SURREY HOUSE, 20 LAVINGTON STREET, LONDON BOROUGH OF SOUTHWARK, SE1 0NZ (SITE CODE: LVI11): ENVIRONMENTAL ARCHAEOLOGICAL ANALYSIS REPORT

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INTRODUCTION

This report summarises the findings arising out of the environmental archaeological analysis undertaken by Quaternary Scientific (University of Reading) in connection with the proposed development at Surrey House, 20 Lavington Street, London Borough of Southwark, SE1 0NZ (National Grid Reference: TQ 32087 80160; 2.8m OD; site code: LVI11; Figure 1). The site is on the valley floor of the River Thames in its tidal reach on the south side of the river and about 0.4km from the modern waterfront. Previous investigations in this part of Southwark (Batchelor *et al*, 2011a, 2011b, 2011c; Branch *et al*, 2002; Cowan *et al*, 2009; Dicks, 2010; Dunwoodie 2006; Sidell *et al*, 2000; Thompson *et al* 1998) have led to the recognition of a substantial palaeochannel (the Bankside Channel) aligned broadly NE to SW from Bankside towards Waterloo alongside the River Thames, with at least two tributary channels joining it from the south - the Borough Channel and Southwark Street Channel. The British Geological Survey (BGS) (1:50,000 Sheet 256 North London 1994) shows the site underlain by Alluvium overlying London Clay bedrock. Borehole records associated with the previous investigations in and around the Bankside Channel indicate the presence of Holocene sediments infilling the palaeochannel and overlying sands and gravels of Late Devensian Lateglacial age (The Shepperton Gravel). The Shepperton Gravel rises from beneath the floor of the palaeochannel both northward and southward to form gravel bars that define the margins of the channel.

To the west of the present site, the form of the Bankside Channel can be made out between Union Street in the south and Southwark Street in the north. In the presumed axis of the channel, at the South Point site on the Blackfriars Road, the surface of the Shepperton Gravel is at -3.49m OD (Branch *et al* 2002) and at nearby sites in Joan Street and Union Street (Sidell *et al* 2000) the surface is between -2.00m and -3.00m OD. Towards the northern edge of the Bankside Channel at Bear Lane and Bear House (Tan, 2008; Batchelor *et al*., 2011a), the gravel surface rises northward from -2.70m to -0.60m OD and further north again in Blackfriars Road (Batchelor *et al* 2008) the gravel rises to 2.67m OD. The form of the channel is also apparent to the east of the present site, where the surface of the Shepperton Gravel is at -3.64m OD at Anchor Terrace (Thompson *et al* 1998), probably close to the axis of the palaeochannel, but rises northward to 0.66m OD in Skinmarket Place

(Thompson *et al* 1998) and southward to 0.8m OD at 97-101 Union Street (Capon 2006). Close to the present site the gravel surface was recorded at -1.6m OD south and east of the site at 65 Southwark Street (Batchelor *et al* 2011b) and between -1.22m and -2.95m OD to the north at St Christopher's House (Howell 2003).

Infilling the Bankside Channel is a sequence of Holocene sediments which includes at most sites a bed of peat, either resting directly on the Shepperton Gravel or separated from it by units of organic sand or silt. Overlying the peat are alluvial silts which in general are less richly organic than the underlying sediments. These transitions from peat to alluvium represent important palaeoenvironmental transitions, with peat representing periods of semi-terrestrial conditions and frequently in the Lower Thames Valley, the growth of fen carr woodland, whilst the alluvium represents periods of inundation.

At Surrey House, the combined results of recent geoarchaeological fieldwork (Green & Batchelor 2011) an archaeological watching brief (Turner, 2010), and an environmental archaeological assessment (Batchelor *et al*., 2012a) indicate the Shepperton Gravel surface dips from south (-2.95m OD; Borehole 3) to north (-4.55m OD; Borehole 4; Figures 2 & 3) across the site. Significantly, the depths towards the northern edge of the site are lower than recorded elsewhere in the Bankside Channel and substantially below the levels recorded in two sites immediately to the north and south of the Surrey House site, respectively at -2.95m OD at St Christopher House (Howell 2003) and at -1.60m OD at 65 Southwark Street to the east (Batchelor *et al*., 2011b; Figure 4). The low level of the base of the Holocene sediment sequence at the Surrey House site may indicate the presence of a continuous deep narrow channel occupying the axis of the Bankside depression or, and perhaps more likely, a localised scour hollow in the surface of the Shepperton Gravel.

