 & 2). Quaternary Scientific were commissioned by CgMs Heritage to undertake the investigations. The site lies on the floodplain of the Lower Thames Valley, to the west and north of the Gores Brook tributary; the northern boundary of the site borders the edge of the floodplain. The modern course of the River flows broadly north-west to south-east *ca*. 1km to the south of the site. The British Geological Survey (BGS) show the site underlain by London Clay bedrock, with Lambeth Group deposits, described as 'clay, silt and sand' outcropping just beyond the southern border of the site. The bedrock is overlain by Holocene alluvium across the vast majority of the site (described as 'clay, peaty, silty, sandy'), with deposits of the Wolstonian (Marine Isotope Stages (MIS) 6-10) Taplow Gravel terrace towards its northern border. In fact, the alluvial deposits of the Lower Thames and its tributaries are almost everywhere underlain by Late Devensian (MIS 2) Late Glacial Gravels (in the Thames valley, the Shepperton Gravel of Gibbard, 1985, 1994), and this gravel is widely recorded in boreholes in the vicinity of the site.

Following on from an initial desk-based deposit modelling exercise (Batchelor, 2017a), the results of subsequent geoarchaeological field investigations (Young & Batchelor, 2017a) indicated that the sediments present beneath the site are similar in character to those recorded elsewhere in the Lower Thames Valley; the Shepperton Gravel is overlain by a sequence of Holocene alluvial sediments, including peat, buried beneath modern Made Ground. The surface of the Shepperton Gravel generally rests between -3 and -4.5m OD across the majority of the site, rising to 2m OD on the northern most part of the site, a level consistent with the surface of the older Wolstonian Taplow Gravel terrace (MIS 6-10; 352,000 to 130,000 BP) which in this area forms the edge of the floodplain. A similar sequence of deposits is recorded across the neighbouring Former Ford Stamping Factory (Batchelor, 2017b) and Beam Park (Young & Batchelor, 2017b) sites to the east.

The Shepperton Gravel (and occasional sand) is overlain by a tripartite sequence of Lower Alluvium, Peat and Upper Alluvium. The peat is generally present in thicknesses of between 1 and 2m, and is recorded at between *ca*. -1 and -4m OD (Young & Batchelor, 2017a). Peat accumulation began at the site from the Middle Neolithic continuing until the Iron Age or Roman period, falling within the general period of peat formation in this area of the Lower Thames Valley. The results of a palaeoenvironmental assessment (Young *et al*., 2017a) are indicative of a peat surface dominated by alder, with an understorey of sedges and occasional grasses and aquatics. Hazel, ash and birch may have occupied the peat surface with alder, but are more likely to grown on the dryland forming mixed deciduous woodland with oak and lime. Although there is no definitive evidence for human activity in the sequence, evidence for burning, a decline in oak and lime towards the top of the sequence and possible cereal pollen provide potential evidence for human impact on the landscape during the late prehistoric and early historic period. Charcoal is also recorded in both boreholes QBH1 and QBH2 towards the base of the peat.

2.2 Palaeoenvironmental and archaeological significance

The existing deposit model for the site, based on both geoarchaeological and geotechnical borehole records, indicates considerable variation in the height of the Gravel surface, and the type, thickness and age of the subsequent Holocene deposits within the vicinity of the site. Such variations are significant as they represent different environmental conditions that would have existed in a given location. For example: (1) the varying surface of the Gravel may represent the location of pre-Holocene river terraces, former channels and bars; (2) the presence of peat represents former terrestrial or semi-terrestrial land-surfaces, and (3) the various alluvial units represent periods of changing hydrological conditions. Thus by studying the sub-surface stratigraphy across the site in greater detail, it will be possible to build an understanding of the former landscapes and environmental changes that took place across space and time.

Organic-rich sediments (in particular peat) also have high potential to provide a detailed reconstruction of past environments on both the wetland and dryland. In particular, they provide the potential to increase knowledge and understanding of the interactions between hydrology, human activity, vegetation succession and climate. Significant vegetation changes include the Mesolithic/Neolithic decline of elm woodland, the Neolithic colonisation and decline of yew woodland; the Late Neolithic/Early Bronze Age growth of elm on Peat, and the general decline of wetland and dryland woodland during the Bronze Age. Such investigations are carried out through the assessment/analysis of palaeoecological remains (e.g. pollen, plant macrofossils & insects) and radiocarbon dating. For example, at Hornchurch Marshes, <2km to the southeast (Batchelor, 2009; Branch *et al*., 2012) analysis of fine-grained mineral-rich sediments and peat revealed the presence of freshwater during the Late Mesolithic, at which point peat accumulation began, corresponding to a regional reduction in sea level. Significant changes in both the wetland and dryland environment were recorded here, including the establishment of alder carr woodland, yew; the decline of both elm during the Neolithic, and decline of lime during the Neolithic & Bronze Age. A subsequent transition to estuarine conditions was dated to *ca*. 3900 cal BP, coinciding with a decline in woodland cover and the expansion of plant communities typically found within reed swamp. Analysis of borehole sequences from Barking Riverside, *ca*. 2km to the southwest (see Figure 1), indicated that peat accumulation began at *ca*. 6000 cal BP (late Mesolithic), and continued until at least *ca*. 3500 cal BP (Bronze Age) (Green *et al*., 2014). The peat at Bridge Road meanwhile, >3km to the east, was found to be of Late Neolithic to Bronze Age date (Meddens & Beasley, 1990). Palaeoenvironmental analysis here revealed that during its accumulation, dense alder carr woodland dominated the wetland, with oak, lime and hazel on the surrounding dryland (Meddens & Beasley, 1990). Palaeoenvironmental assessment carried out at New Road, Rainham revealed a thin sequence of peat and alluvial deposits dating to the Bronze Age. This indicated similar vegetation communities, but the local environment became more open in response to wetter conditions and clearance (Krawiec, 2014). Peat deposits have also been recorded accumulating from the Late Mesolithic to the Iron Age East of Ferry Lane on the High Speed 1 route (Bates & Stafford, 2013).

Finally, areas of high gravel topography, soils and peat represent potential areas that might have been utilised or even occupied by prehistoric people, evidence of which may be preserved in the archaeological (e.g. features and structures) and palaeoenvironmental record (e.g. changes in vegetation composition). This is of particular significance at the present site, as a possible 4m wide Bronze Age causeway, constructed of gravel and burnt flint (MLO59097, TQ 4850 8320 was identified at Hays Storage Dagenham immediately adjacent to the eastern part of the site (Divers, 1996; Figures 1 & 2), Radiocarbon dating of the possible causeway at Hays Storage Service Ltd. suggested that the possible causeway was in use for over 100 years between 1520 and 1400 BC (Divers, 1996). The possible trackway was orientated NNE/SSW and recorded at a depth of -1.70m OD, and traced for 23m within the upper level of a peat deposit also dated to the Bronze Age. The Dagenham Idol, a Neolithic wooden figurine, was also discovered during the installation of sewer pipes in 1922, approximately 200m to the east of the site. In addition, a series of prehistoric archaeological features were identified less *ca*. 3km to the east at Bridge Road (Meddens & Beasley, 1990; Beasley, 1991), whilst. The features recorded at Bridge Road included stake holes and spreads of fire-cracked pebbles associated with the foreshore of a former channel, and later, stakes, wattling and a brushwood trackway associated with peat formation (Meddens & Beasley, 1990; Beasley, 1991). Further important prehistoric and historic archaeological remains in the nearby area are highlighted in the Archaeological Desk-Based Assessment for the site (CgMs Heritage, 2016).

A recently completed archaeological evaluation and watching brief (PCA, 2017) did not identify prehistoric remains on the site, though a large, horizontal piece of wood was recorded at the base of geoarchaeological borehole QBH2, between -3.16 and *at least* -3.82m (Young & Batchelor, 2017a); it is uncertain whether this was of natural or anthropogenic origin. Charcoal was also recorded towards the base of the peat in both geoarchaeological boreholes during the palaeoenvironmental assessment (Young *et al*., 2017a). Interestingly, Divers (1996) noted that fallen yew and alder trees were recorded lower down in the peat sequence at the Hays Storage site, below the possible causeway identified there. Perhaps significantly, a large charred wood fragment (20x20mm) was identified just above this wood, at between -2.86 to -2.88m OD; charcoal was also recorded in QBH1 between -1.90 and -2.00m OD. Again, it is unclear if this charcoal is a result of human activity or a natural fire event.

2.3 Aims and objectives

Five significant research aims were originally proposed within the geoarchaeological Written Scheme of Investigation (WSI; Batchelor, 2017b) for the site as follows:

1. To clarify the nature of the sub-surface stratigraphy across the site;
2. To clarify the nature, depth, extent and date of any alluvium and peat deposits
3. To investigate whether the sequences contain any artefact or ecofact evidence for prehistoric or historic human activity
4. To investigate whether the sequences contain any evidence for natural and/or anthropogenic changes to the landscape (wetland and dryland)
5. To integrate the new geoarchaeological record with other recent work in the local area for publication in an academic journal

The original geoarchaeological and palaeoenvironmental fieldwork and assessment successfully achieved the first two of these aims and demonstrated the potential of aims 3-5 being addressed through further investigation. Specifically, the sequence from the Goresbrook Park site provides an opportunity to consider the vegetation history of this part of the Lower Thames Valley, where prehistoric human activity is known to have taken place: the results can be integrated with other sites being investigated along an east-west transect close to the floodplain edge, including investigations at the Former Ford Factory (Batchelor et al., 2018a), Merrielands, Dagenham (Batchelor *et al*., 2018b), Hornchurch Marshes (Batchelor, 2009; Branch *et al*., 2012) and Beam Park Phases 1 & 2 (Young et al., 2018a, b) (see Figure 1).

It was therefore recommended that a targeted program of analysis is carried out focussed on: (1) radiocarbon dating to provide a better chronological framework for the sequence that can be used to compare the data with other sites in this area; (2) pollen analysis of existing samples from QBH1 and QBH2 to increase knowledge/understanding of vegetation history and evidence of human activity, and (3) diatom analysis of the upper two samples from QBH1, to investigate in more detail the transition from peat to alluvium towards the top of the sequence. This work will complete aims 1-4, and provide a detailed environmental reconstruction that can be used to address aim 5.

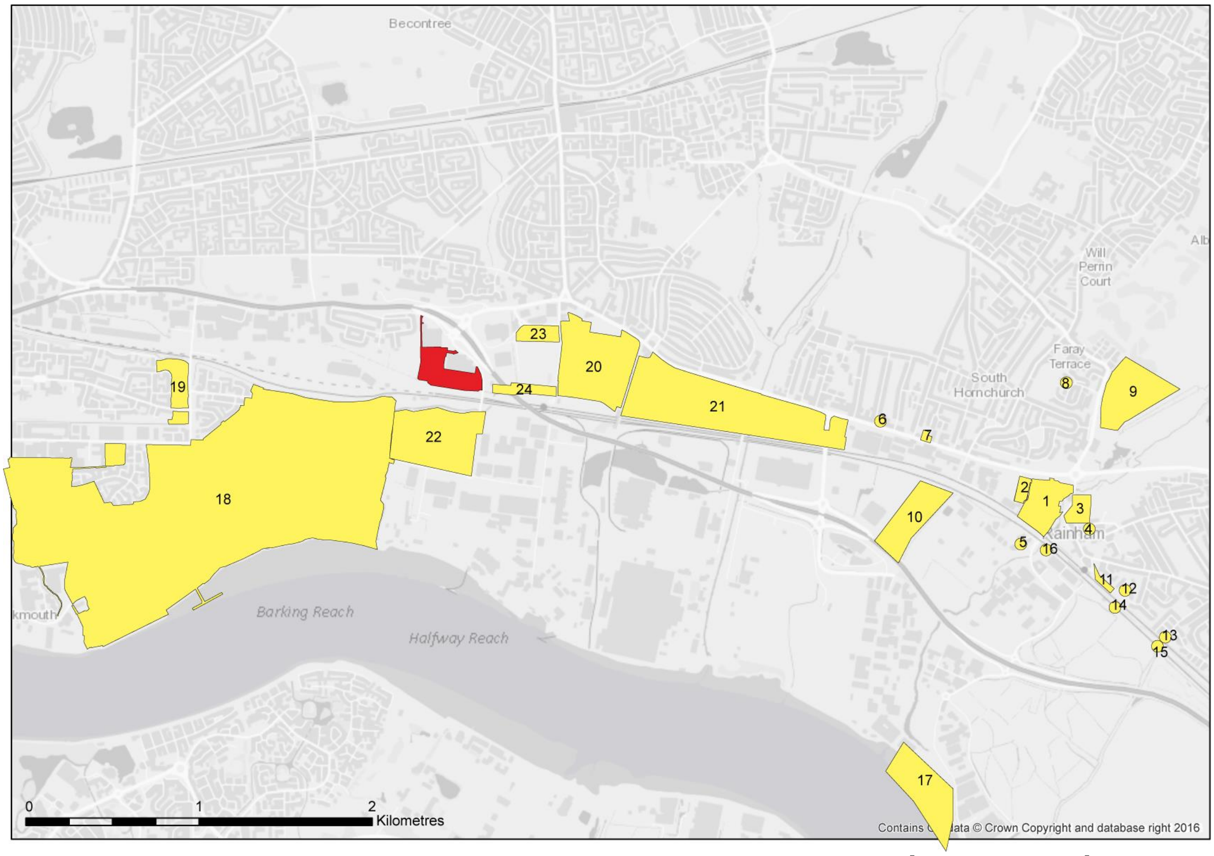

Figure 1: Location of Goresbrook Park / Hays Storage Dagenham (Divers, 1996), London Borough of Barking and Dagenham (highlighted in red) and selected other archaeological and palaeoenvironmental sites: (1) Dovers Corner (Batchelor & Young, 2016); (2) the Passivhaus Housing Development (NRD13; Dyson, 2013); (3) Bridge Road (RA-BR89; Meddens & Beasley, 1990; Beasley, 1991); (4) Viking Way (RA-VW 96; Beasley, 1996); (5) Union Railways (URA97; MoLAS, 1997); (6) the former Manser Works (MNM03; Potter, 2003); (7) 155-163 New Road (NRI07; Pre-Construct Archaeology, 2007); (8) the Lessa Sports Ground (LSA98; MoLAS, 1998, 2001); (9) Scott & Albyn's Farm, Rainham Road (RNH96; HO-CP95; Hertfordshire Archaeological Trust, 1995, 2000); (10) Hornchurch Marshes (MOY03; Branch et al., 2012; Batchelor 2009), (11) the former Rainham Squash and Snooker Club (RSQ04; Archaeological Solutions Ltd, 2005); (12) the former Rainham Football Club (RA-FG95; Thames Valley Archaeological Society, 1995); (13) Brookway Allotments (RA-BA92; Newham Museum Service, 1992); (14) 24.455, East of Ferry Lane, HS1 (Bates & Stafford 2013); (15) 24.755, East of Ferry Lane, HS1 (Bates & Stafford 2013); (16) Rainham Creek (Bates & Stafford 2013); (17) Frog Island (MER11; Batchelor *et al.*, 2011); (18) Barking Riverside (Green *et al.*, 2012); (19) Renwick Road (Green et al., 2012); (20) Former Ford Stamping Factory (Batchelor *et al.*, 2018a); (21) Beam Park (Young & Batchelor, 2017b); (22) London Sustainable Industries Park (MoLA, 2010); (23) Merrielands Crescent (Batchelor *et al.*, 2018b); (24) Chequers Lane (Batchelor & Young, 2018)

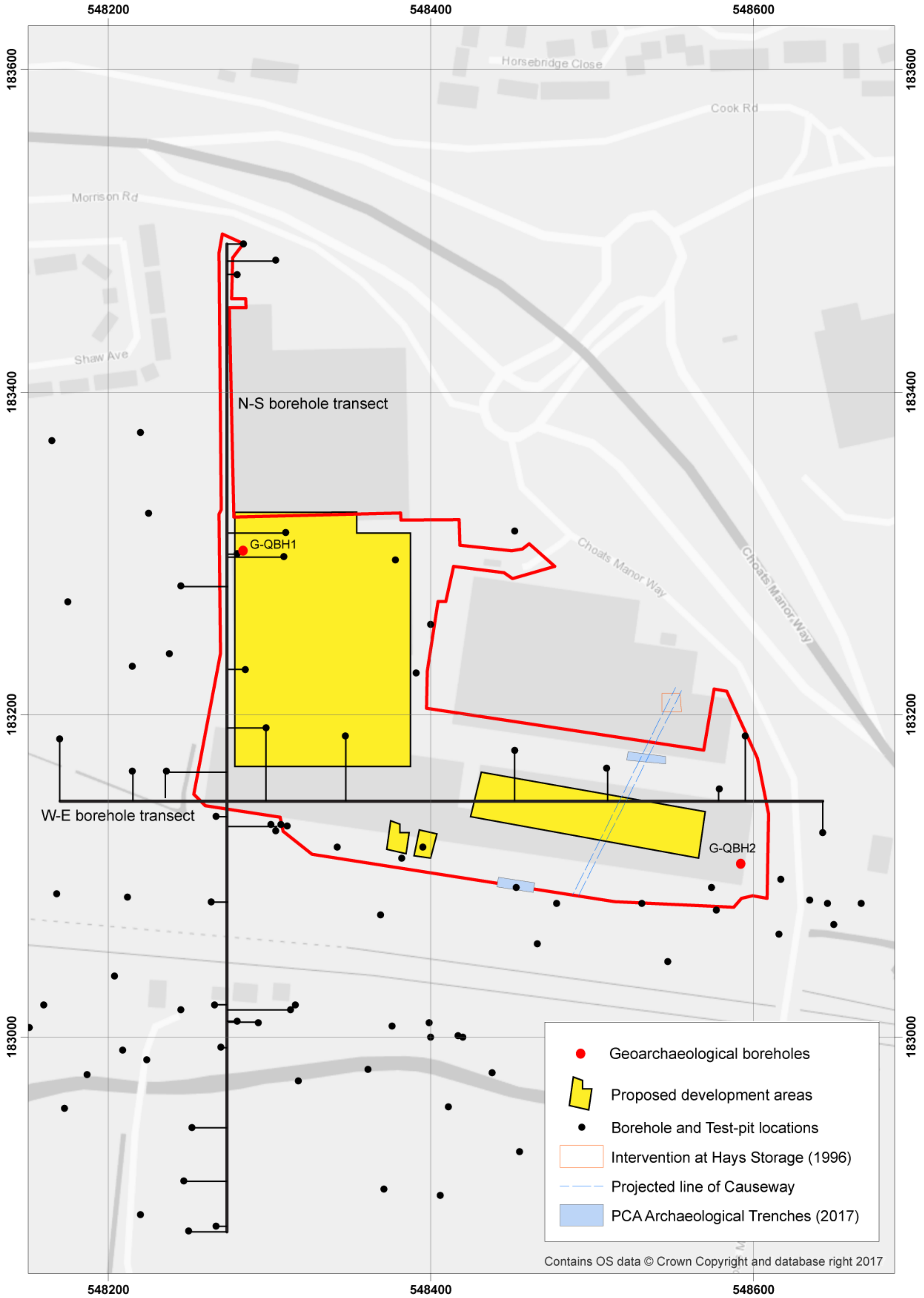

Figure 2: Location of the geoarchaeological and geotechnical boreholes and test-pits across the Goresbrook Park site. Also displayed is the location of the possible causeway discovered at Hays Storage Dagenham, and its projected orientation (Divers, 1996).