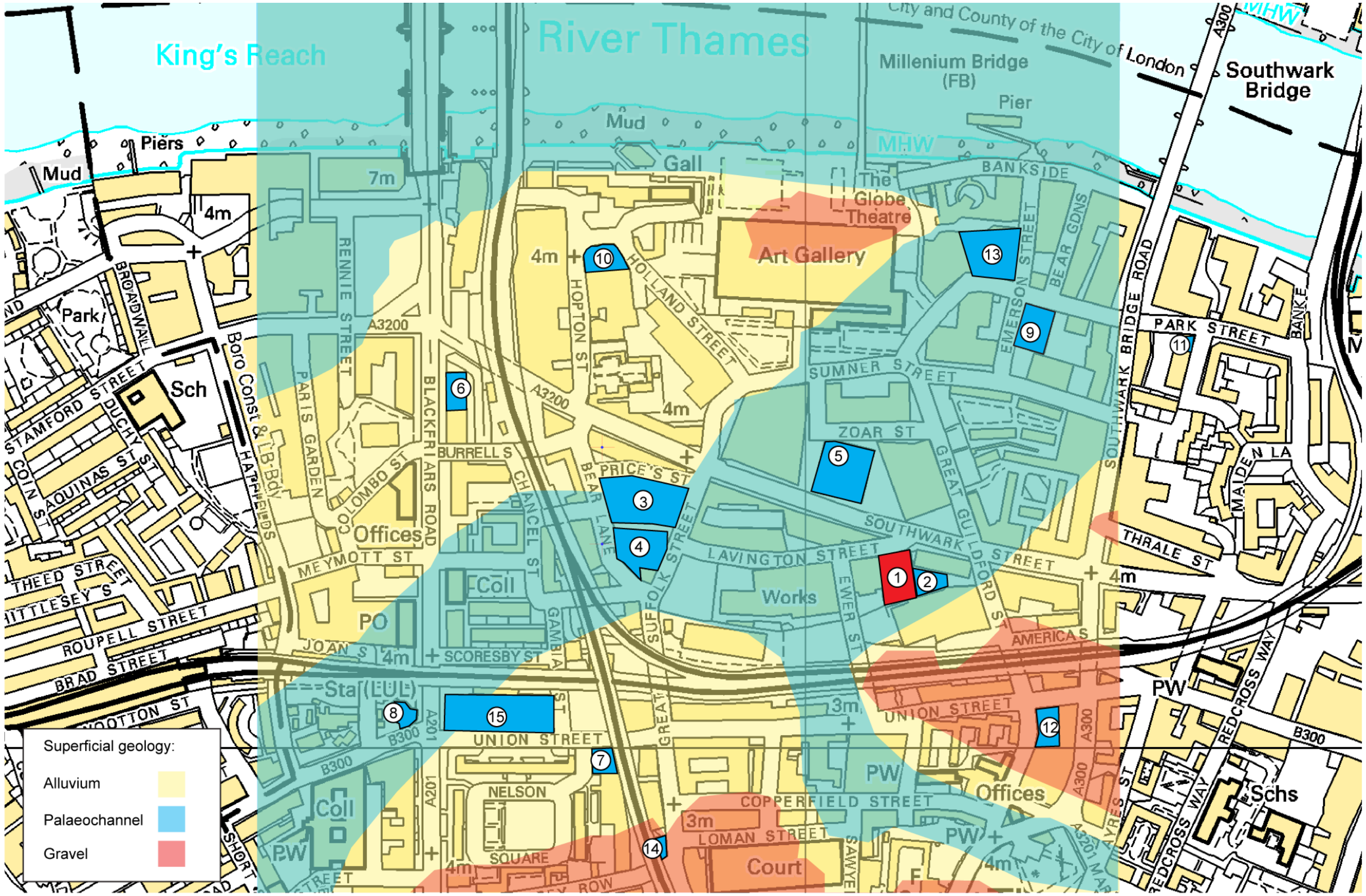
The same investigations have revealed 3-4m of peat and alluvium overlying the Shepperton Gravel, capped by Made Ground. The peat sequence dates from 10,130-9690 cal BP (Early Mesolithic) to 4840-4640 cal BP (Late Neolithic). Significantly, geoarchaeological investigations from the neighbouring 65 Southwark Street (Figure 1), recorded a similar, but shorter and shallower alluvial sequence (Batchelor *et al*., 2011b) in which the peat was younger, dating from 5610-5480 to 4290-4090 cal BP (Early to Late Neolithic; Batchelor *et al*., 2011b). Elsewhere at Bear House (Batchelor *et al*., 2011a) and Bear Lane (Tan, 2008), radiocarbon dating indicates that towards the northern edge of the Bankside Channel the peat deposits accumulated from at least 4820-4570 to 3140-2870 cal BP (Late Neolithic to Late Bronze Age). At sites towards the middle of the projected course of the Bankside

Channel such as St Christopher House (*ca*. 100m northeast of the site; Maloney, 2003, 2004) radiocarbon dating indicate that the channel dated from at least 10,650-10,250 cal BP and included both peat and alluvial deposits (Maloney, 2004), whilst historic records indicate it had infilled by the Late 17th Century (Turner, 2009).

The results of the Surrey House pollen and plant macrofossil assessment indicate a mainly moderate to high concentration of remains, in a good state of preservation. Within the lower half of the borehole (below *ca*. -3.90m OD), these records indicate a local environment dominated by herbaceous and aquatic vegetation including sedges, grasses, bur-reed and bulrush, whilst pine and birch woodland probably grew nearby on the dryland. Above *ca*. -3.90m OD, the same records indicate a transition towards the development of alder-willow dominated carr woodland on the wetland, with mixed deciduous woodland growing on the dryland. Throughout the period of peat formation the results of organic matter determinations indicate that the site was subject to periodic or even frequent flooding. At the transition into the overlying alluvium the results of the pollen assessment indicate a gradual transition towards more open and wetter conditions, as would be expected during the inundation of the peat. No diatom, Mollusca, Ostracoda or Foraminifera remains were recorded within the lower parts of the sequence, but some were recorded (sometimes in abundance) within the overlying alluvium. These remains have the potential to provide information on the palaeohydrology of the site (i.e. marine, brackish or freshwater conditions).

The potential for tracking prehistoric cultural activity is also demonstrated from sites along the Bankside Channel. At St Christopher's House for example, three timber structures dated to 3450-3240 cal BP (2 structures) and 2750-2350 cal BP (1 structure) were recorded within the channel's sedimentary sequence (Maloney, 2004). Whilst at two sites located on a gravel eyot further to the north of the site (44-47 Hopton Street, Maloney, 2001; 245 Blackfriars Road, Thompson *et al*., 2008), various artefacts reflective of occupation dating from the Neolithic cultural period onwards have been recorded. No anthropogenic indicators of prehistoric activity were recorded during the assessment of the Surrey House sequence, perhaps because the sequence predates that of the archaeological evidence recorded nearby.

Following the results of the Surrey House environmental archaeological assessment, a detailed analysis was recommended of the borehole BH4 sequence to provide a quantified reconstruction of the environmental history of the site and its surroundings during the Mesolithic and Neolithic cultural periods. In order to achieve this aim, the following objectives were proposed: (1) further radiocarbon determinations, to enhance the range-finder dates (in particular that age of the base of the peat ((10,130-9690 cal BP)); (2) analysis of the archaeobotanical remains (pollen, waterlogged wood and seeds) to provide a detailed reconstruction of the vegetation history, and (3) analysis of the Mollusca from the top of the sequence to provide a reconstruction of the hydrological history (e.g. marine, brackish or freshwater).