3. METHODS

3.1 Previous investigations (Field investigations, lithostratigraphic descriptions and deposit modelling)

Two geoarchaeological boreholes (boreholes QBH1 and QBH2) were put down at the site in July 2017 by Quaternary Scientific (Figure 2). The borehole core samples were recovered using an Eijkelkamp window sampler and gouge set using an Atlas Copco TT 2-stroke percussion engine. This coring techniques provide a suitable method for the recovery of continuous, undisturbed core samples and provides sub-samples suitable for not only sedimentary and microfossil assessment and analysis, but also macrofossil analysis. Spatial co-ordinates for each borehole were obtained using a Leica Differential GPS (see Table 1). It was not possible to record the entire Holocene alluvial sequence in QBH2, due to the presence of a thick (≥0.66m) layer of wood at between 4.34 to 5.00m bgl which prevented drilling beyond this depth (see Young & Batchelor, 2017a).

A combination of laboratory- and field-based lithostratigraphic descriptions of the new borehole samples was carried out using standard procedures for recording unconsolidated sediment and peat, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter) and inclusions (e.g. artefacts). The procedure involved: (1) cleaning the samples with a spatula or scalpel blade and distilled water to remove surface contaminants; (2) recording the physical properties, most notably colour; (3) recording the composition e.g. gravel, fine sand, silt and clay; (4) recording the degree of peat humification, and (5) recording the unit boundaries e.g. sharp or diffuse. The results are displayed in Tables 2 and 3.

The deposit model for the site was based on a review of 143 borehole records, including the two new geoarchaeological records. Sedimentary units from the boreholes were classified into six groups: (1) Bedrock (London Clay / Lambeth Group), (2) Gravel, (3) Lower Alluvium. (4) Peat, (5) Upper Alluvium and (6) Made Ground. In addition, 743 geoarchaeological, archaeological and geotechnical records were collated to examine key deposits across the wider area. The classified data for groups 1-6 were then input into a database within the RockWorks 16 geological utilities software, the output from which was displayed using ArcMAP 10. Models of surface height were generated for the Gravel, Lower Alluvium, Peat and Upper Alluvium using an Inverse Distance Weighted algorithm (Figures 3-5, 7 and 9). Thickness of the Peat, total Holocene alluvium (incorporating the Lower Alluvium, Peat and Upper Alluvium) and Made Ground (Figures 6, 8 and 10) were also modelled (also using an Inverse Distance Weighted algorithm). Borehole transects are displayed in Figures 11 (north-south) & 12 (west-east).

As reported by Young & Batchelor (2017a), in general, both the distribution and density of boreholes across the site is good; however, not all boreholes record the entire Holocene alluvial sequence, and thus for selected stratigraphic units the reliability is better in certain areas of the site. The reliability of the models generated using RockWorks is therefore variable. In general, reliability improves from outlying areas where the models are largely supported by scattered archival records towards the core area of boreholes. Because of the 'smoothing' effect of the modelling procedure, the modelled levels of stratigraphic contacts may differ slightly from the levels recorded in borehole logs and section drawings. As a consequence of this the modelling procedure has been manually adjusted so that only those areas for which sufficient stratigraphic data is present will be modelled. In order to achieve this, a maximum distance cut-off filter equivalent to a 50m radius around each record is applied to all the site-wide deposit models, and 100m for the wider gravel surface model. In addition, it is important to recognise that multiple sets of boreholes are represented, put down at different times and recorded using different drilling/descriptive terms and subject to differing technical constraints in terms of recorded detail including the exact levels of the stratigraphic boundaries.

Table 1: Spatial attributes and lithostratigraphic data for the geoarchaeological boreholes at Goresbrook Park, London Borough of Barking and Dagenham.

Borehole	Easting	Northing	Elevation (m OD)	Total Depth (m)	Upper Alluvium surface (m bgl)	Peat surface (m bgl)	Lower Alluvium surface (m bgl)	Sand surface (m bgl)	Gravel surface (m bgl)
QBH1	548282.99	183301.78	2.41	6.0	2.45	3.69	4.63	5.76	5.87
QBH2	548595.65	183105.09	1.18	5.0	2.75	3.00	Not reached	Not reached	Not reached

3.2 Organic matter determinations

A total of 13 subsamples from borehole QBH1 were taken for determination of the organic matter content (Table 4; Figure 14). These records were important as they can identify increases in organic matter possibly associated with more terrestrial conditions. The organic matter content was determined by standard procedures involving: (1) drying the sub-sample at 110^{0}C for 12 hours to remove excess moisture; (2) placing the sub-sample in a muffle furnace at 550°C for 2 hours to remove organic matter (thermal oxidation), and (3) re-weighing the sub-sample obtain the 'loss-on-ignition' value. The samples were then re-weighed after 2 hours at 950°C for determination of the calcium carbonate content (see Bengtsson & Enell, 1986).

3.3 Radiocarbon dating

Seven subsamples of twig wood, identified charcoal or aerial sedge remains were extracted from the peat in each of boreholes QBH1 and QBH2 for radiocarbon dating. The samples were submitted for AMS radiocarbon dating to the BETA Analytic Radiocarbon Dating Facility, Miami, Florida. The results have been calibrated using OxCal v4.2 (Bronk Ramsey, 1995; 2001 and 2007) and the IntCal13 atmospheric curve (Reimer *et al.*, 2013). The results are displayed in Figure 14 and in Tables 5 and 6.

3.4 Pollen analysis

Seven subsamples from borehole QBH1 and five from QBH2 were extracted for pollen analysis. The pollen was extracted as follows: (1) sampling a standard volume of sediment (1ml); (2) adding two tablets of the exotic clubmoss *Lycopodium clavatum* to provide a measure of pollen concentration in each sample; (3) deflocculation of the sample in 1% Sodium pyrophosphate; (4) sieving of the sample to remove coarse mineral and organic fractions (>125μ); (5) acetolysis; (6) removal of finer minerogenic fraction using Sodium polytungstate (specific gravity of 2.0g/cm^3); (7) mounting of the sample in glycerol jelly. Each stage of the procedure was preceded and followed by thorough sample cleaning in filtered distilled water. Quality control is maintained by periodic checking of residues, and assembling sample batches from various depths to test for systematic laboratory effects. Pollen grains and spores were identified using the University of Reading pollen type collection and the following sources of keys and photographs: Moore *et al* (1991); Reille (1992).

The analysis procedure consisted of counting all pollen to 300 Total Land Pollen where possible (TLP; trees, shrubs and herbs) where possible. Aquatic pollen and spores were also counted. Pollen grains and spores were identified using the University of Reading pollen type collection and the following sources of keys and photographs: Moore et al (1991); Reille (1992). Pollen percentage and pollen concentration diagrams were produced in 'Tilia'. Pollen percentage values were calculated as follows: Tree, shrub and herb taxa were calculated as a percentage of total land pollen (TLP); other remains (aquatics, spores, unidentifiable grains) were calculated as a percentage of TLP. The concentration of microcharcoal with dimensions >20um along at least one axis, was also recorded together with total pollen concentration. The results are displayed in Figures 15 and 16.

3.5 Diatom assessment

Two samples from the top of borehole QBH1 were submitted for diatom analysis. 0.5g of sediment was required for the diatom sample preparation. Samples were first treated with hydrogen peroxide (30% solution) and/or weak ammonia (1% solution) depending on organic and/or calcium carbonate content, respectively. Due to the high silt and clay content of most samples, all samples chosen for analysis were then treated with sodium hexametaphosphate and left overnight, to assist in minerogenic deflocculation. Samples were finally sieved using a 10μm mesh to remove fine minerogenic sediments. The residue was transferred to a plastic vial from which a slide was prepared for subsequent assessment.

A minimum of 400 diatoms were identified for each sample depth. Diatom species were identified with reference to van der Werff and Huls (1958-74), Hendy (1964) and Krammer & Lange-Bertalot (1986-1991). Ecological classifications for the observed taxa were then achieved with reference to van der Werff and Huls (1958-74), Vos and deWolf (1988; 1993), Van Dam *et al.*, (1994), Denys (1991-92; 1994) and Round *et al.* (2007). The results are displayed in Tables 7, 8 and Figure 17.

3.6 Macrofossil assessment

A total of five samples from QBH1 and six from QBH2 were extracted and processed for the recovery of macrofossil remains, including waterlogged plant macrofossils, wood, insects and Mollusca (Tables 9 and 10). The samples were focussed on the peat horizons in both boreholes, in QBH2 extending down to the surface of the timber recorded at the base of this borehole. The extraction process involved the following procedures: (1) measuring the sample volume by water displacement, and (2) processing the sample by wet sieving using 300μm and 1mm mesh sizes. Each sample was scanned under a stereozoom microscope at x7-45 magnifications, and sorted into the different macrofossil classes. The concentration and preservation of remains was estimated for each class of macrofossil (Tables 9 and 10). Preliminary identifications of the waterlogged seeds and wood have been made using modern comparative material and reference atlases (e.g. Hather, 2000; NIAB, 2004; Cappers *et al.* 2006). Nomenclature used follows Stace (2005).

4. RESULTS, INTERPRETATION & DISCUSSION OF THE GEOARCHAEOLOGICAL FIELD INVESTIGATIONS, DEPOSIT MODELLING & RADIOCARBON DATING

The results of the lithostratigraphic descriptions and deposit modelling were reported previously (Young & Batchelor, 2017a) and are shown in Tables 2 and 3, with the results of the deposit modelling displayed in Figures 3 to 13. Figures 3 to 11 are surface elevation and thickness models for each of the main stratigraphic units, whilst Figures 12 and 13 are two-dimensional transects across the site. The results of the deposit modelling indicate that the number and spread of the logs is sufficient to permit modelling with a high level of certainty across the vast majority of the site.

The full sequence of sediments recorded in the boreholes comprises:

Made Ground
Upper Alluvium – widely present
Peat – widely present
Lower Alluvium – widely present
Sand – present across the south-western part of the site
Gravel – widely present

4.1 Gravel

Gravel was present in all the boreholes that penetrated to the bottom of the Holocene sequence. The modelling exercise indicates that the surface of the Gravel falls from the northern most part of the site, where it is recorded at around 2m OD to between -3 and -4.5m OD across much of the rest of the site (Figures 3 & 12-13). The surface of the Gravel was reached in only one of the new geoarchaeological boreholes; in QBH1 it is recorded at -3.46m OD.

Across much of the site, this unit most likely represents the Shepperton Gravel deposited during the Devensian Late Glacial (MIS2; 15,000 to 10,000 BP) and comprises the sands and gravels of a high-energy braided river system which, while it was active would have been characterised by longitudinal gravel bars and intervening low-water channels in which finer-grained sediments might have been deposited. Such a relief pattern would have been present on the valley floor at the beginning of the Holocene when a lower-energy fluvial regime was being established. The rise in Gravel surface to 2m OD towards the northern most part of the site is consistent with the position of the site on the edge of the floodplain. Indeed, this elevation is indicative of the older Wolstonian Taplow Gravel terrace (MIS 6-10; 352,000 to 130,000 BP) which in this area forms the edge of the floodplain; Gibbard (1994) shows the surface of the Mucking (Taplow) Gravel falling to around 1m OD in the area of South Hornchurch (p 54). However, it is difficult to differentiate the deposits of the Taplow and Shepperton Gravel on the basis of elevation alone.

Beyond the margins of the site, the surface of the Taplow Gravel can also be confidently recognised, where it reaches between *ca*. 1.5 and -1m OD on the northern part of the Beam Park site (Young & Batchelor, 2017b; Figure 4), and along Ripple Road where it reaches between 0 and 3m OD to the west and east. From the terrace edge, the Gravel surface generally falls to between -3 and -6m OD representative of the Shepperton Gravel. Particularly deep depressions are recognised however, towards the south-west of Beam Park where the Gravel surface is consistently recorded at between *ca*. -7.5 and -9.58m OD. Although the extent and orientation of this depression is not yet fully understood, due to the absence of data to the south, it is possible that this feature represents a former channel. In addition, towards the north-west of Beam Park, three borehole records indicate thick alluvial deposits resting directly on Bedrock at up to -14m OD. It is possible that these records are erroneous, but it is of note that similarly deep depressions are recorded adjacent to the terrace edge at Barking Riverside (Green *et al.*, 2014). Higher gravel surfaces above -2m OD can also be recognised across the wider area, including on the southern part of Barking Riverside, and to the south of Choats Road.

4.2 Sand

A horizon of sand is the lowest unit in the Holocene alluvial sequence, and where present, it rests directly on the surface of the underlying Shepperton Gravel. Where it is identified, it can be interpreted as being deposited under low to moderate energy fluvial conditions, most likely within former channel features. On the present site, Sand is recognised in 23 sequences, varying in thickness between 0.2 and at least 2m (Figures 5 & 12-13). In borehole QBH1, it was recorded overlying the Gravel at between -3.35 to -3.46m OD. The Sand appears to be present mainly in the southwestern area of the site. However, its absence in the other sequences does not necessarily mean it is not present as an individual unit; it is rarely possible to confidently separate Sand from Shepperton Gravel or indeed the silty sandy deposits of the Lower Alluvium, due to the nature of the coring methods and less precise method of geotechnical description. In the case of the modelling exercise, differentiation between the Sand and Gravel is made based upon the presence of more than rare occurrences of Gravel within the sediment.

4.3 Lower Alluvium

The Lower Alluvium rests directly on either the Shepperton Gravel or Sand and was recorded in the majority of those records that penetrated sufficiently deeply across the site. The surface of the Lower Alluvium (Figures 6 & 12-13) is relatively even, ranging between -2 and -3.5m OD. It is however absent towards the very north of the site, probably as a consequence of its location above the floodplain edge.

The deposits of the Lower Alluvium are described as a predominantly silty or clayey, tending to become increasingly sandy downward in most sequences, and occasionally organic. The Lower Alluvium frequently contains detrital wood or plant remains, and in many cases is described as organic and with occasional Mollusca remains. In borehole QBH1 the Lower Alluvium was recorded between -2.22 and -3.35m OD, the results of the loss-on-ignition analysis (Table 4) indicating that the Lower Alluvium is generally less than 15% organic. However, a richly organic unit (32% organic) is recorded between -2.22 and -2.37m OD at the interface between this unit and the overlying Peat.

The sediments of the Lower Alluvium are indicative of deposition during the Early to Mid-Holocene, when the main course of the Thames was probably confined to a single meandering channel. During this period, the surface of the Shepperton Gravel was progressively buried beneath the sandy and silty flood deposits of the river. The richly-organic nature of the Lower Alluvium suggests that this was a period during which the valley floor was occupied by a network of actively shifting channels, with a drainage pattern on the floodplain that was still largely determined by the relief on the surface of the underlying Shepperton Gravel.

4.4 Peat

Overlying the Lower Alluvium / Sand or in some cases Shepperton Gravel in the vast majority of the boreholes is a unit of Peat. The peat is indicative of a transition towards semi-terrestrial (marshy) conditions, supporting the growth of sedge fen/reed swamp and/or woodland communities across the floodplain. The results of the loss-on-ignition analysis of samples from QBH1 (see Table 4 and Figure 14) indicate that this unit is consistently between 75 and 80% organic, indicative of occasional flood events bringing minerogenic material on to the surface of the peat during its accumulation.

The Peat generally varies in thickness between 1 and 2m across the vast majority of the site (Figure 7). In geoarchaeological borehole QBH1 it was recorded at between -1.28 and -2.22m OD, and below -1.82m OD in borehole QBH2 (the base of the Peat in this borehole was not reached, but it lies at *at least* -3.16m OD). The Peat has the potential to contain archaeological remains as demonstrated by possible trackway/causeway findings at both Hays Storage Dagenham (Divers, 1996) and Bridge Road, Rainham (Meddens & Beasley, 1990; Beasley, 1991). Generally, these remains have been recorded towards the top of the Peat, and relatively close to the floodplain edge. In QBH2 a large, horizontal piece of wood was recorded between -3.16 and *at least* -3.82m OD. It is uncertain at this stage what this piece of wood may relate to. It is of note that a large charred wood fragment (20x20mm) was identified just above this wood, at between -2.86 to -2.88m OD.

As might be expected given the lower elevation of the peat in QBH2, the results of the radiocarbon dating indicate that peat accumulation began earlier here; accumulation began some time prior to 5590-5320 cal BP (3640-337 0cal BC; Middle Neolithic), indicating that the wood recorded at the base of this sequence (whatever its origin) pre-dates this. In borehole QBH1 peat accumulation began at around 4430-4250 cal BP (2480-2300 cal BC; Late Neolithic). The peat appears to have continued accumulating until later in QBH2; in QBH1 peat cessation occurred at around 2740-2490 cal BP (790-540 cal BC; Early-Middle Iron Age), whilst in QBH2 peat accumulation continued until at least 2000-1870 cal BP (45 cal BC - 80 cal AD; Roman). Nearby sites such as Hornchurch Marshes (Batchelor, 2009; Branch et al., 2012), Barking Riverside (Green et al., 2014), Bridge Road (Meddens & Beasley, 1990; Beasley, 1991) and the Former Ford Stamping Factory (Young *et al*., 2017) have all recorded Peat accumulation from the late Mesolithic to Bronze Age; the later dates for the upper surface of the peat (Iron Age/Roman) at Goresbrook Park therefore represent a later record of peat formation than has previously been recorded in this area.

Within the peat sequences themselves, alder charcoal was identified at -1.90 to -2.00m OD in QBH1 and -2.86 to -2.88m OD in QBH2. This could be of natural origin, or the result of anthropogenic burning. Furthermore, despite being at opposing ends of the site, and at different depths, the charcoal was radiocarbon dated similarly to 5290-4970 cal BP and 5590-5320 cal BP respectively. It is of note however that the dates represent an age reversal in QBH1 and are of the same age as the underlying wood in QBH2 (Figure 14). Taphonomy is the most likely reason for this, particularly in QBH1 where the possibility that the twig wood represents rooting from a younger tree. A less likely (but not inconceivable) possibility is that dead Neolithic aged wood was being preferentially burnt over living material on a younger peat surface. Whether or not this is true, the existing evidence indicates that at least one episode of burning took place on a peat surface pre-dating the possible Hays Storage causeway which occurred between approximately 3470 and 3350 cal BP (1520 and 1400 BC; Divers 1996).