(1) Surrey House (LVI11)
(2) 65 Southwark Street (SOU11; Batchelor *et al.*, 2011)
(3) Bear House (BJH10; Batchelor *et al.*, 2011)
(4) Bear Lane (BLZ07; Tan *et al.* 2008)
(5) St. Christopher's House (SCH03; London Archaeologist, 2004)
(6) 231-241 Blackfriars Rd (BFX08; Batchelor *et al.*, 2008)
(7) Jubillee Line, Union St (UNL08; Sidell *et al.*, 2000)
(8) Joan St (JOA91; Sidell *et al.*, 2000)
(9) 135 Park St (PKP09; Batchelor and Young, 2009)
(10) 44-47 Hopton St (HNT94; London Archaeologist, 2001)
(11) Anchor Terrace (Thompson *et al.*, 1998)
(12) 97-101 & 103 Union Street (Capon, 2006)
(13) Skinmarket Place (Thompson *et al.*, 1998)
(14) Great Suffolk Street (GUF10; Batchelor *et al.*, 2011)
(15) South Point (BKA02; Branch *et al.*, 2002)

Figure 1: Location of Surrey House and nearby sites. The projected course of the Bankside Channel, as indicated by Dunwoodie *et al*. (2006) and adapted after Young *et al*. (2010), is also shown.

Figure 2: Location of the archaeological and geoarchaeological boreholes at Surrey House, London Borough of Southwark (site code: LVI11)

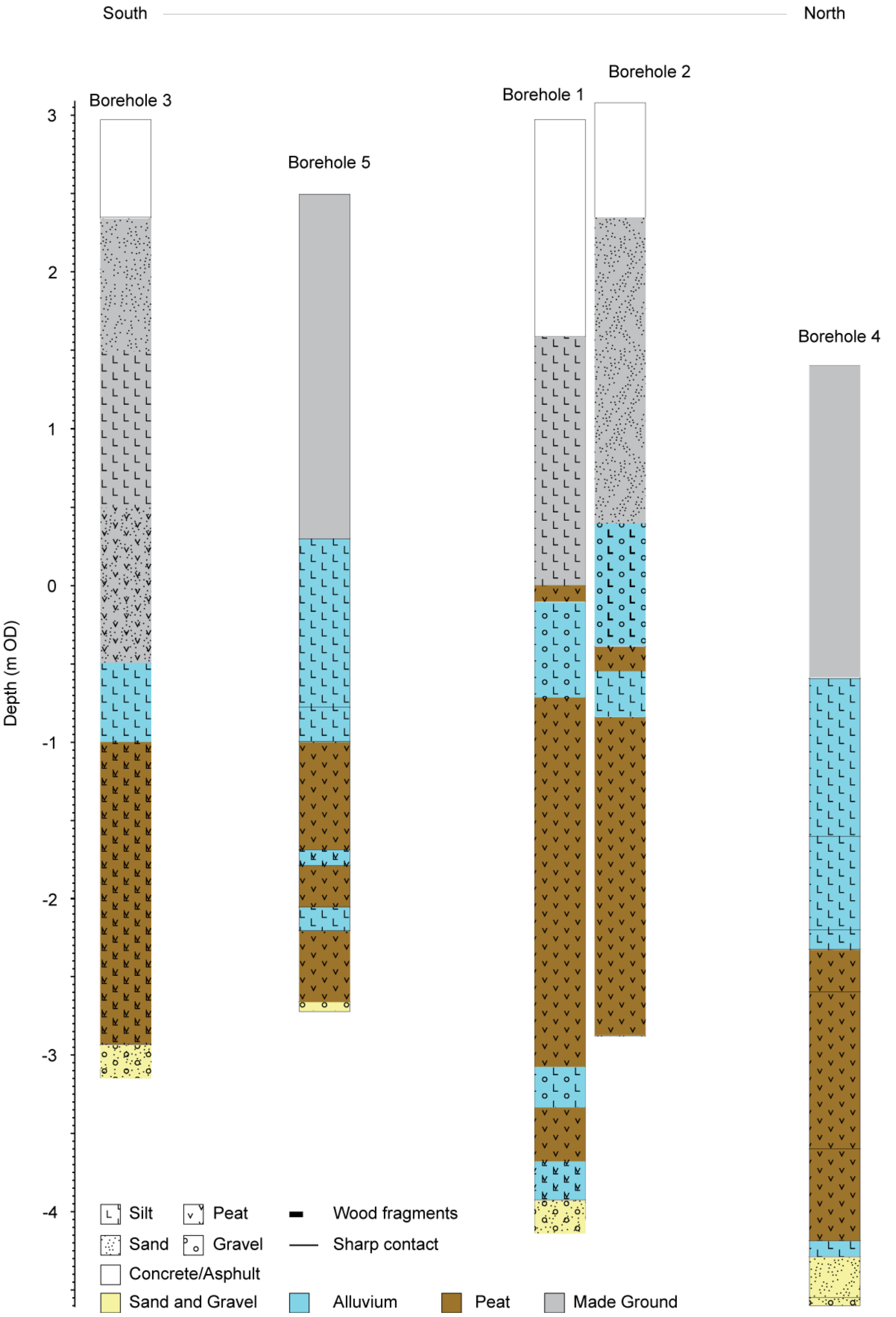


Figure 3: North-south transect of boreholes across Surrey House, London Borough of Southwark (site code: LVI11)