The Peat is absent on the northern most part of the site, and an isolated few other sequences (TQ48SE1238, 1363, 1237, 1242, 1162, 1092) all of which are beyond the margins of the site. Within these sequences, mineral-rich deposits were recorded ranging in size from clay to gravel sized clasts. The surface of the Peat is relatively even, generally lying between -1 and -2m OD (Figure 8 & 12-13).

4.5 Upper Alluvium

The Upper Alluvium generally rests directly Peat, and was recorded in all records across the site with the exception of those in the northern most part. The deposits of the Upper Alluvium are described as predominantly silty or clayey which are very occasionally organic-rich. The results of the loss-on-ignition analysis indicate that this unit is generally less than 10% organic (see Table 4). The surface of the Upper Alluvium is relatively even, generally lying at between *ca*. -1.5 and 2m OD (Figure 9 & 12-13); in boreholes QBH1 and QBH2 it is recorded at -0.04 and -1.57m OD respectively. The sediments of the Upper Alluvium are indicative of deposition within low energy fluvial and/or semi-aquatic conditions during the Holocene. The high mineral content of the sediments may reflect increased sediment loads resulting from intensification of agricultural land use from the later prehistoric period onward, combined with the effects of rising sea level.

The combined Holocene alluvial sequence, incorporating the Sand, Lower Alluvium, Peat and Upper Alluvium ranges between 2 & 4m in thickness, and is generally thicker where the Shepperton Gravel surface is lower towards the south of the site (Figure 10). It is worth noting however, that the thickness of the Total Alluvium noted on the northern most part of the site, likely represents Pleistocene sands resting on the Taplow Terrace, rather than Holocene floodplain deposits.

4.6 Made Ground

Between 1 & 3m of Made Ground caps the Holocene alluvial sequence across the vast majority of the site.

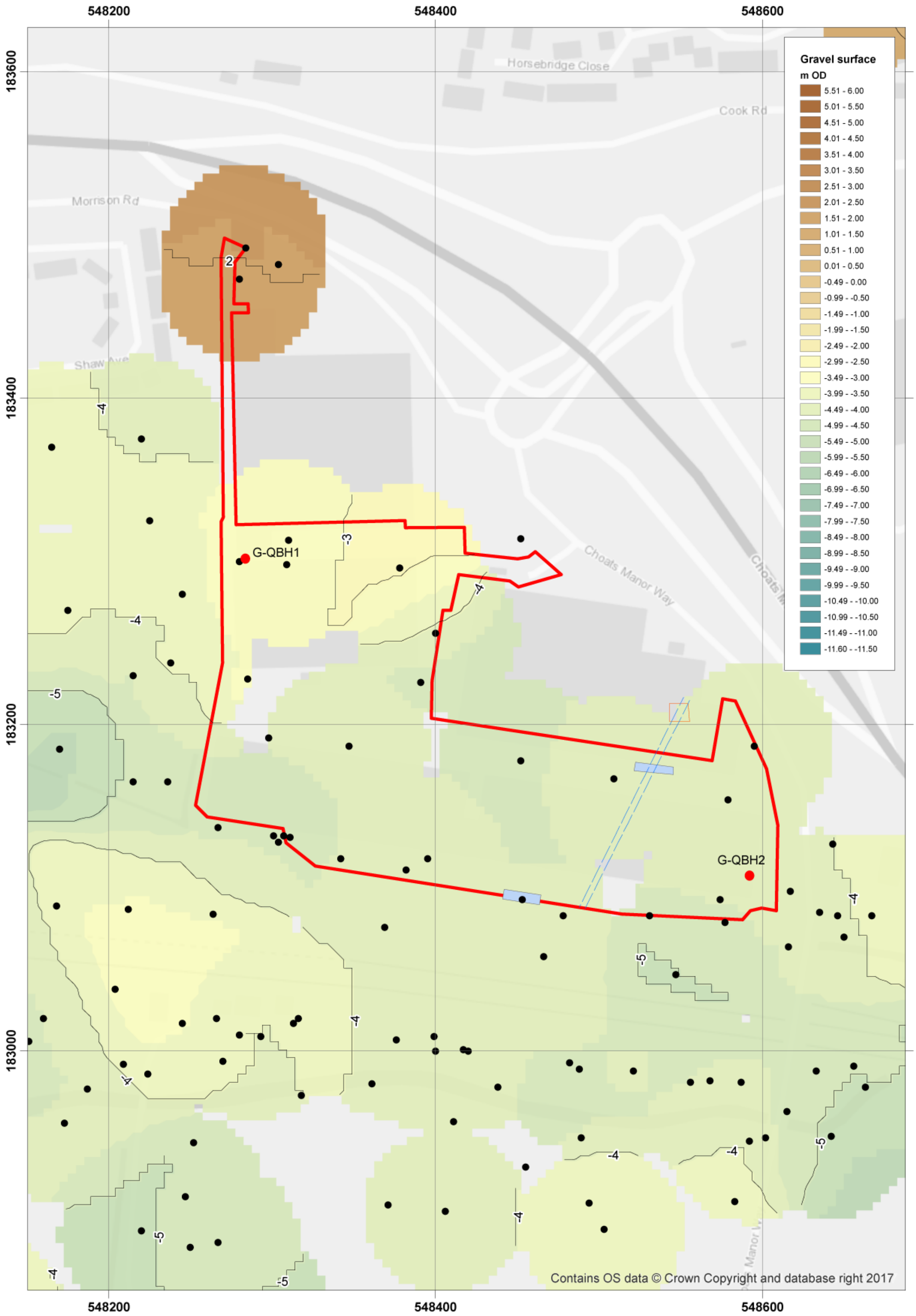

Figure 3: Top of the Gravel (m OD)

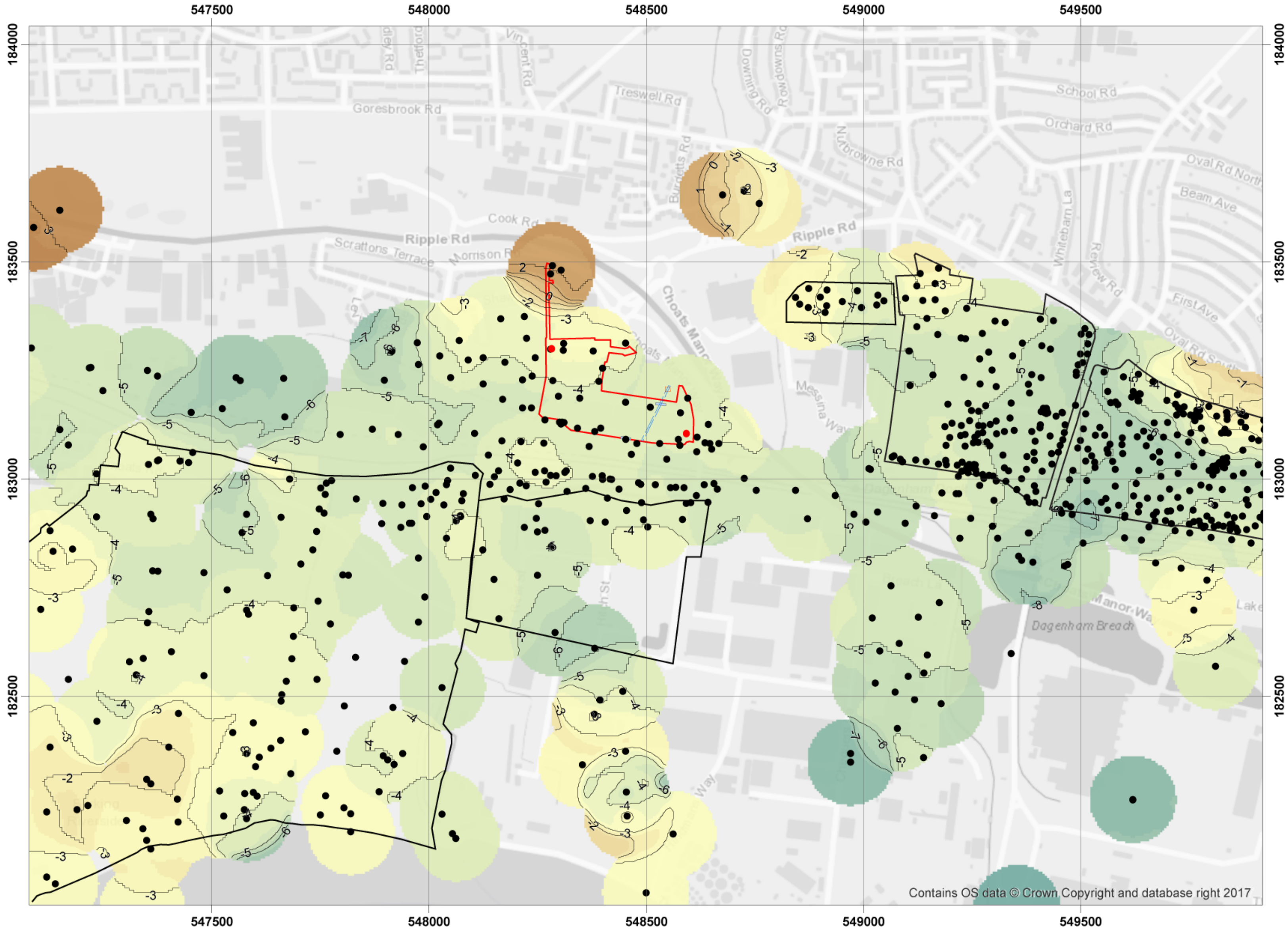

Figure 4: Top of the Gravel across the wider area (m OD) (site outline in red)

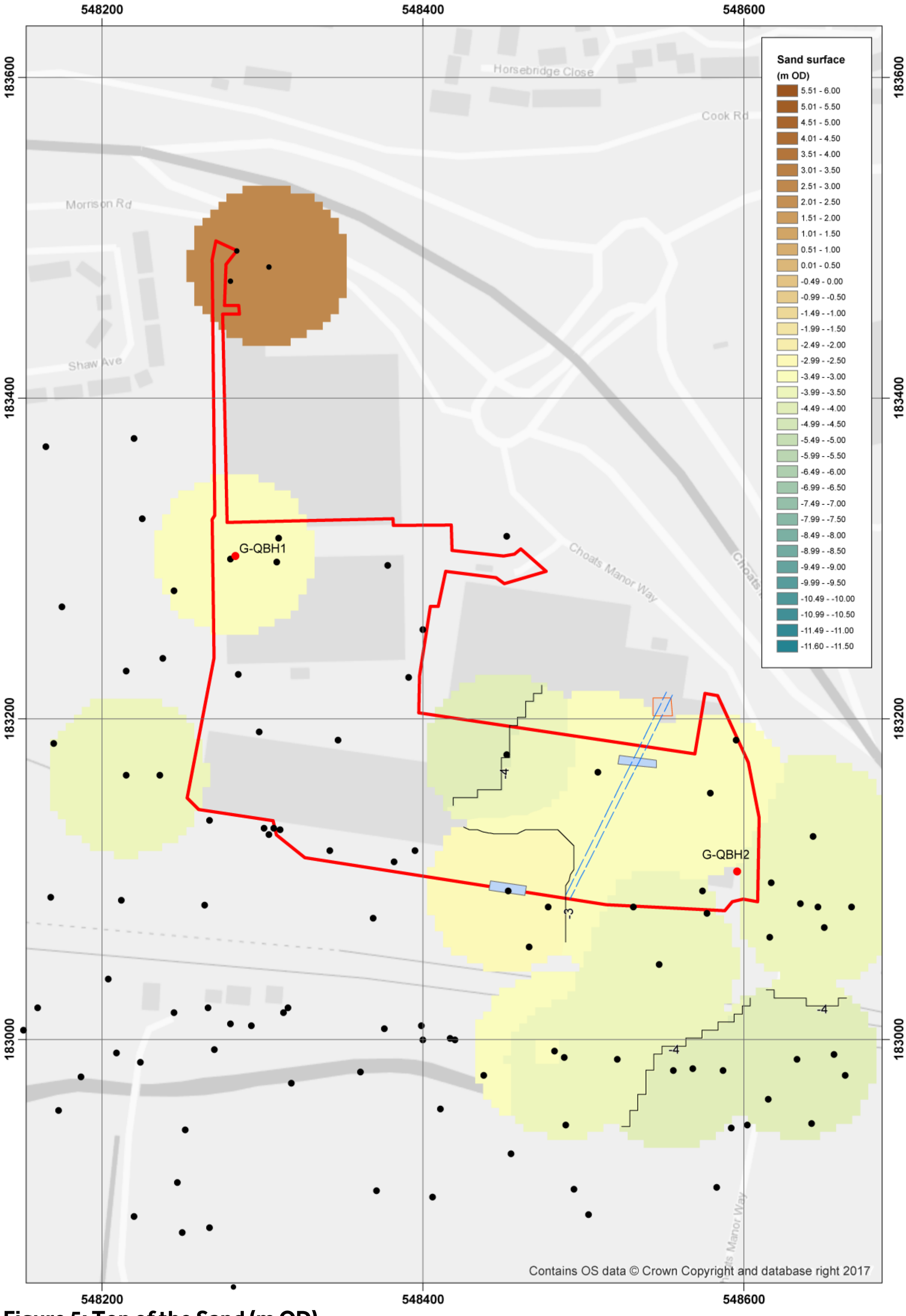

Figure 5: Top of the Sand (m OD)

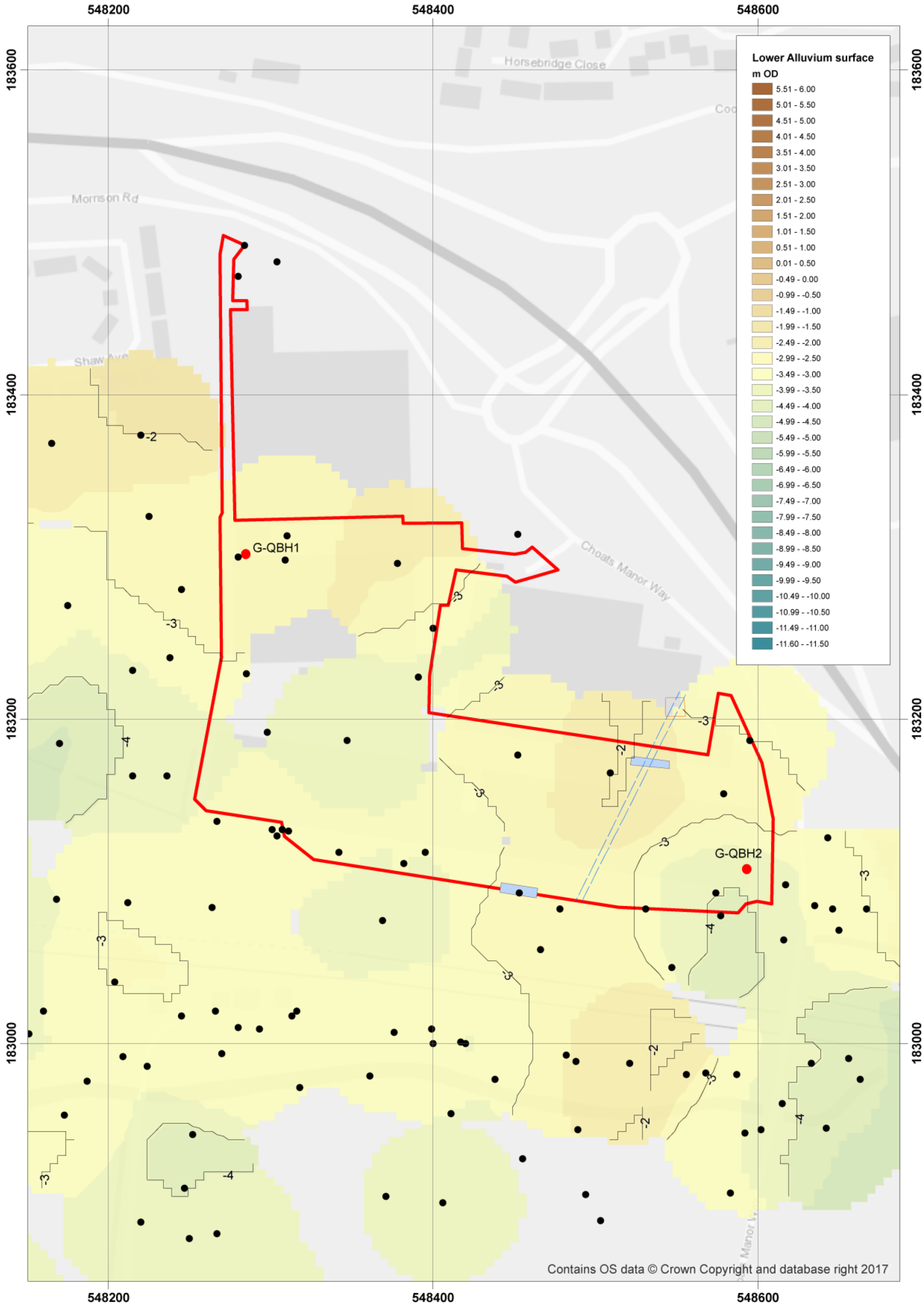

Figure 6: Top of the Lower Alluvium (m OD)

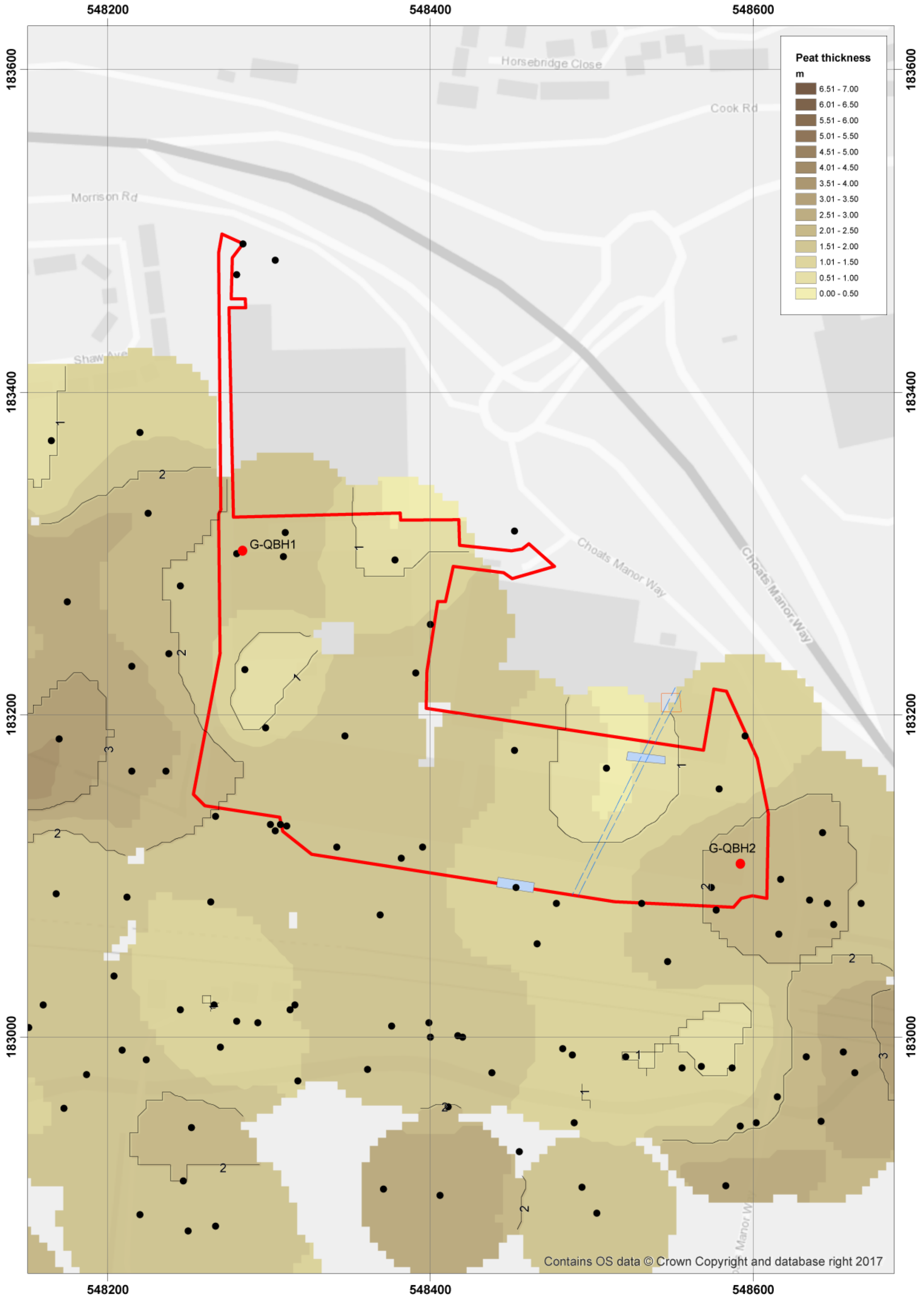

Figure 7: Thickness of the Peat (m)

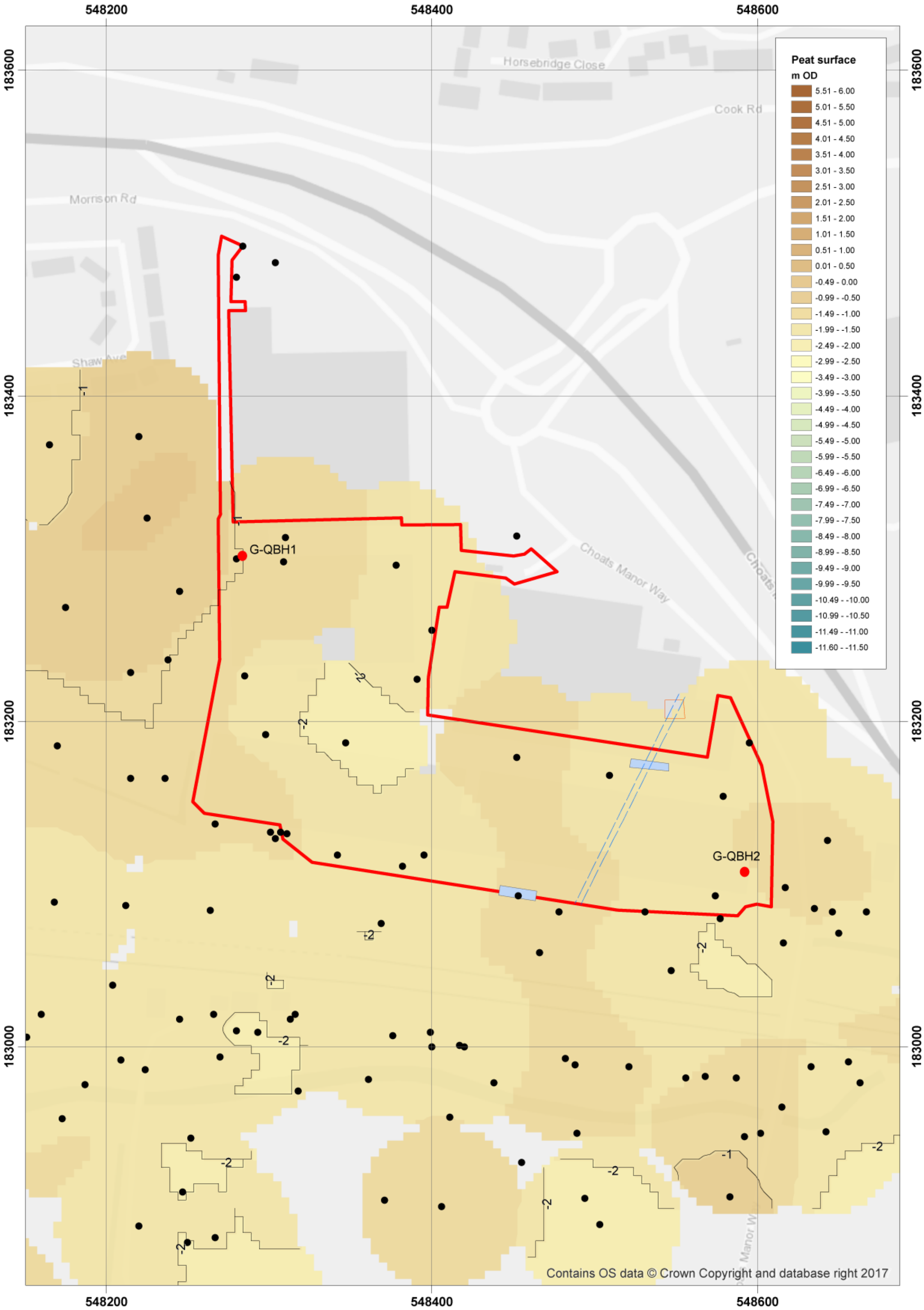

Figure 8: Top of the Peat (m OD)

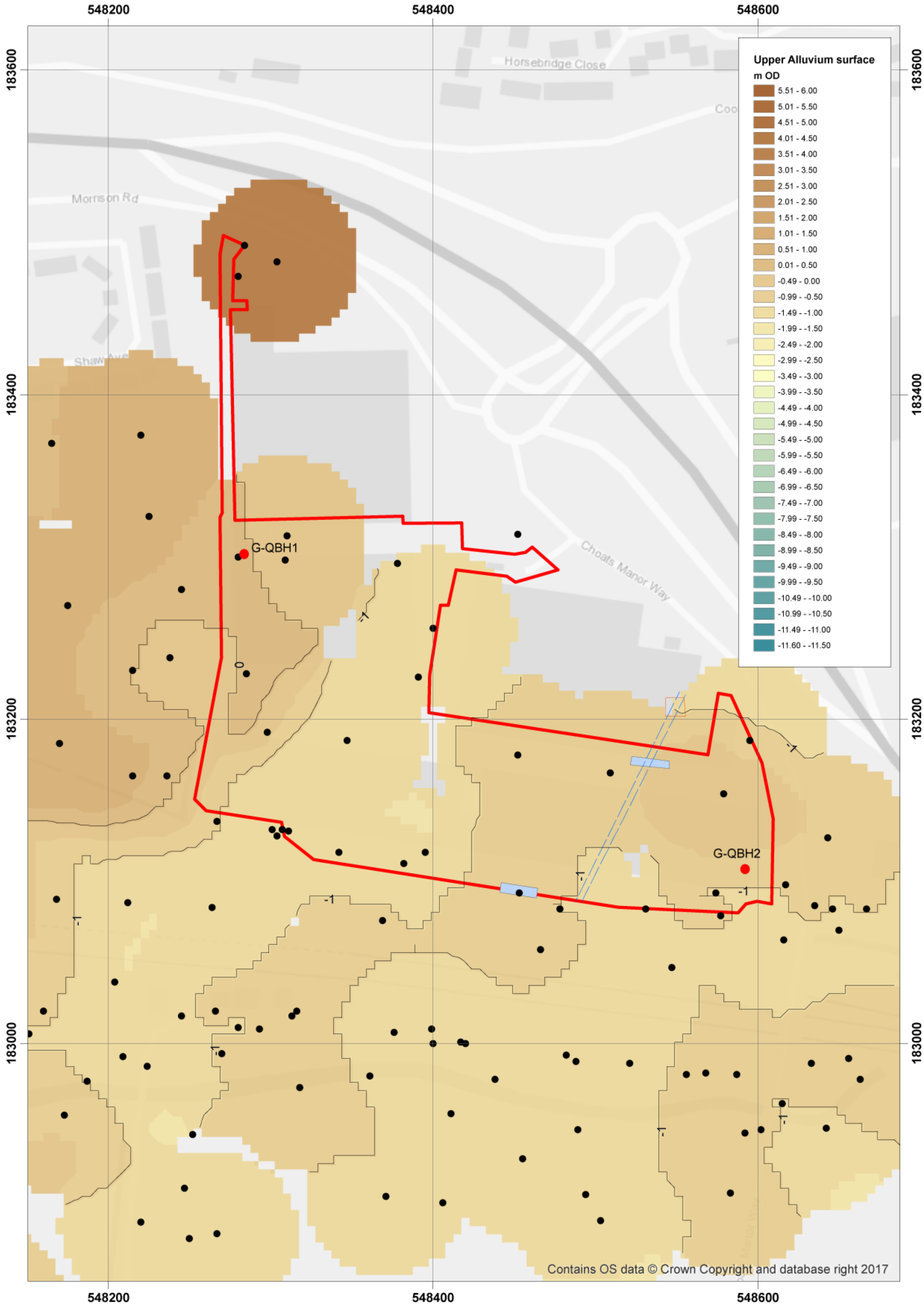

Figure 9: Top of the Upper Alluvium (m)

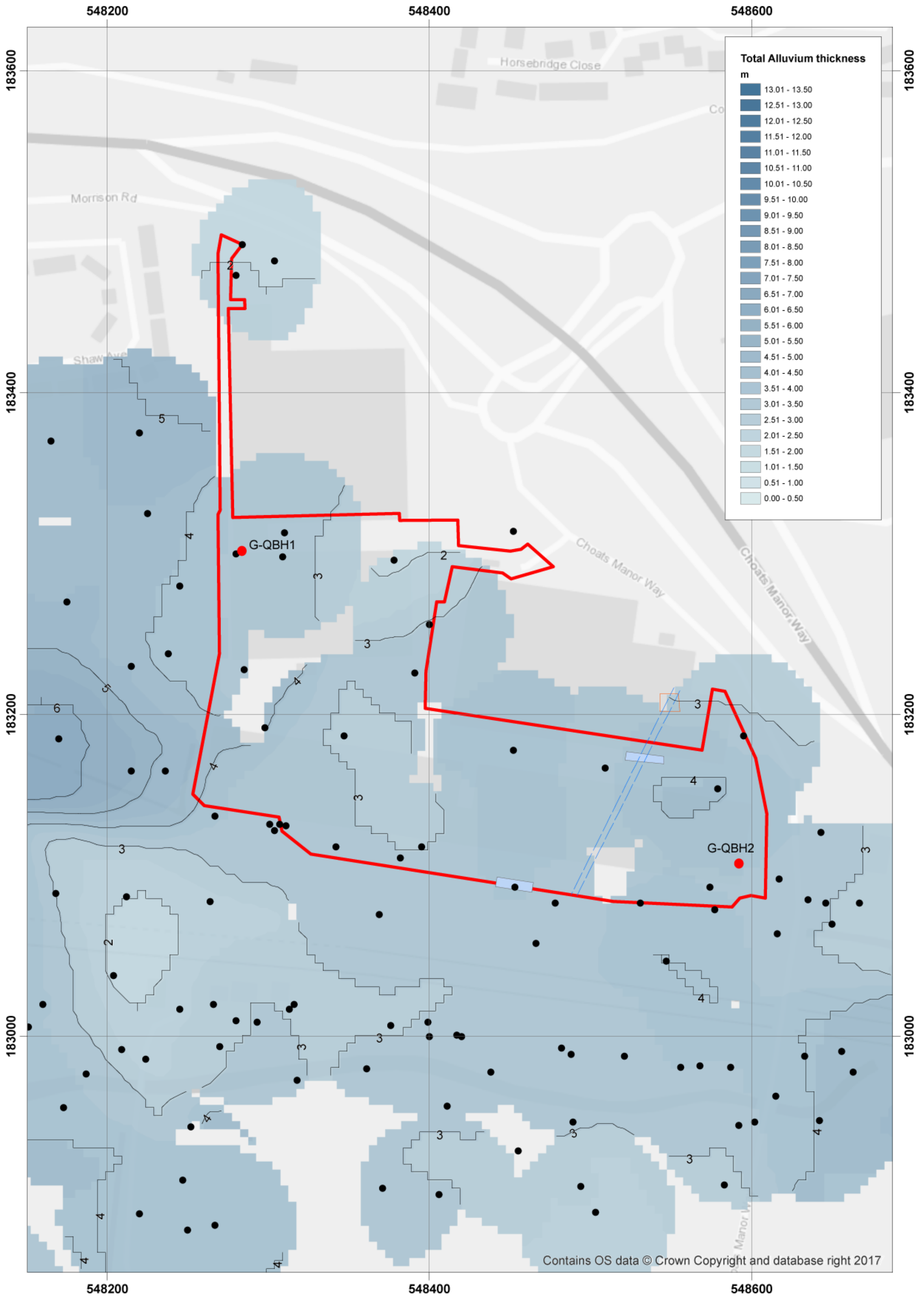

Figure 10: Thickness of the Total Alluvium (Lower Alluvium, Peat and Upper Alluvium) (m)

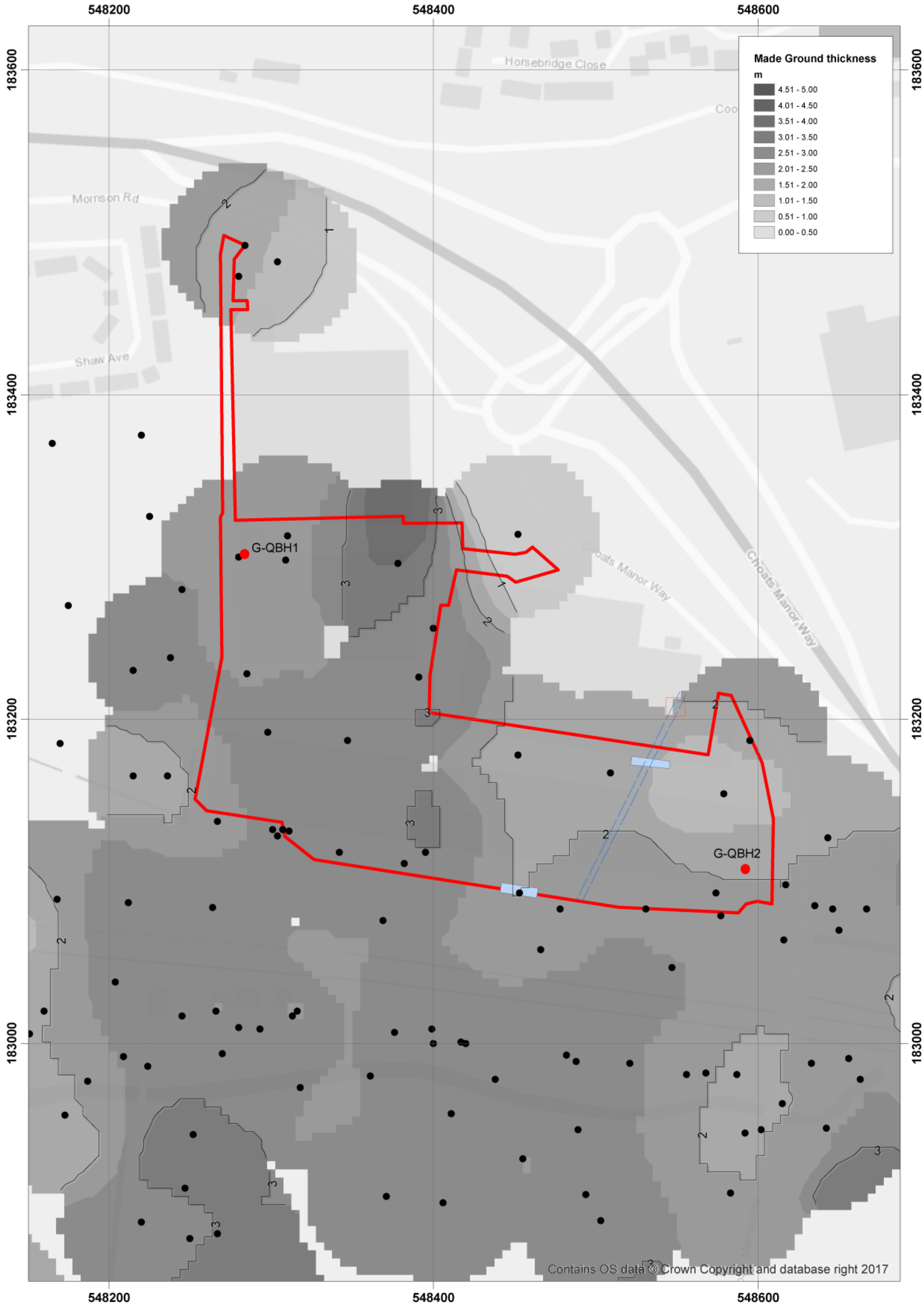

Figure 11: Thickness of Made Ground (m)