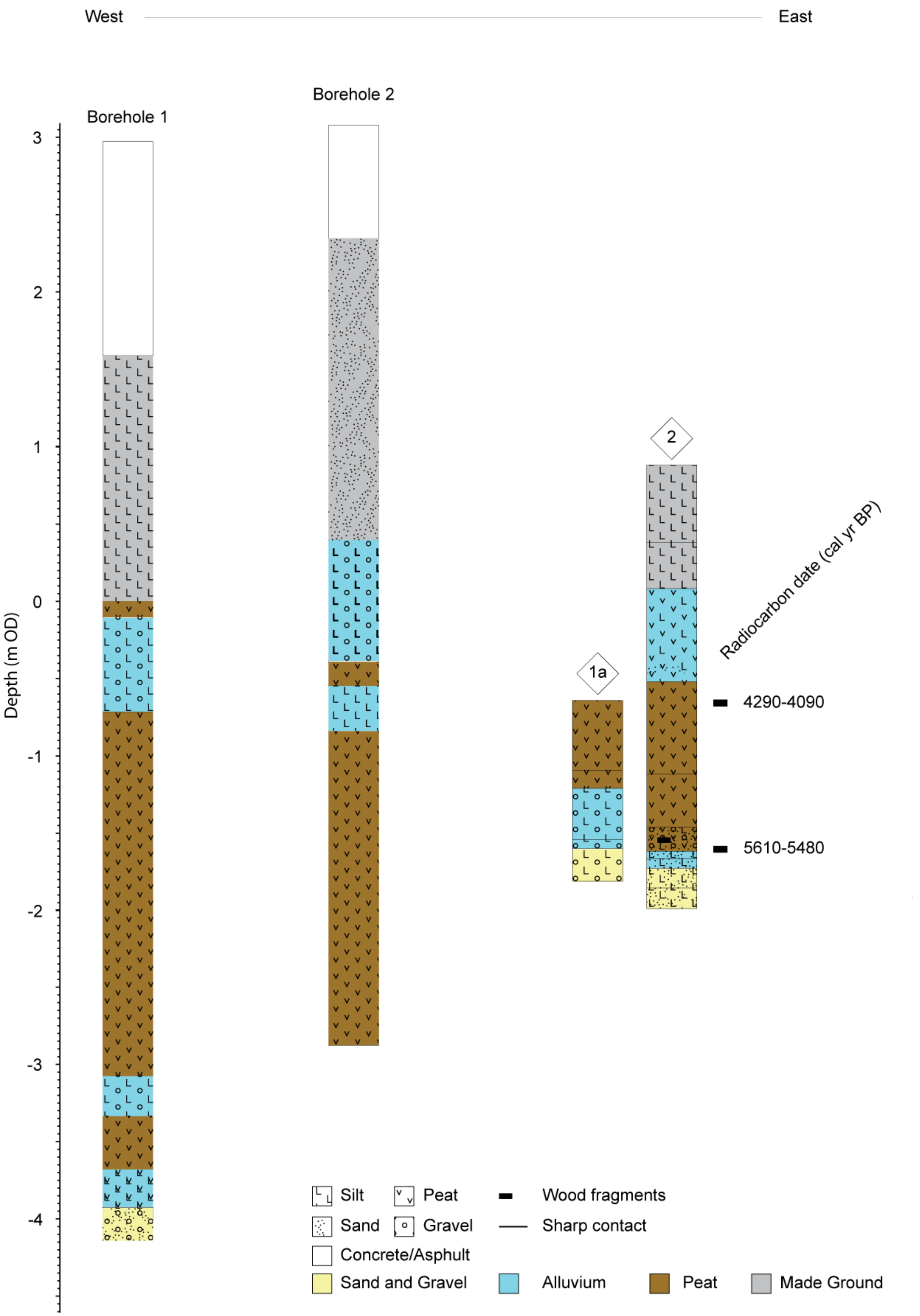


Figure 4: West-East transect of boreholes across Surrey House and 65 Southwark Street (site codes: LVI11 and SOU11)

METHODS

Field investigations

Two boreholes (Boreholes 4 and 5) were put down at the site in June 2011 (Figure 2). The boreholes were recovered using an Eijkelkamp window sampler and gouge set driven by an Atlas Copco TT 2-stroke percussion engine. Each borehole was put down until coarse grained unconsolidated sediments had been recorded. The spatial attributes of each proposed borehole location were recorded by Bowmer and Kirkland Ltd (Table 1). The spatial attributes for the original archaeological watching brief boreholes are also shown (boreholes 1 to 3), and the spatial attributes of recent geoarchaeological boreholes from 65 Surrey House are presented in Table 1 only. During the course of the Surrey House watching brief, surface heights relative to ordnance datum were not recorded. These have instead been interpolated here from a pre-demolition survey.

Table 1: Borehole attributes, Surrey House, London Borough of Southwark (site code: LVI11)

Borehole number	Easting	Northing	Elevation (m OD)
Surrey House geoarchaeological boreholes			
Borehole 4	532082.057	180176.900	1.40
Borehole 5	532089.102	180151.952	2.80
Surrey House archaeological watching brief boreholes			
Borehole 1	532072	180162	*3.00*
Borehole 2	532056	180199	*3.08*
Borehole 3	532087	180140	*3.00*
65 Southwark Street geoarchaeological boreholes			
Borehole <1a>	532108.773	180148.300	2.86
Borehole <2>	532118.593	180158.858	2.88

Lithostratigraphic descriptions

Borehole core samples were retained and described in the laboratory 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, and Figures 3 and 4. The archaeological watching brief descriptions are provided in Tables 4 to 6 and displayed in Figures 3 to 5, adjusted to the interpolated ordnance datum height.

Organic matter determinations

Forty-three sub-samples from borehole BH4 were taken for determination of the organic matter content (Table 7; Figure 5*)*. These records are 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 (see Bengtsson and Enell, 1986).

Radiocarbon dating

Four sub-samples of peat were extracted from select horizons within the peat of borehole BH4. Each sample was processed by wet sieving and the macrofossil remains were picked out and identified. From the near base of the peat, unidentifiable plant remains were selected for dating, from the centre *Alnus* catkins and waterlogged wood were selected, and from the near top, an identified twig remain. The samples were submitted for AMS radiocarbon dating to Beta Analytic INC, Radiocarbon Dating Laboratory, Florida, USA. The results have been calibrated using OxCal v4.0.1 Bronk Ramsey (1995, 2001 and 2007) and IntCal04 atmospheric curve (Reimer *et al*., 2004). The results are displayed in Table 8 and Figure 5.