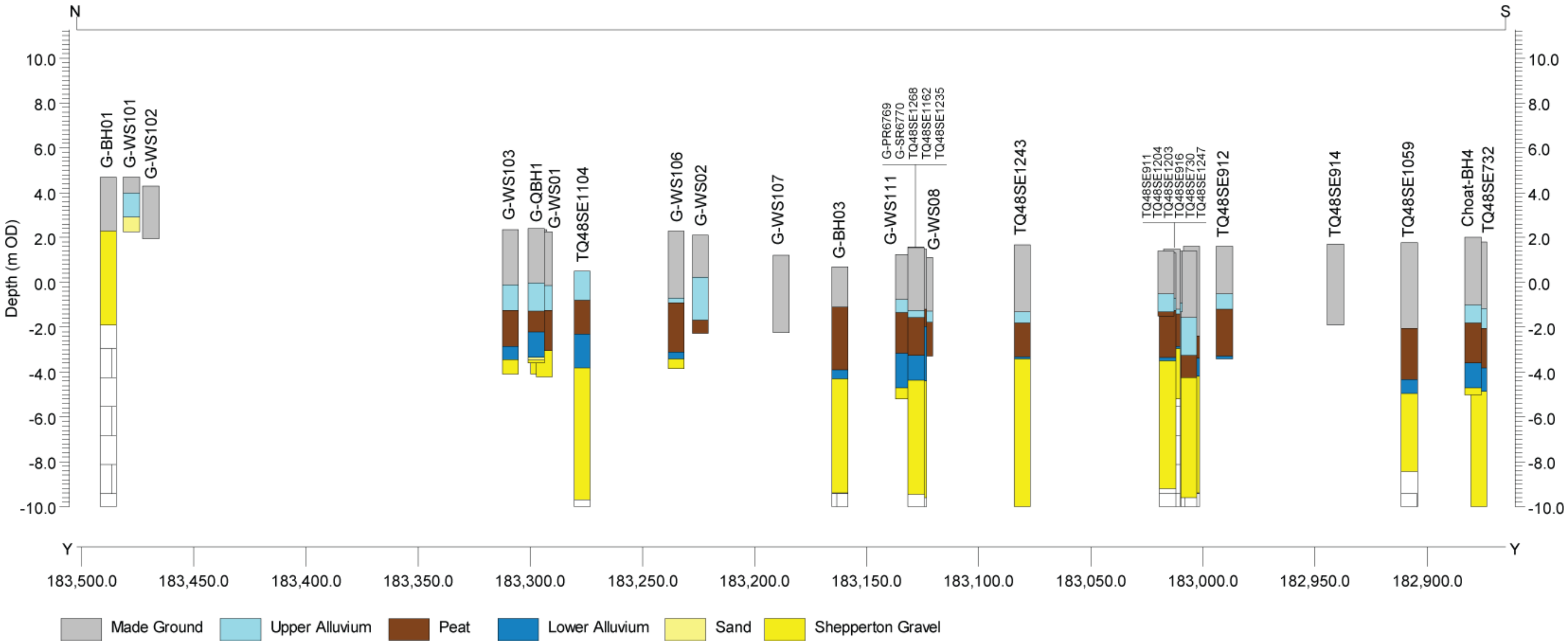

Figure 12: Site-wide north-south borehole transect

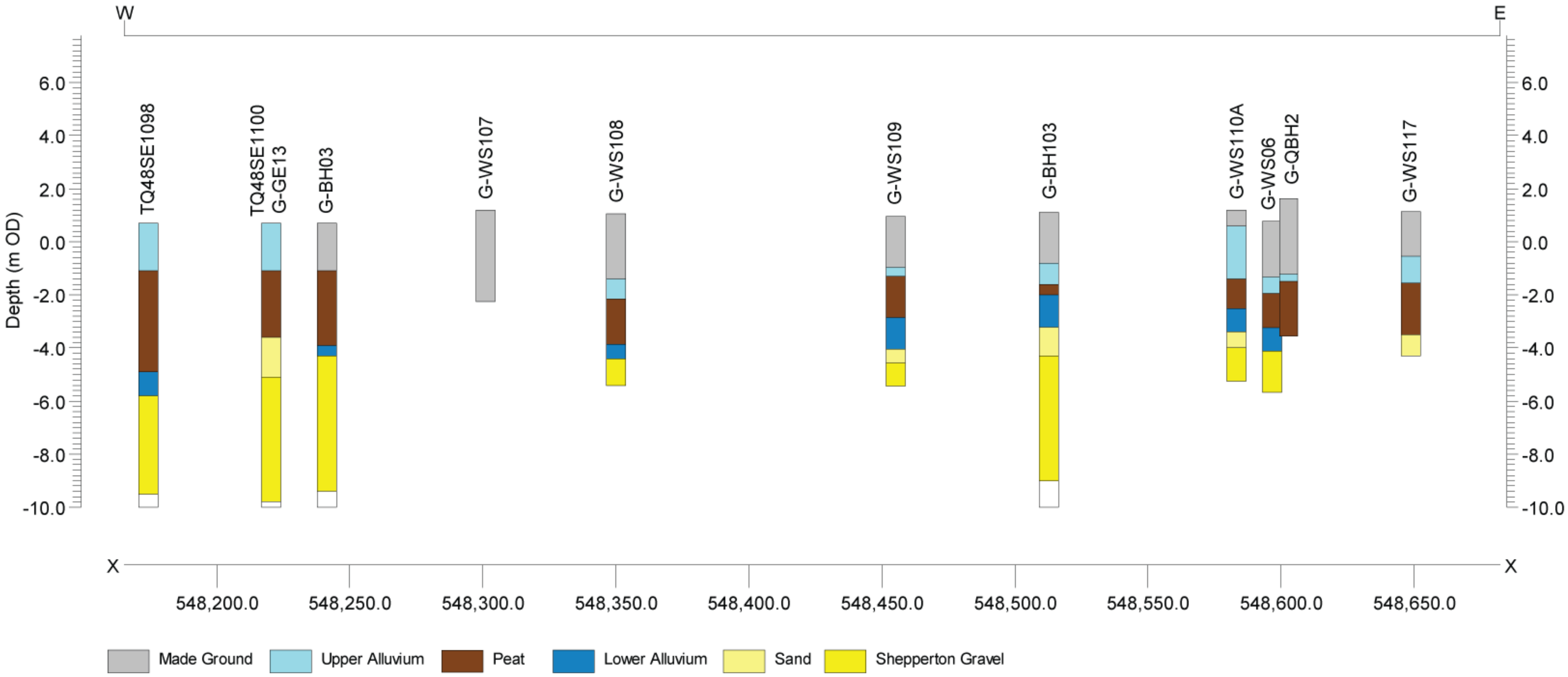

Figure 13: Site-wide west-east borehole transect

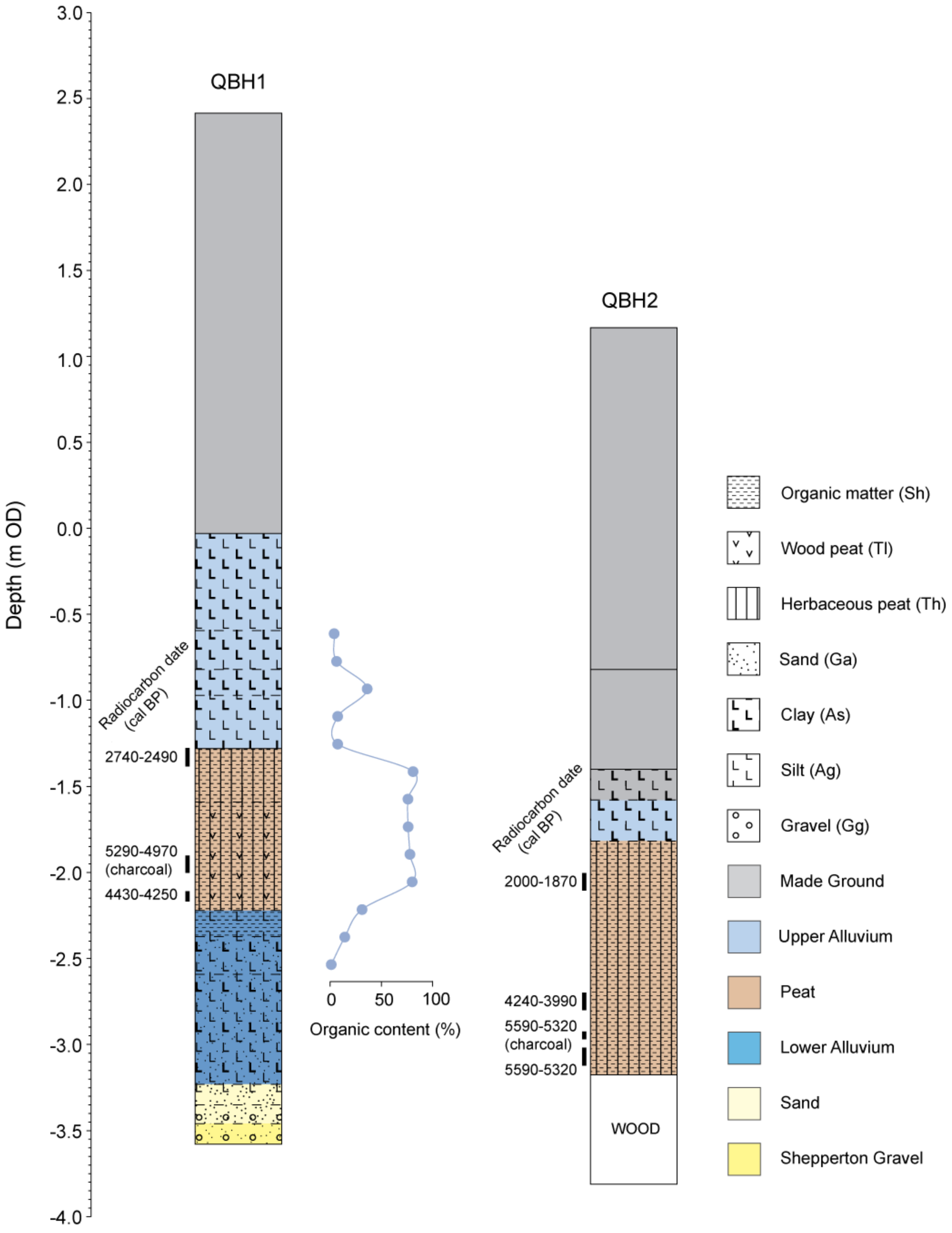

Figure 14: Results of the lithostratigraphic descriptions, organic content determinations and radiocarbon dating of boreholes QBH1 and QBH2 at Goresbrook Park, London Borough of Barking and Dagenham.

Table 2: Lithostratigraphic description of borehole QBH1, Goresbrook Park, London Borough of Barking and Dagenham.

Depth (m OD)	Depth (m bgl)	Description	Stratigraphic group
2.41 to -0.04	0.00 to 2.45	Made Ground of concrete hardstanding over concrete and brick rubble in a matrix of brown silty clay.	MADE GROUND
-0.04 to -0.59	2.45 to 3.00	As3 Ag1; blue grey silty clay with frequent worm/root hollows. Diffuse contact in to:	UPPER ALLUVIUM
-0.59 to -0.82	3.00 to 3.23	As3 Ag1; dark olive grey silty clay with some vertical rooting. Rare iron staining Diffuse contact in to:	
-0.82 to -0.97	3.23 to 3.38	As3 Ag1 Sh+; dark greyish brown silty clay with a trace of organic matter. Some structure/colouration indicative of soil formation. Diffuse contact in to:	
-0.97 to -1.28	3.38 to 3.69	Ag3 As1; grey silty clay. Sharp contact in to:	
-1.28 to -1.59	3.69 to 4.00	Sh3 Th^{3}1; humo. 3; well humified dark reddish brown herbaceous peat. Diffuse contact in to:	PEAT
-1.59 to -2.22	4.00 to 4.63	Sh2 Tl^{2}1 Th^{2}1; humo. 2; moderately humified dark reddish brown herbaceous and wood peat. Diffuse contact in to:	
-2.22 to -2.37	4.63 to 4.78	Ag2 Sh2 Th+; dark greyish brown very organic silt with a trace of herbaceous material (in situ). Diffuse contact in to:	LOWER ALLUVIUM
-2.37 to -2.59	4.78 to 5.00	Ag2 As1 Ga1 Dh+; dark olive grey sandy clayey silt with a trace of detrital herbaceous material. Some vertical sedge rooting. Diffuse contact in to:	
-2.59 to -3.23	5.00 to 5,64	Ag2 Ga1 As1 Dl+; grey sandy clayey silt with a trace of detrital wood. Diffuse contact in to:	
-3.23 to -3.35	5.64 to 5.76	Ga3 Ag1 Gg+; grey silty sand with occasional gravel clasts (flint). Diffuse contact in to:	
-3.35 to -3.46	5.76 to 5.87	Ga3 Gg1; orange gravelly sand. Clasts are flint, sub-angular to rounded, up to 20mm in diameter. Diffuse contact in to:	SAND
-3.46 to -3.59	5.87 to 6.00	Gg3 Ga1; orange sandy gravel. Clasts are flint, sub-angular to well-rounded, up to 30mm in diameter.	GRAVEL

Table 3: Lithostratigraphic description of borehole QBH2, Goresbrook Park, London Borough of Barking and Dagenham.

Depth (m OD)	Depth (m bgl)	Description	Stratigraphic group
1.18 to -0.82	0.00 to 2.00	Made Ground of concrete hardstanding over concrete and brick rubble.	MADE GROUND
-0.82 to -1.40	2.00 to 2.58	Made Ground of concrete and brick rubble; frequent glass.	
-1.40 to -1.57	2.58 to 2.75	As3 Ag1; blue grey silty clay with frequent worm/root hollows. Possibly reworked. Diffuse contact in to:	
-1.57 to -1.82	2.75 to 3.00	As3 Ag1; greyish brown silty clay. Some structure/colouration indicative of soil formation. Diffuse contact in to:	UPPER ALLUVIUM
-1.82 to -3.16	3.00 to 4.34	Sh3 $Th^2$1 Tl+ Ag+; humo. 3; dark reddish brown well humified herbaceous peat with traces of woody material and silt. Charcoal fragment (20x20mm) at -2.86 to -2.88m OD. Sharp contact in to:	PEAT
-3.16 to -3.82	4.34 to 5.00	Large wood branch/timber. Not possible to core beyond 5.00m bgl.	WOOD

Table 4: Results of the borehole QBH1 organic matter determinations, Goresbrook Park, London Borough of Barking and Dagenham.

Depth (m OD)		Organic matter content (%)
From	To	
-0.62	-0.63	5.01
-0.78	-0.79	7.33
-0.94	-0.95	36.65
-1.10	-1.11	8.48
-1.26	-1.27	8.28
-1.42	-1.43	80.90
-1.58	-1.59	75.88
-1.74	-1.75	76.09
-1.90	-1.91	77.88
-2.06	-2.07	80.05
-2.22	-2.23	31.79
-2.38	-2.39	15.15
-2.54	-2.55	2.16

Table 5: Results of the borehole QBH1 radiocarbon dating, Goresbrook Park, London Borough of Barking and Dagenham.

Laboratory code / Method	Material and location	Depth (m OD)	Uncalibrated radiocarbon years before present (yr BP)	Calibrated age BC/AD (BP) (2-sigma, 95.4% probability)	δ13C (‰)
BETA 478986 AMS	Twig wood/aerial sedge remains; top of peat	-1.28 to -1.33	2510 ± 30	790-540 cal BC 2740-2490 cal BP	-26.0
BETA-504247	Charcoal – *Alnus glutinosa*	-1.90 to -2.00	4460 ± 30	3340-3020 cal BC 5290-4970 cal BP	-26.6
BETA 478987 AMS	Twig wood; base of peat	-2.12 to -2.17	3920 ± 30	2480-2300 cal BC 4430-4250 cal BP	-27.9

Table 6: Results of the borehole QBH2 radiocarbon dating, Goresbrook Park, London Borough of Barking and Dagenham.

Laboratory code / Method	Material and location	Depth (m OD)	Uncalibrated radiocarbon years before present (yr BP)	Calibrated age BC/AD (BP) (2-sigma, 95.4% probability)	δ13C (‰)
BETA 478988 AMS	Aerial sedge remains; top of peat	-2.01 to -2.11	1980 ± 30	50 cal BC-80 cal AD 2000-1870 cal BP	-24.7
BETA-504249	Twig wood	-2.70 to -2.80	3760 ± 30	2290-2040 cal BC 4240-3990 cal BP	-26.8
BETA-504248	Charcoal – *Alnus glutinosa*	-2.86 to -2.88	4740 ± 30	3640-3370 cal BC 5590-5320 cal BP	-27.2
BETA 478989 AMS	*Alnus glutinosa* catkins; above wood	-3.02 to -3.12	4720 ± 30	3640-3370 cal BC 5590-5320 cal BP	-27.7

5. RESULTS & INTERPRETATION OF THE POLLEN ASSESSMENT

5.1 Results of the QBH1 pollen analysis

Pollen analysis was carried out on the peat deposit of QBH1. The resultant pollen percentage diagram has been divided into four local pollen assemblage zones (GOR1-1 to GOR1-4), based upon variations in pollen content. The characteristics of the zones are as follows:

LPAZ GOR1-1 -2.52m OD *Alnus – Quercus – Corylus* type

Prior to 5290-4970 cal BP

This zone is represented by a single sample from the Lower Alluvium. Tree (70%) and shrub (15%) are high, dominated by *Alnus* (30%) with *Quercus* (20%), *Corylus* type (15%), *Tilia*, *Ulmus*, *Betula*, *Salix* and *Fraxinus* (all <5%). Herbs (15%) comprise Cyperaceae (10%) with *Chenopodium* type, Lactuceae and Poaceae (all <5%). Aquatics are represented by sporadic grains of *Typha latifolia* and *Nuphar* type. Spores (20%) are dominated by *Dryopteris* type with *Polypodium vulgare* and *Pteridium aquilinum*. Microcharcoal is occasionally recorded.

LPAZ GOR1-2 -1.98m OD Cyperaceae – *Alnus – Salix*

ca. 5290-4970 cal BP

This zone is also represented by a single sample and originates from the base of the Peat. Herbs values are highest, dominated by Cyperaceae (55%) with sporadic occurrences of Poaceae. Trees and herbs are dominated by *Alnus* and Salix (both 15%) with *Quercus* (10%) and *Corylus* type (5%). Aquatic taxa are absent and spores are dominated by *Dryopteris* type (20%) with sporadic spores of *Polypodium vulgare*. Microcharcoal is recorded in moderate concentrations.

LPAZ GOR1-3 -1.98 to -1.50m OD *Alnus – Quercus – Corylus* type

ca. 5290-4970 to prior to 2740-2490 cal BP

This zone is represented by three samples within the Peat. Tree (70%) and shrub (20%) pollen values are high, dominated by *Alnus* (40-60%) with *Quercus* and *Corylus* type (both 15%), *Betula*, *Tilia* (both 5%), *Taxus*, *Ulmus*, *Fraxinus* and *Salix* (all <5%). Herbs (10%) are dominated by Cyperaceae (<10%) with sporadic occurrences of Poaceae, *Galium* type, *Rumex acetosa* / *acetosella*, Apiaceae, and *Plantago lanceolata*. Aquatics are absent, whilst spores increase, dominated by *Dryopteris* type (up to 80%) with sporadic values of *Polypodium vulgare* and *Pteridium aquilinum*. Microcharcoal is recorded in negligible / occasional concentrations.

LPAZ GOR1-4 -1.50 to -1.26m OD Cyperaceae – Poaceae – *Alnus*

From prior to 2740-2490 cal BP

The final zone is represented by two samples from the top of the Peat. It is characterised by an increase in herb pollen (to >50%), dominated by Cyperaceae and Poaceae (both up to 20%) with *Ranunculus* type, *Sinapis* type, *Chenopodium* type, Apiaceae, *Rumex acetosa* / *acetosella*, *Plantago lanceolata*, Asteracae, Lactuceae and *Cereale* type (all <5%). Aquatic taxa (35%) are dominated by *Sparganium* type, with lesser amounts of *Potamogeton* type, *Typha latifolia* and *Nuphar* type. Spores

(10-40%) are dominated by *Dryopteris* type with occasional spores of *Pteridium aquilinum*. Microcharcoal is recorded in moderate concentrations.

5.2 Results of the QBH2 pollen analysis

Pollen analysis was carried out on the peat deposit of QBH2. The resultant pollen percentage diagram has been divided into three local pollen assemblage zones (GOR2-1 to GOR2-3), based upon variations in pollen content. The characteristics of the zones are as follows:

LPAZ GOR2-1 -3.16 to -2.68m OD *Alnus – Salix - Quercus*
ca. 5590-5320 to 4240-3990 cal BP

This zone is represented by two samples from the base of the Peat. Trees and herbs are dominated by *Alnus* (30%), *Salix* (20%) and *Quercus* (15%) with *Corylus* type (5%) and sporadic occurrences of *Taxus*, *Tilia, Ulmus*, *Betula* and *Sambucas nigra* (all <3%). Herbs (20%) include Cyperaceae (6%), Poaceae, and Apiaceae (both <5%). Aquatics (<5%) are represented by *Typha latifolia*, *Sparganium* type and occasional *Nuphar* type. Spores are dominated by *Dryopteris* type (30%) with occasional *Polypodium vulgare*. Microcharcoal increased from absent to moderate concentrations.

LPAZ GOR2-2 -2.68 to -2.04m OD *Alnus – Quercus – Corylus* type
ca. 4240-3990 to 2000-1870 cal BP

This zone is represented by two samples within the Peat. Tree (>70%) and shrub (20%) pollen values are high, dominated by *Alnus* (50-70%) with *Quercus* and *Corylus* type (both 15%), *Tilia, Salix* (both 5%), *Taxus*, *Ulmus*, *Fraxinus* and *Betula* (all <5%). Herbs (20%) are dominated by Cyperaceae (<10%) with Poaceae, Chenopodium type, Caryophyllaceae, *Filipendula* type, Asteraceae and Lactuceae (all <5%). Aquatics comprise sporadic occurrences of *Nuphar* type, whilst spores decline, dominated by *Dryopteris* type (up to 30%) with sporadic values of *Polypodium vulgare* and *Pteridium aquilinum*. Microcharcoal concentrations are negligible.

LPAZ GOR2-3 -2.04 to -1.88m OD Cyperaceae – Poaceae – *Alnus*
Post *ca.* 2000-1870 cal BP

The final zone is represented by one sample from the top of the Peat. It is characterised by an increase in herb pollen (to >50%), dominated by Poaceae (25%) with Cyperaceae (10%), *Ranunculus* type, *Sinapis* type, *Chenopodium* type, Apiaceae, *Rumex acetosa* / *acetosella*, *Plantago lanceolata*, Asteracae, Lactuceae and *Cereale* type (all <5%). Aquatic taxa (5%) are represented by *Sparganium* type. Spores (20%) are dominated by *Drypoteris type* with occasional spores of *Pteridium aquilinum* and *Polypodium vulgare*. Microcharcoal is frequently recorded.

5.3 Results of the pollen analysis

As outlined in 5.1 and 5.2, the pollen and non-pollen palynomorph analysis focused on parts of the sedimentary sequence most likely to represent semi-terrestrial or terrestrial environments on the wetland; i.e. the peat sediments. Whilst this prevented a reconstruction of vegetation history through the complete sedimentary sequence (as carried out and advocated by Allen and Scaife, 2000), there are a number of taphonomic issues that complicate the interpretation of palynological data from the mineral-rich sediments of low-energy fluvial and estuarine environments, including: (1) long distance travel of pollen by fluvial or aeolian means (e.g. Moore *et al*., 1991; Scaife & Burrin, 1992), and (2) the reworking and redeposition of pollen from older sediments (e.g. Cushing, 1967; Waller, 1993; Campbell, 1999). Concentration of the pollen investigations on the semi-terrestrial peat deposits reduces the impact of these particular taphonomic issues. However, another issue specific to pollen studies in coastal lowland wetlands is that of taxonomic precision and distinguishing the environment of origin. The identification of pollen grains (in particular herb taxa) is frequently limited by morphological similarities between grains of different species, and often only the genus can be established. In addition, the herbs found in one wetland habitat are often palynologically indistinguishable from other members of their genera/family that may have originated from different wetland or dryland environments (Waller, 1993, 1998; Waller *et al*., 2005; see for example Wheeler, 1980a, b). These issues are taken into account in the following results and interpretations.

The two diagrams from QBH1 and QBH2 are described together as there are affinities between both the nature of the assemblages in each zone, and their chronology:

Approximate chronology	QBH1	QBH2
Top of Peat: Post *ca*. 3000 cal BP	LPAZ GOR1-4	LPAZ GOR2-3
Middle of Peat: *ca*. 5000-3000 cal BP	LPAZ GOR1-3	LPAZ GOR2-2
Base of Peat: Prior to *ca*. 5000 cal BP	LPAZ GOR1-2	LPAZ GOR2-1
Top of the Lower Alluvium	LPAZ GOR1-1	

The vegetation assemblage is interpreted below using the 'Approximate chronology' titles above.

Top of the Lower Alluvium

This period consists of a single pollen sample from the top of the Lower Alluvium in QBH1; it is undated, but likely to date to the late Mesolithic / early Neolithic. The results of the pollen-stratigraphic analysis indicate that during this period, *Alnus* (alder) dominated the wetland environment with sporadic *Salix* (willow) and a ground flora including Cyperaceae (sedges), Poaceae (grasses – e.g. *Phragmites australis* – common reed), *Dryopteris* type (buckler ferns), and occasional *Polypodium vulgare* (polypody fern). Combined, these taxa indicate the presence of alder carr communities growing on sufficiently dry and stable surfaces of the floodplain. Sporadic values of *Chenopodium* type (goosefoot family) are also of note, since genera of the Chenopodiaceae family can occur in two main locations: (1) waste, dry ground and cultivated land (e.g. *Chenopodium album* – fat hen), and (2) salt marshes (e.g. *Suaeda maritima* – annual sea-blite. Since there are no other indicators of disturbance, the presence of *Chenopodium* type pollen is considered more likely to represent occasional fluvial inundation of the site and the influence of estuarine conditions during deposition of the Lower Alluvium.

Quercus (oak) and *Corylus* type (e.g. hazel) may have accompanied alder and willow on the peat surface. However, these taxa more commonly occur on dryland where they would have formed a mosaic of mixed deciduous woodland with *Tilia* (lime). Indeed, since lime is of entomophilous (insect pollinated) even the relatively low *Tilia* pollen values recorded could indicate it was a dominant component of the adjacent dryland woodland during this period. The understorey would have comprised hazel shrubs together with grasses and a range of herbs more commonly found in rough grassland.

Ulmus pollen values are low suggesting elm represented only a small proportion of the local woodland cover near. The reduction of elm populations is recorded within pollen diagrams across north-western Europe during the early Neolithic; in the Lower Thames Valley (e.g. Batchelor *et al*., in press) and British Isles (Parker *et al*., 2002) it is recorded between approximately 6300 and 5300 cal BP. It is therefore possible (but by no means certain), that the reason for the low values indicate that the sequence post-dates this well-documented decline.

There are no definitive indicators of human activity during this period.

Base of Peat: Prior to *ca*. 5000 cal BP

This period consists of LPAZ GOR1-2 from QBH1 and LPAZ GOR2-1 from QBH2, with the samples originating from the base of the Peat, and considered to predate 5000 cal BP (i.e. the early Neolithic). This period is characterised by the dominance of sedges, alder and willow with bur-reed (*Sparganium* type) and bulrush (*Typha latifolia*), representing wet peat surface conditions and the growth of alder-willow dominated swamp carr and sedge fen communities. Areas of still or slowly moving water are also indicated by the growth of water-lily (*Nuphar* type). No taxa indicative or potentially indicative of saltmarsh taxa are recorded, suggesting that the site was probably not influenced by saline conditions during this period.

Despite the apparently wet nature of the peat surface, one or more episodes of burning are indicated between ca. 5500 and 5000 cal BP by moderate concentrations of microcharcoal in both boreholes. This occurs in the same part of the sequences as the alder charcoal is recorded (see section 4.4). As previously outlined, it is uncertain whether the burning was of natural or anthropogenic origin, but it definitively occurred on the peat surface.

On the dryland, the continued growth of oak and lime dominated woodland is indicated, and there remains no definitive evidence for a decline in elm woodland.

Middle of Peat: ca. 5000 to 3000 cal BP

This period consists of LPAZ GOR1-3 from QBH1 and LPAZ GOR2-2 from QBH2, with the samples originating from the middle of the Peat, and considered to represent the period of 5000 to 3000 cal BP (the later Neolithic and Bronze Age periods). It is characterised by the development of a more mature alder woodland community on the peat surface, with a reduction in willow, sedge and aquatic taxa.

This more mature floodplain woodland most likely included yew (Taxus) which is recorded in the pollen record, albeit in limited proportions. Yew is now known to have been an important component of the alder-dominated woodland on the peat surface of the Lower Thames Valley, spanning from at least the East India Docks (Pepys, 1665) in the west to Aveley Parish and Erith Forest in the east (Wilkinson and Murphy, 1995; Seel, 2001), according to multi-proxy palaeoenvironmental investigations. Locally, yew pollen and wood has been recorded at the Former Ford Stamping Factory (Batchelor et al., 2018a), Beam Park Phases 1 & 2 (Young et al., 2018a, b), Hornchurch Marshes (Branch et al., 2012) and Barking Riverside (Green et al., 2014). Combined, these investigations from the Lower Thames Valley tend to indicate that yew colonised the floodplain woodland around 5000 cal BP, declining approximately 1000 years later; findings that are broadly supported by the results from Goresbrook Park.

On the dryland, the continued growth of oak and lime dominated woodland is indicated. The increase of *Tilia* pollen may suggest the encroachment of lime towards the floodplain, but is far more likely to be a taphonomic effect of the reduction in willow population.

There are no definitive indicators of human activity during this period.

Top of Peat: ca. 3000 cal BP onwards

This period consists of LPAZ GOR1-4 from QBH1 and LPAZ GOR2-3 from QBH2, with the samples originating from the top of the Peat, and considered to post-date 3000 cal BP (Bronze Age onwards).

It is marked by the decline of tree and shrub pollen, whilst the range and percentage values of herbaceous taxa increases. On the floodplain, the initial decline of alder is mirrored by the expansion of grasses (probably including reeds) and sedges, bur-reed and bulrush indicating a wetter peat surface and a transition towards sedge fen / reed-swamp communities. A saline influence also cannot be ruled out due to the presence of *Chenopodium* type (goosefoot family); members of this family can occupy disturbed ground (e.g. *Chenopodium album* - fat hen) or saltmarsh (e.g. *Suaeda maritima* – annual seablite).

On the dryland, the reduction of oak, lime and possibly hazel is suggestive of a reduction in the dryland woodland. The increase of a large array of herbaceous taxa could suggest that this decline was a consequence of woodland clearance for settlement and agricultural purposes, which took place from the Bronze Age onwards. It is certainly of note that a few grains of cereal pollen were present, potentially indicating nearby cultivation or crop-processing activities. However, the *Cereale* type group includes both cereals and wild grasses (Andersen, 1979), and previous studies have suggested a strong association between these grains and those of other wetland herbaceous and aquatic taxa (e.g. Poaceae, Cyperaceae, *Sparganium*). Thus it is possible that these grains could represent wild grasses found in wetland habitats (e.g. *Glyceria* sp. - mannagrass) (Waller & Grant, 2012; Perez et al., 2015).

The near synchronous change in vegetation on both the floodplain and dryland woodland does suggest a link between the two environments and is a common feature of pollen-stratigraphic records from across the Lower Thames Valley (see e.g. Waller & Grant, 2012; Batchelor et al., in prep).

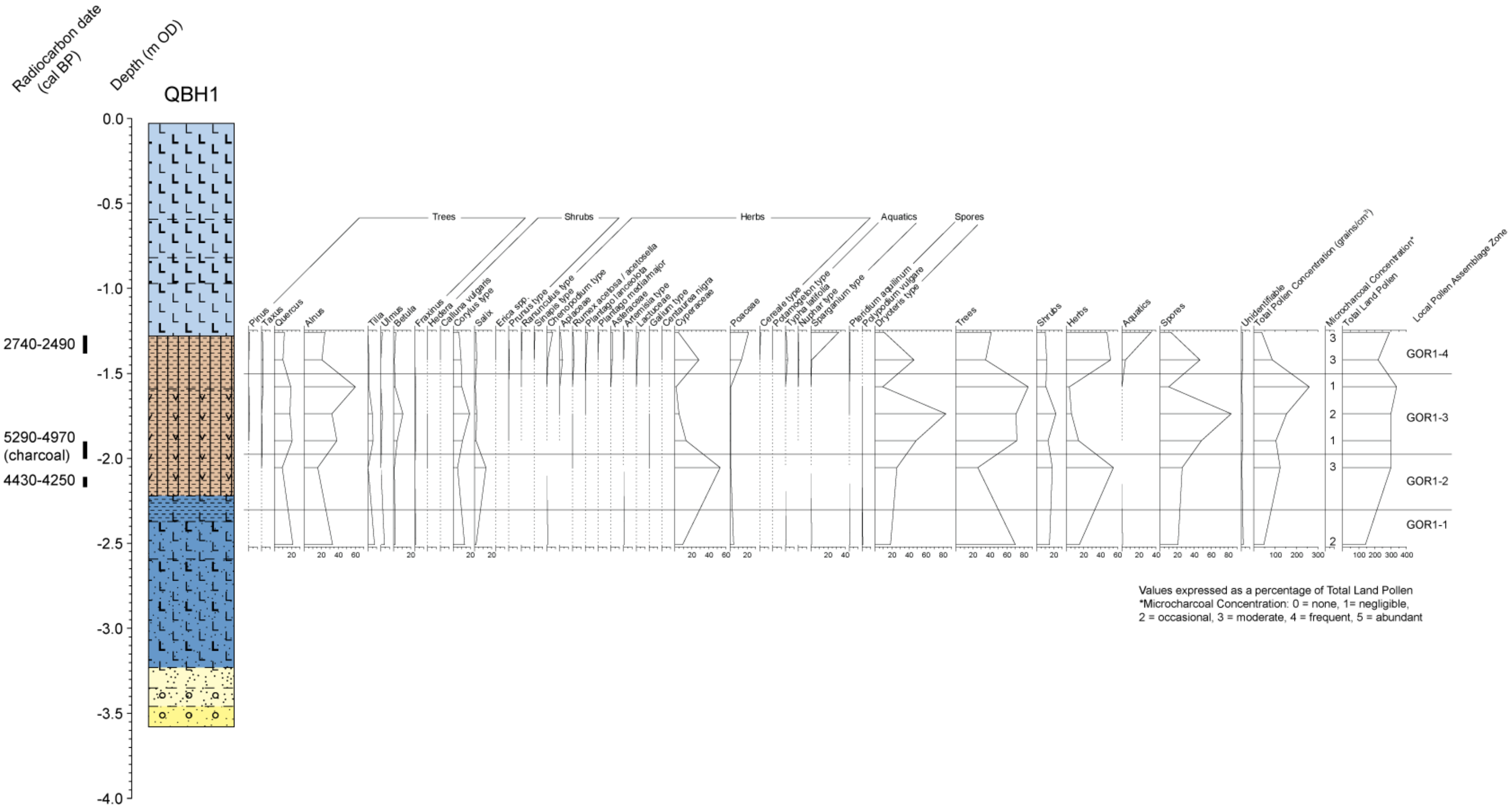

Figure 15: Pollen percentage diagram, QBH1, Goresbrook Park

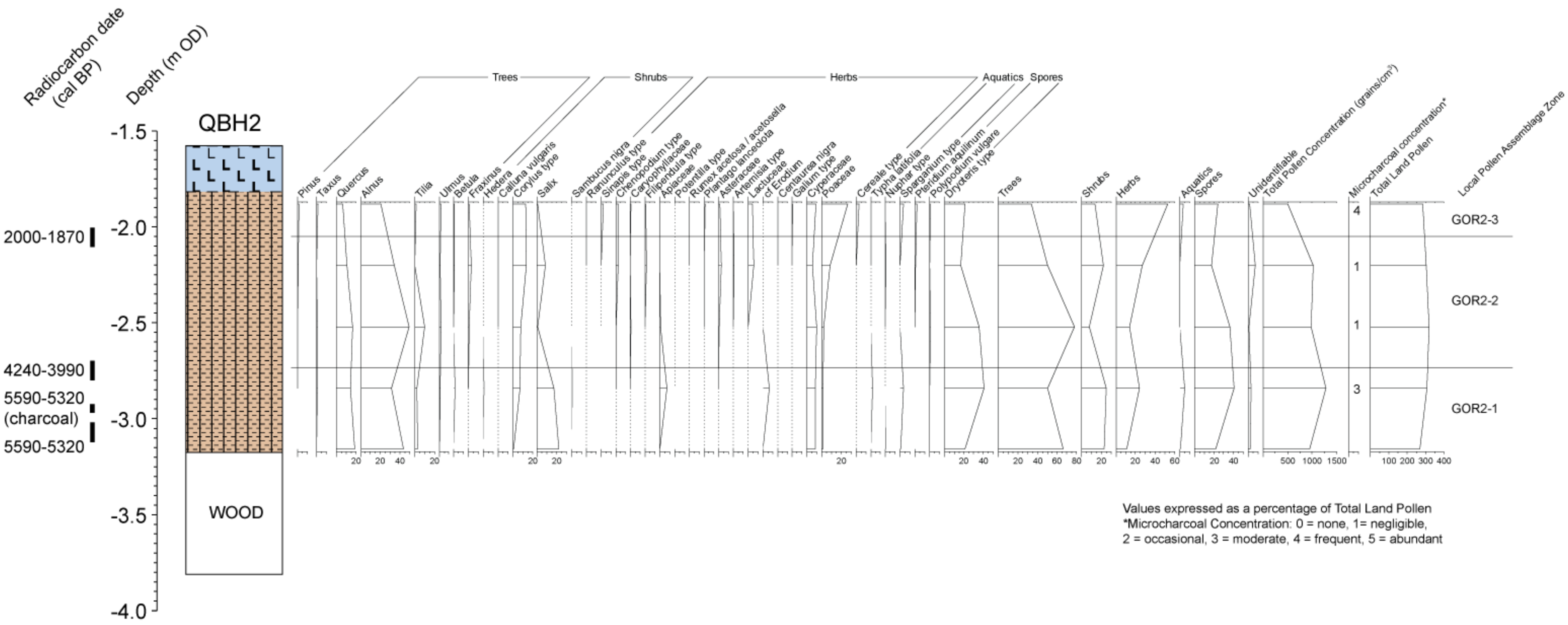

Figure 16: Pollen percentage diagram, QBH2, Goresbrook Park

6. RESULTS & INTERPRETATION OF THE DIATOM ASSESSMENT

Diatom analysis was targeted on the contact between the Peat and Upper Alluvium in QBH1. A summary of the diatom results is provided in Tables 7 & 8. In the majority of cases, taxa were identifiable to species level, but in some instances, identifications were only possible to genera level. Only taxa with presence above 2% Total Diatom Valves (TDV) are displayed for ease of subsequent interpretation. Table 7 displays the diatom species present within each sample. The diatoms encountered have been displayed according to their broad salinity and life form classifications, for example: 'marine planktonic' species are those encountered in open marine waters with salinities typically >20-30‰, found floating in the water column; 'brackish benthic' species are encountered in waters more typically associated with shallow estuarine settings with salinities of 1-9‰. In addition, their benthic status indicates that these species live attached to, or within the sediment substrate under investigation. Benthic taxa can be further divided, based on substrate preference:

- Epiphytic taxa - found attached to organic material (plants and decomposing organic debris),
- Epipelic taxa - attach themselves for muddy deposits,
- Epipsammic taxa - associated with sandy substrates,
- Aerophilous taxa - require a period of both aquatic submergence and emergence, and in the case of coastal sequences are strongly associated with the intertidal zone.

These additional benthic subdivisions will be referred to, where relevant and within Table 1. In addition, the importance of differentiating between planktonic and benthic species will be outlined in greater detail at a later stage, but in essence benthic taxa are seen as providing a more reliable indicator of the more detailed environmental conditions that prevailed in the past. This is because they are likely to have lived *in-situ* within the sediment under analysis. This is in contrast to the planktonic taxa which live suspended in the water column and hence have the *potential* to be carried into a depositional environment after death.

Table 1 provides greater focus on the salinity requirements of the diatom taxa encountered, dividing the species into the following categories: Polyhalobous (>30‰; fully marine), Mesohalobous (0.2-30‰; brackish water), Oligohalobous (<0.2‰; salt tolerant) and Halophobous (0‰; exclusively freshwater).The Oligohalobous category can be further subdivided into Oligohalobous halophilous (salt-tolerant freshwater) and Oligohalobous indifferent (tolerant of slightly saline water). This classification enables the overall salinity of the depositional environment to be taken considered, incorporating both planktonic and benthic taxa together. In the case of the samples under investigation, no halophobous taxa were encountered.

Due to the dominance of marine and brackish taxa, the dataset has the potential to be incorporated into the palaeoenvironmental scheme of Vos and de Wolf (1993). This scheme enables the likely position of the sediment sample within the palaeo-tidal frame to be determined. Table 8 summarises the assemblage compositions that are associated with differing elevations within the littoral zone.

6.1 Results of the diatom analysis

Diatom preservation was good in both samples and full counts were achieved. The diatom assemblages display an overall dominance of marine, marine brackish and brackish taxa, with a low but significant component of freshwater taxa. Both planktonic and benthic species contributed to the floral diversity. Of the benthic taxa present, most are typically associated with muddy (epipelon) and organic rich (epiphytic) substrates; some are aerophilous taxa (and hence infer periods of sub-aerial exposure). Such groupings indicate a setting in which tidal influence prevails. The continued presence of marine and brackish planktonic and tychoplanktonic taxa further supports this tidal setting, inferring that deposition of the lower part of the Upper Alluvium took place within the intertidal zone. Taking into account this stratigraphic context, the vertical shift from an underlying peat unit into an apparent layer of alluvium is suggestive of a rise in relative sea level.

The two samples were taken from either side of the stratigraphic boundary of the freshwater peat overlain by estuarine alluvium. The presence in both samples, of a mixture of marine, brackish and freshwater diatoms (from both the planktonic and benthic realms), indicates that tidal conditions must have been influential during the formation of the Peat and Upper Alluvium, at least during the period immediately prior to estuarine inundation and subsequent alluvial submergence. It is noted that there was a minerogenic component within the peat sample, and this may be the source of the more saline tolerant taxa. Whilst the overall salinity classifications remain broadly similar, Table 7 shows that there is a shift in assemblage between the two samples. The sample from the peat, has a greater abundance of lower salinity planktonic and benthic taxa, whilst the one from the Upper Alluvium contains an assemblage more typified by brackish and marine flora.

The assemblage from the Peat (-1.30m OD) contains planktonic taxa in relative abundance, but with the brackish species *Cyclotella striata* dominating the planktonic assemblage. Higher salinity planktonic and tychoplanktonic taxa, such as *Actinoptychus senarius, Rhaphoneis amphiceros* and *Delphineis surirella* are present, but are much less common. In terms of benthic flora, the lower sample contains a mixture of marine-brackish, brackish-fresh and fresh taxa, most typified by *Nitzschia navicularis, Nitzschia sigma* and *Gyrosigma acuminata,* all of which are affiliated with muddy settings. A small suite of aerophilous taxa is encountered, including the marine-brackish species *Diploneis interrupta*, inferring periods of tidal emergence and submergence on site. There is however a clear presence of brackish and freshwater taxa often affiliated with muddy substrates and vegetation, including *Surirella brebissonii, Cocconeis pediculus, Cymatopleura solea* and *Synedra unla*

The assemblage from the Upper Alluvium (-1.26m OD) contains a much more diverse planktonic and tychoplanktonic assemblage, with a shift towards a greater marine influence. Whilst the brackish taxa *Cyclotella striata* remains somewhat dominant, higher salinity taxa are more abundant with *Paralia sulcata*, *Pseudomelosira westi* and *Thalassiosira eccentrica, Odontella* sp, and the tychoplanktonic taxa *Rhaphoneis amphiceros and Delphineis surirella* present. The influence of open marine inundation is therefore greater at this point in time. The benthic taxa demonstrate a reduction in the influence of freshwater flora and those associated with vegetation, to be replaced by a greater percentage contribution from taxa preferring muddy substrates, particularly reflected by the dominance of *Nitzschia navicularis*.

In terms of salinity preferences, Table 7 confirms the absence of any halophobous taxa, with salt tolerant species dominating the profile. A similar trend is displayed as the planktonic vs benthic picture, with an increase in the influence of polyhalobous and mesohalobous taxa with height, with oligohalobous indifferent taxa more typical within the lower sample. In terms of lifeform classifications, epiphytic and epipelon taxa are more typical within the Peat sample, which some aerophilous species also contributing. In contrast, epipelon species almost wholly dominate the sample from the Upper Alluvium.

4.2 Interpretation of the diatom analysis

The diatom assemblages present within QBH1 reveal a clear palaeoenvironmental picture associated with the transition from freshwater to estuarine conditions. The cessation of peat deposition has been dated to around 2490-2740 cal BP (Early-Middle Iron Age), with the diatoms extracted from the peat indicating estuarine conditions were already affecting the site prior to the subsequent shift to the Upper Alluvium. The diatom flora from within the Peat sample contains more species affiliated with (1) lower salinity conditions (2) organic remains and (3) subaerial exposure. This trend is exemplified by the initial relative dominance of the brackish planktonic taxa *Cyclotella striata*, supported by the lower salinity tolerant benthic taxa such as *Cocconeis pediculus, Cymatopleura solea* and *Synedra unla* and the aerophilous taxa *Diploneis interrupta*. The fact that the plankton is relatively low in diversity and dominated by the brackish taxa *C. striata* (rather than the more typical marine taxa as encountered in the sample above) indicates that whilst influential, marine inundation was likely relatively limited (restricted to high tides etc.). By contrast, the overlying Upper Alluvium, records a reduction in the influence of freshwater flora and an increase in the abundance of marine planktonic and tychoplanktonic taxa, in addition to the overall dominance of marine-brackish epipelon species associated with muddy saltmarsh/mudflat substrates. Such a shift therefore reflects the increased sea-level influence.

On the basis of the other palaeoenvironmental data, there is little doubt that the Peat formed in a terrestrial/freshwater realm. The pollen and plant macrofossil results infer the dominance of freshwater flora throughout its depositional history. However, the increase of sedges, grasses and bur-reed are recorded in the uppermost sample of QBH1, which is indicative of a much wetter environment on the floodplain. Evidence of such increased surface wetness is not surprising considering the imminent inundation of the Thames lowlands in response to sea-level rise. It is therefore likely that whilst the Peat was created within a freshwater setting, many of the diatoms encountered in the uppermost sample of the peat were subsequently incorporated into the peat *in response* to the initial episode of marine inundation. Whilst some of the fresh (and some fresh-brackish) epiphytic taxa may be a reflection of the true assemblage that developed at the time of peat deposition, the abundance of brackish plankton, supported by the marine-brackish taxa most often encountered on muddy substrates epipelon, are likely to have been introduced by the onset of tidal inundation, prior to the shift to subsequent minerogenic estuarine sedimentation.

As outlined above, the Vos and deWolf (1993) classification enables the altitude at which the sample developed on the coastal zone to be inferred (i.e. subtidal, intertidal, supratidal) which, when applied to multiple samples within a sequence, can be used to infer changes in palaeo-depositional altitude over time. This can in turn be used to provide a semi-quantitative indicator of changes in relative sea level. For example, a gradual shift from assemblages indicating deposition in supratidal settings, to those more associated with subtidal conditions, would be interpreted as indicating a progressive increase in the influence of relative sea level. Such a shift is suggested by the stratigraphy consisting of peat overlain by alluvium. This apparent marine 'transgression' can be caused by a number and/or combination of factors. These include (but are not restricted to) an increase in eustatic (global) sea-level, a decrease in the rate of terrestrial sedimentation along the coastal zone (to effectively lower the coastline above that of rising sea level) or crustal movements often resulting from glacio-istostasy (an artefact of the impact previous glacial episodes in the UK). Such interpretations are only possible (and useful) if placed within a chronological framework.

The benefit of the Vos and deWolf (1993) scheme is that, whilst it does take into account the presence of planktonic taxa, it also provides substantial windows in which planktonic species can be present. For example, marine planktonic species can contribute anywhere between 10-70% TDV in any of the diatom assemblage associated with deposition in the supratidal realm. This approach is however necessary due to the potential for large amounts of planktonic diatoms to 'flood' into sediments due to their derived nature, biasing salinity classes allocated to each sample. This potential bias is often displayed within diatom diagrams due to the abundance of planktonic taxa in most deposits (and yet not necessarily reflecting the depositional conditions).

The brackish planktonic species *Cyclotella striata* is encountered in both samples, but in greatest abundance within the peat unit. This taxon contributes between 25-35% TDV. According to Vos and deWolf (1993), brackish plankton typically contribute up to 30% TDV throughout much of the intertidal and supratidal area, but can also contribute larger amounts (20-70% TDV) within the subtidal zone, due to this being where the greatest amount of water mixing takes place (hence the greatest opportunity for fresh, brackish and marine plankton to be encountered together; see Table 8). However we can confidently discount the subtidal realm for both samples; the peat sample is a freshwater deposit as concluded through the pollen and plant macrofossil studies, whilst the relative abundance of other diatom ecological groupings within both samples, with specific reference to the lower salinity epiphytic and aerophilous taxa that are commonly encountered, further reinforces such a conclusion. Epiphytic taxa require organic remains of living aquatic plants to thrive, which is not typically encountered in the subtidal realm. In addition, aerophilous taxa require repeated periods of aerial exposure and tidal submergence; within the subtidal zone, such periods of aerial exposure is severely restricted to spring tides.

Discounting estuarine tidal channels as the likely depositional environment, the benthic taxa can now be further critiqued. The sample from the Peat at -1.30m OD, contains a mixture of fresh and fresh brackish epiphytic taxa, supported by marine brackish aerophilous taxa. However marine-brackish epipelon dominate. As concluded above, the assemblage is likely a mix of freshwater taxa that lived within the peatland during its formation, combined with those taxa that initially colonised the floodplain during the earliest phase of marine transgression. Therefore whilst we are unable to allocate the sample a definitive depositional interpretation according to Vos and deWolf (1993), it can be stated that the more saline tolerant taxa from this deposit likely infer deposition in a setting similar to 'pools in salt marshes' (suggesting saline incursions during highest tides taking place and affecting the floral diversity of peatland hollows). The overlying sample from the base of the Upper Alluvium (-1.26m OD) contains an abundance of both marine brackish epipelon taxa, with an almost total absence of aerophilous taxa and limited fresh-brackish or fresh taxa. Based on the assemblage composition it is concluded that deposition took place within the supratidal area, likely in a 'mudflat' setting, although some of the flora are associated with 'salt marshes around MHW' and hence it is likely to be a marginal setting between the two (Figure 2). This reconstruction therefore supports the interpretation of a marine transgressive phase taking place.

The interpretation based on Vos and de Wolf (1993) must however be treated with caution. The scheme requires the grouping of diatom taxa into ecological categories (marine-brackish epipelon, brackish aerophilous etc) and unfortunately not all species have been allocated such groupings, or contradictions are encountered within the ecological and palaeoecological literature. This does therefore require some assumptions to be made.

Table 7: Diatom flora encountered during analysis of samples from QBH1 Goresbrook Park

	Species	lifeform	salinity preference	Sample Depth (m O.D.)	
				-1.26	-1.30
Planktonic	*Actinoptychus senarius*	M Plank	A	3	11
	Cerataulis smithi	M Plank	A	2	1
	Odontella rhombus	M Plank	A	1	
	Paralia sulcata	M Plank	A	11	
	Pseudomelorira westii	M Plank	A	5	
	Thalassiosira eccentrica	M Plank	A	7	1
	Delphineis surirella	M Tych	B	5	18
	Odontella aurita	M Tych	B	4	
	Rhaphoneis amphiceros	M Tych	B	26	13
	Cyclotella striata	B Plank	B	121	147
Benthic	*Diploneis ovalis*	MB Aero	C	1	1
	Diploneis interrupta	MB Aero	C	2	14
	Ophepora pacifica	MB Epipsammon	B	7	
	Campylodiscus echeneis	MB Epipel	B		2
	Diploneis didyma	MB Epipel	B	8	
	Gyrosigma acuminata	MB Epipel	B	9	32
	Navicula avenacea	MB Epipel	B	1	1
	Navicula peregrina	MB Epipel	B	6	16
	Nitzschia navicularis	MB Epipel	B	124	71
	Nitzschia punctata v. panduriformis	MB Epipel	B	1	2
	Nitzschia sigma	MB Epipel	B	18	65
	Scoliopleura tumida	MB Epipel	B		1
	Achnanthes brevipes	MB Epiphyt	B	3	8
	Caloneis amphisphaena	B unknown	B	5	1
	Pinnularia viridis	BF Aero	C	1	
	Gyrosigma scaplroides	BF Epipel	C	1	2
	Surirella brebissonii	BF Epipel	C	9	2
	Cocconeis pediculus	BF Epiphyt	C	19	24
	Cymatopleura solea	F Epipel	D		7
	Diatoma vulgare	F Epiphyt	D	5	1
	Gomphonema parvulum	F Epiphyt	D	1	1
	Synedra unla	F Epiphyt	D	5	23
	Total			408	465

Key: M Plank = marine planktonic; M Tych = marine tychoplanktonic, B Plank = brackish planktonic; F Plank = fresh planktonic; M Epipel = marine epipelon, MB Aero = marine-brackish aerophilous; MB Epipel = marine-brackish epipelon; MB Epiphyt = marine-brackish epiphytic; B epipel = brackish epipelon, BF epipel = brackish-fresh epipelon; BF Epiphyt = brackish-fresh epiphytic; F Epipel = Fresh epipelon; F Epiphyt = fresh epiphytic.
Salinity preferences: A = polyhalobous; B = mesohalobous; C = oligohalobous halophilous; D = oligohalobous indifferent; E – euhalobous (n/a); F = unknown

Table 8: Relation between the relative abundance (%TDV) of the ecological groups and the sedimentary environments, modified from Vos & de Wolf (1993)

Ecological groups	Macro- and mesotidal environments							Microtidal and non-tidal environments		
	Subtidal area		Intertidal area		Supratidal area			Marine/brackish		non-marine (fresh)
	open marine tidal channels	estuarine tidal conditions	sand-flats	mud-flats	salt-marshes, around MHW	salt-marshes, above MHW	pools in the salt-marshes	tidal lagoons, small tidal inlet	lagoons, no tides	rivers, ditches, lakes
Marine plankton	10-80	10-60	1-25	10-70	10-70	10-70	10-50	10-60	0-10	0-5
Marine tychoplankton	20-90	15-60	1-25	10-70	10-70	10-70	10-50	10-60	0-10	0-5
Brackish plankton	1-10	20-70	1-10	1-30	1-30	1-30	1-15	1-15	0-10	0-5
Marine/brackish epipsammon	1-40	1-45	50-95	1-45	0-15	0-15	0-15	0-25	0-5	0-1
Marine/brackish epipelon	0-5	0-5	1-30	15-50	1-40	0-5	5-30	5-50	5-60	0-1
Marine/brackish aerophilous	0-1	0-1	0-1	0-1	10-40	15-95	10-40	0-1	0-1	0-1
Brackish/freshwater aerophilous	0-1	0-1	0-1	0-1	10-40	15-95	10-40	0-1	0-1	0-10
Marine/brackish epiphytes	0-1	0-1	0-5	0-5	0-5	0-5	10-60	10-75	10-90	0-5
Brackish/freshwater plankton	0-1	0-25	0-1	0-1	0-1	0-1	0-1	0-20	0-25	0-5
Brackish/freshwater tychoplankton	0-1	0-1	0-5	0-5	0-5	0-5	5-50	5-50	5-80	0-10
Brackish/freshwater epiphytes	0-1	0-1	0-5	0-5	0-5	0-5	1-50	1-50	1-80	0-10
Freshwater epiphytes	0-1	0-1	0-1	0-1	0-5	0-5	0-10	0-10	0-10	1-75
Freshwater epipelon	0-1	0-1	0-1	0-1	0-1	0-1	0-10	0-5	0-10	1-75
Freshwater plankton	0-1	0-1	0-1	0-1	0-1	0-1	0-5	0-15	0-20	10-95

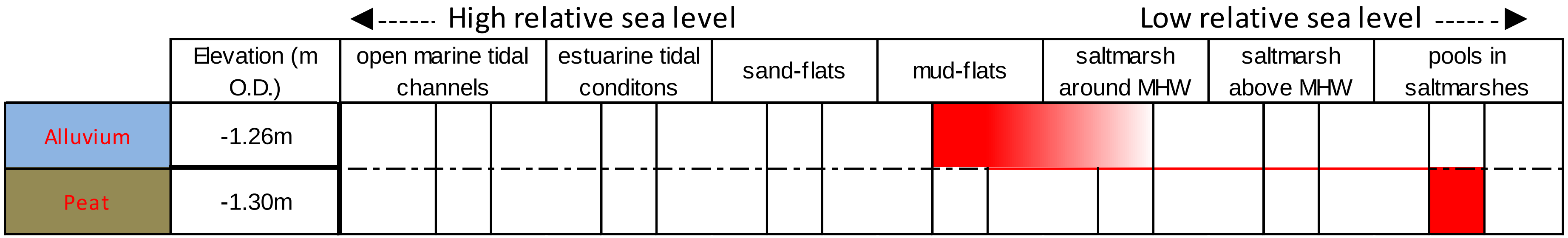

Figure 17: Summary of the costal conditions that prevailed at Goresbrook Park, based on Vos & deWolf (1993)

7. RESULTS & INTERPRETATION OF THE MACROFOSSIL ASSESSMENT

A total of five samples from QBH1, and six from QBH3, were extracted and processed for the recovery of macrofossil remains, including waterlogged plant macrofossils, wood, insects and Mollusca (Tables 9 and 10). The samples were focussed on the peat horizons in both boreholes, in QBH2 extending down to the surface of the timber recorded at the base of this borehole.

At the base of the peat in borehole QBH1 the sample from -2.12 to -2.17m OD is dominated by high quantities of waterlogged wood; low quantities were also recorded in the samples from -1.28 to -1.33, -1.70 to -1.80 and -1.90 to -2.00m OD, although wood was absent in the sample from -1.49 to -1.59m OD. The upper part of the sequence is dominated by waterlogged sedge remains, generally lacking the diagnostic epidermal tissue necessary for identification; particularly high quantities were recorded in the samples from -1.49 to -1.59 and -1.70 to -1.80m OD. Notably, charred wood was identified in high quantities in the sample from -1.90 to -2.00m OD. No bone, Mollusca or insects were recorded in this sequence.

A very similar sequence of macrofossil remains was identified in borehole QBH3, albeit with the equivalent horizons occurring at a lower elevation. In the basal samples from the peat in this borehole, waterlogged wood was present in high concentrations in the sample from -3.02 to -3.12m OD, and was recorded in low concentrations in the samples from -2.51 to -2.61 and -2.90 to -3.00m OD; the samples from -2.01 to -2.80m OD were dominated by waterlogged sedge remains, again lacking the diagnostic epidermal tissue necessary for identification. Waterlogged seeds were recorded in the uppermost (-2.01 to -2.11m OD) and at the base of the peat sequence (-3.02 to -3.12m OD), including *Rubus* cf. *fruticosus* (e.g. bramble) and *Alnus glutinosa* (alder) respectively. This assemblage is too small to attempt a full environmental interpretation, but these taxa are consistent with alder carr/sedge fen environments. A very similar assemblage of charred remains to that in borehole QBH1 (-1.90 and -2.00m OD) was identified in the sample from -2.90 to -3.00m OD; here, high concentrations of charcoal was recorded, including specimens greater than 4mm in diameter. No Mollusca, bone or insects were identified in the samples from QBH2.

Table 9: Results of the macrofossil assessment of samples from borehole QBH1, Goresbrook Park, London Borough of Barking and Dagenham.

				Charred					Waterlogged				Mollusca		Bone			
Depth (m OD)	Unit	Volume processed (ml)	Fraction	Charcoal (>4mm)	Charcoal (2-4mm)	Charcoal (<2mm)	Seeds	Chaff	Wood	Seeds	Sedge remains (e.g. stems/roots)	Identifications	Whole	Fragments	Large	Small	Fragments	Insects
-1.28 to -1.33	Peat	0.05	>300μm	-	-	1	-	-	1	-	1		-	-	-	-	-	-
-1.49 to -1.59		0.10	>300μm	-	-	-	-	-	-	-	5		-	-	-	-	-	-
-1.70 to -1.80		0.10	>300μm	-	-	-	-	-	1	-	4		-	-	-	-	-	-
-1.90 to -2.00		0.10	>300μm	2	3	2	-	-	1	-	-	*Alnus glutinosa* charcoal	-	-	-	-	-	-
-2.12 to -2.17		0.05	>300μm	-	-	-	-	-	4	-	-		-	-	-	-	-	-

Key: 0 = Estimated Minimum Number of Specimens (MNS) = 0; 1 = 1 to 25; 2 = 26 to 50; 3 = 51 to 75; 4 = 76 to 100; 5 = 101+

Table 10: Results of the macrofossil assessment of samples from borehole QBH2, Goresbrook Park, London Borough of Barking and Dagenham.

				Charred					Waterlogged				Mollusca		Bone			
Depth (m OD)	Unit	Volume processed (ml)	Fraction	Charcoal (>4mm)	Charcoal (2-4mm)	Charcoal (<2mm)	Seeds	Chaff	Wood	Seeds	Sedge remains (e.g. stems/roots)	Identifications	Whole	Fragments	Large	Small	Fragments	Insects
-2.01 to -2.11	Peat	0.05	>300μm	-	-	-	-	-	-	1	3	*Rubus* cf. *fruticosus (bramble) x 1*	-	-	-	-	-	-
-2.30 to -2.40		0.10	>300μm	-	-	-	-	-	-	-	1		-	-	-	-	-	-
-2.51 to -2.61		0.05	>300μm	-	-	-	-	-	1	-	3		-	-	-	-	-	-
-2.70 to -2.80		0.05	>300μm	-	-	-	-	-	-	-	5		-	-	-	-	-	-
-2.90 to -3.00		0.05	>300μm	2	2	3	-	-	1	-	-	*Alnus glutinosa* charcoal	-	-	-	-	-	-
-3.02 to -3.12		0.05	>300μm	-	-	-	-	-	4	1	-	*Alnus glutinosa* catkin (alder) x 1	-	-	-	-	-	-

Key: 0 = Estimated Minimum Number of Specimens (MNS) = 0; 1 = 1 to 25; 2 = 26 to 50; 3 = 51 to 75; 4 = 76 to 100; 5 = 101+

8. DISCUSSION & CONCLUSIONS

As outlined in section 2.3, the overarching aims of the geoarchaeological and palaeoenvironmental investigations at the Goresbrook Park site were as follows:

1. To clarify the nature of the sub-surface stratigraphy across the site;
2. To clarify the nature, depth, extent and date of any alluvium and peat deposits
3. To investigate whether the sequences contain any artefact or ecofact evidence for prehistoric or historic human activity
4. To investigate whether the sequences contain any evidence for natural and/or anthropogenic changes to the landscape (wetland and dryland)
5. To integrate the new geoarchaeological record with other recent work in the local area for publication in an academic journal

The following section addresses these aims by comparing the findings from Goresbrook Park with those resulting from previous similar investigations undertaken in the local area, and includes information derived from the archaeological evaluation (PCA, 2017). Thereby, placing the findings and their importance within a wider regional context.

8.1 Stratigraphic and hydrological history

The combined results of geoarchaeological investigations and deposit modelling indicate that the sediments present beneath the site are similar to those recorded elsewhere in the Lower Thames Valley. The Shepperton Gravel is overlain by a sequence of Holocene alluvial sediments, including peat, buried beneath modern Made Ground. The surface of the Shepperton Gravel generally rests between -3 and -4.5m OD across the majority of the site, rising to 2m OD on the northern most part of the site, representative of the Taplow Gravel terrace and floodplain edge. A similar sequence of deposits is recorded across the neighbouring Beam Park (Young & Batchelor, 2017b) and Former Ford Stamping Factory (Young *et al.*, 2017) sites to the east. The Shepperton Gravel (and occasional sand) is overlain by a tripartite sequence of Lower Alluvium, Peat and Upper Alluvium.

The Peat generally varies in thickness between 1 and 2m across the vast majority of the site, and is generally recorded at elevations between *ca*. -1 and -5m OD. In geoarchaeological borehole QBH1 it was recorded at between -1.28 and -2.22m OD, and below -1.82m OD in borehole QBH2 (the base of the Peat in this borehole was not reached, but it lies at *at least* -3.16m OD). As might be expected given the lower elevation of the peat in QBH2, the results of the radiocarbon dating indicate that peat accumulation began earlier here; some time prior to 5590-5320 cal BP (Early-Middle Neolithic), indicating that the wood recorded at the base of this sequence (whatever its origin) pre-dates this. In borehole QBH1 peat accumulation began at around 4430-4250 cal BP (Late Neolithic), although this is now considered an unreliable date, as charcoal above, is dated to 5290-4970 cal BP. It seems most likely that the twig wood used for the 4430-4250 represents root wood, thus providing a too young a date for this part of the sequence.

In QBH1 peat cessation occurred at around 2740-2490 cal BP (540 to 790 cal BC; Early-Middle Iron Age), whilst in QBH2 peat accumulation continued until at least 2000-1870 cal BP (80 cal AD to 45 cal BC; Roman). Nearby sites such as Hornchurch Marshes (Batchelor, 2009; Branch et al., 2012), Barking Riverside (Green et al., 2014), Bridge Road (Meddens & Beasley, 1990; Beasley, 1991) and the Former Ford Stamping Factory (Batchelor et al., 2018a) have all recorded Peat accumulation from the late Mesolithic to Bronze Age; the later date for the upper surface of the peat (Iron Age/Roman) at the present site therefore represents a later record of peat formation than has previously been recorded in this area, and the possibility of an eroded contact and integration of later material should not be ruled out.

The diatom flora from the top of the Peat contain more species affiliated with (1) lower salinity conditions (2) organic remains and (3) subaerial exposure. The overall indication is that whilst influential, marine inundation was likely relatively limited (restricted to high tides etc.) at this time. By contrast, the Upper Alluvium immediately above the Peat, records a reduction in the influence of freshwater flora and an increase in the abundance of marine planktonic and tychoplanktonic taxa, in addition to the overall dominance of marine-brackish epipelon species associated with muddy saltmarsh/mudflat substrates. Such a shift therefore reflects the increased sea-level influence.

Radiocarbon dating provides an age of *ca*. 2740-2490 cal BP (Early-Middle Iron Age) for the cessation of peat development, prior to a period of relative sea-level rise and the transition to estuarine conditions. During the late Holocene, sea-level rise was relatively limited. This was partly a consequence of the reduction in global eustatic sea-level rise (resulting from reduced ice melt etc.) and increases in terrestrial sedimentation along the coast, elevating the land above marine influence Devoy (1979) described the regional stratigraphic sequence, and how this reflects changes in sea level over time. Devoy's stratigraphic model was further developed by Sidell (2003), who proposed a distinct positive sea-level tendency (i.e. marine inundation) for the (inner) Thames Estuary, taking place downstream at *ca*. 3450 cal BP. In contrast, the upstream (inner) Thames Estuary experiences a positive sea-level tendency much later, *ca*. 2100 cal BP. The date of 2740-2490 cal BP at Goresbrook Park therefore sits in the middle of these dates. This can be compared to a transgressive boundary at Merrielands Crescent, a proximal site *ca*. 1km north of Goresbrook Park. At Merrielands, this transgression has been dated to *ca*. 3450-3250 cal BP, securely matching with Sidell's (2003) downstream (inner) Thames model. However this is some c. 800yrs earlier than that experienced at Goresbrook Park. Assuming all transgressive boundaries are conformable and no erosive epoxides have impacted on the integrity of these sequences, there is therefore significant spatial variability in the timing of the marine transgressive phase in proximal areas. As above, this may indicate that the dates for the cessation of Peat formation may be erroneous.

9.2 Vegetation history

The radiocarbon-dated palaeoenvironmental record from the Goresbrook Park site contains two relatively low-resolution record of vegetation history from the Neolithic to Roman period. Nevertheless, the results of the pollen and plant macrofossil assessment indicate that during the earlier Neolithic period, the floodplain environment was dominated by alder and willow swamp carr woodland and sedge fen. Despite the absence of prehistoric remains found during the archaeological evaluation and watching brief (PCA, 2017), alder charcoal and microcharcoal was recorded between 5500 and 5000 cal BP indicating at least one episode of burning during this period on the peat surface. Whether this is of natural or anthropogenic origin cannot be ascertained with certainty however. During the later Neolithic and Bronze Age, drier peat surface conditions are indicated by the development of a more mature fen carr woodland dominated by alder with yew; willow, sedges and aquatic taxa were reduced. Oak, hazel and birch may have occupied the peat surface during the late Mesolithic and Neolithic, but more likely formed mixed deciduous woodland on the dryland with lime. Sometime during or after the late Bronze Age (from *ca*. 3000 cal BP), woodland declined on both the peat surface and dryland to be replaced by herbaceous communities, most likely in response to a combination of clearance and an increased marine influence.

The vegetation history of the Goresbrook Park site during this period is broadly similar to that recorded at the Ford Stamping Plant (Batchelor et al., 2018a), Merrielands Crescent (Batchelor et al., 2018b), Beam Park Phases 1 & 2 (Young et al., 2018a, b), Barking Riverside (Green et al, 2014) and Hornchurch Marshes sites (Branch, 2012). There are however important variations at the current site which are not recorded elsewhere, including: (1) dominance of alder-willow swamp carr woodland and sedge fen during the early Neolithic; (2) the occurrence of charcoal and microcharcoal between 5500 and 5000 cal BP, and (3) the later decline in dryland and wetland woodland from the late Bronze Age onwards.

At the Ford Stamping Plant (Batchelor et al., 2018a), the sequence from other sites was different to those sequences recorded elsewhere as it recorded the following: (1) the localised growth of birch woodland during the early stages of peat formation around 6450-6310 cal BP (late Mesolithic); (2) a transition from alder fen carr towards alder carr and sedge fen communities on the floodplain reflective of wetter conditions around 6180-5920 cal BP (early Neolithic), (3) the expansion of yew woodland from shortly after 4830-4570 to 3400-3565 cal BP (middle Neolithic to middle Bronze Age) and (4) a decline in dryland woodland after 3400-3565 cal BP, not matched by a decline of floodplain woodland (middle Bronze Age).

At Merrielands Crescent (Batchelor et al., 2018b), the results of a higher resolution analysis indicated a peat surface occupied by alder and willow, forming carr woodland, with an understorey of sedges and grasses. Oak, elm and hazel are likely to have either accompanied alder on the floodplain or formed part of a mosaic of mixed deciduous woodland on the dryland. Lime formed an important component of the dryland woodland, particularly during the early stages of peat formation, but underwent an abrupt decline around 5300-5040 cal BP, most likely as a consequence of paludification. Similarly to Goresbrook Park, elm pollen values were low suggestive of a sequence post-dating the Neolithic decline. Towards the end of peat formation, woodland declined on both the floodplain and dryland. The increase in a wide variety of herbaceous taxa together with high levels of microcharcoal indicate the importance of Bronze Age activity in this process (Batchelor *et al.*, 2018b).

At Hornchurch Marshes, *ca*. 2km to the southeast (Batchelor, 2009; Branch *et al*., 2012) analysis of fine-grained mineral-rich sediments and peat revealed the presence of freshwater during the Late Mesolithic, at which point peat accumulation began, corresponding to a regional reduction in sea level. Significant changes in both the wetland and dryland environment were recorded here, including the establishment of alder carr woodland, the presence of yew, the decline of elm during the Neolithic, and decline of lime during the Neolithic & Bronze Age. A subsequent transition to estuarine conditions was dated to *ca*. 3900 cal BP, coinciding with a decline in woodland cover and the expansion of plant communities typically found within reed swamp.

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10. APPENDIX 1: OASIS FORM

Project details

Project name	Goresbrook Park
Short description of the project	Geoarchaeological and palaeoenvironmental of two sequences was carried out at the Goresbrook Park site. The Shepperton Gravel at the site is overlain by a tripartite sequence of Lower Alluvium, Peat and Upper Alluvium. The Peat generally ranges between 1 and 2m in thickness, and lies at elevations of between ca. -1 and -5m OD. Peat accumulation began towards the southeast of the site during the Early to Middle Neolithic, and during the Late Neolithic towards the northwest. Peat accumulation continued at the site until the Iron Age, and towards the southeast, the Roman period. The results of the analysis are indicative of a peat surface dominated by alder and willow, with an understorey of grasses, sedges and occasional aquatics, with mixed deciduous woodland on the dryland including oak and lime. Charcoal and microcharchoal were recorded in the sequence between ca. 5000 and 5500 cal BP, and there are indicators of late prehistoric woodland clearance towards the top of the sequence.
Project dates	Start: 15-07-2017 End: 14-12-2018
Previous/future work	No / No
Type of project	Environmental assessment
Significant Finds	PEAT Early Neolithic
Significant Finds	PEAT Iron Age
Significant Finds	PEAT Roman
Survey techniques	Landscape

Project location

Country	England
Site location	GREATER LONDON BARKING AND DAGENHAM DAGENHAM Goresbrook Park
Postcode	RM9 6RS
Site coordinates	TQ 48432 83233 51.527966794075 0.140026310543 51 31 40 N 000 08 24 E Point

Project creators

Name of Organisation	Quaternary Scientific (QUEST)
Project brief originator	CgMs Consulting
Project design originator	Dr C.R. Batchelor
Project director/manager	C.R. Batchelor
Project supervisor	D.S. Young
Type of sponsor/funding body	Developer

Project archives

Physical Archive Exists?	No
Digital Archive Exists?	No
Paper Archive recipient	LAARC
Paper Contents	"Environmental","Stratigraphic"
Paper Media available	"Report"

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	Goresbrook Park, London Borough of Dagenham. Desk-Based Geoarchaeological Deposit Model Report.
Author(s)/Editor(s)	Batchelor, C.R.
Other bibliographic details	Quaternary Scientific (QUEST) Unpublished Report July 2017; Project Number 195/16.
Date	2017
Issuer or publisher	Quaternary Scientific
Place of issue or publication	University of Reading

Project bibliography 2

Publication type	Grey literature (unpublished document/manuscript)
Title	Goresbrook Park, London Borough of Barking and Dagenham: Environmental Archaeological Assessment Report.
Author(s)/Editor(s)	Young, D.S.
Author(s)/Editor(s)	Batchelor, C.R.
Author(s)/Editor(s)	Hill, T.
Other bibliographic details	Quaternary Scientific (QUEST) Unpublished Report. Project Number 195/16
Date	2017
Issuer or publisher	Quaternary Scientific
Place of issue or publication	University of Reading

Project bibliography 3

Publication type	Grey literature (unpublished document/manuscript)
Title	GORESBROOK PARK, LONDON BOROUGH OF BARKING AND DAGENHAM: Geoarchaeological and Palaeoenvironmental Analysis Report

Author(s)/Editor(s)	Batchelor, C.R.
Author(s)/Editor(s)	Young, D.S.
Author(s)/Editor(s)	Hill, T.
Author(s)/Editor(s)	Marini. N.A.F
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Date	2018
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