Age-depth modelling

Age-depth models were created using OxCal version 4.0.1 Bronk Ramsey (1995, 2001), and follow the approach of Blockley *et al.* (2007). Radiocarbon dates were initially inserted into a '*Sequence*' which makes no prior assumption about sedimentation rate, only that age increases with depth. This allows the exclusion of any dates that disagreed with this assumption. The age-depth model was then constructed using a '*P-Sequence*', which allowed the insertion of stratigraphic information. The *P-Sequence* allows a degree of control over the assumed rate of sedimentation during model construction by varying the value of '*k*'. '*k*' is defined by the size of deposition events (Bronk Ramsey, 2007). A low *k* value indicates a variable sedimentation rate, and higher *k* values reflect more stable deposition, suitable for the accumulation of fine grained sediments and peat (Marshall, pers comm.). Appropriate *k* values for peat range between 100 and 300 events/metre (Blockley, pers comm.). However, a *k* factor of 50 was selected in this case as it accounts for variations in the rate of peat accumulation caused, for example by flooding events; furthermore, the model rejected k factor values higher than this. Where changes in lithostratigraphy or other evidence indicated a change in the rate of sedimentation (such as a change from clay deposition to peat accumulation), '*boundaries*' were inserted into the age depth model (discussed further in Bronk Ramsey, 2007; Blockley *et al.*, 2007). The output of the constructed age-depth model provides an Overall Agreement Indice (OAI). If these indices fall below 60%, the model is statistically unreliable and must be rejected (Bronk Ramsey, 2007). The deposit model was used to calculate the dates of each Local Pollen Assemblage Zone (see below), the results of which are displayed in Table 9.

Pollen-stratigraphic analysis

Twenty-eight sub-samples from borehole BH4 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 scanning the prepared slides, and recording the taxa present until a count of 300 total land pollen (TLP - trees, shrubs and herbs; excludes aquatics and spore taxa) was achieved (Figure 6). On five slides, a full count could not be achieved; instead the main taxa recorded are displayed in Table 10). The addition and counting of *Lycopodium* spores has also permitted the calculation of pollen concentration (grains/cm^3).

Macrofossil assessment

A total of eighteen small bulk samples from borehole BH4 were extracted for the recovery of macrofossil remains including waterlogged plant macrofossils, waterlogged wood, insects and Mollusca. The extraction process involved the following procedures: (1) removing a sample up to 10cm in thickness; (2) measuring the sample volume by water displacement, and (3) 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 (Table 11).

Waterlogged plant macrofossil analysis (seeds and wood)

Each sample was scanned under a stereozoom microscope at x7-45 magnifications, and the plant macrofossils were picked out. All extracted waterlogged seeds, and 10 randomly selected fragments of wood were identified from each sample. Identifications of the archaeobotanical remains (waterlogged seeds and wood), have been made using modern comparative material and reference atlases (Cappers *et al.* 2006, Hather 2000, Schweingruber 1990, Schoch *et al*. 2004). Nomenclature used follows Stace (2005). The quantities of waterlogged seeds and wood were recorded for each sample, with identifications of the main taxa (Table 12).

Mollusca analysis

One sample was identified during the macrofossil assessment as having a moderate concentration of remains. The Mollusca were identified using the University of Reading reference collection and the following sources of keys and photographs: Ellis (1969), Davies (2008), Kerney (1999) and Kerney and Cameron (1979).

RESULTS AND INTERPRETATION OF THE LITHOSTRATIGRAPHIC DESCRIPTIONS AND ORGANIC MATTER DETERMINATIONS

The sediment sequences from the two geoarchaeological boreholes (Boreholes 4 and 5; Tables 2 and 3) and those recorded during the course of the archaeological watching brief (Boreholes 1, 2 and 3; Tables 4 to 6) are broadly similar with sequences recorded elsewhere in the Bankside Channel. The results of the organic matter determinations carried out on borehole BH4 are displayed in Table 7 and Figure 5.

In Borehole BH4 (Table 2), gravel (Unit 1) is recorded at -4.55m OD beneath a thin (0.37m) sequence of fine-grained organic sediments (Units 2 and 3), and thick (1.85m) of peat between -4.18 and -2.13m OD (Unit 4). The peat is overlain by a sequence of 1.73m of moderately organic silt (Unit 5) to -0.60m OD. In Borehole BH5 (Table 3), a total thickness of 1.65m of peat is separated into two sub-units (Units 2 and 4) by a thin (0.14m) bed of organic silt (Unit 3). The lower peat sub-unit rests on inorganic gravelly sand at -2.64m OD (Unit 1) and the upper peat sub-unit is overlain by 1.29m of silt with common detrital plant remains from -0.99m OD (Unit 5). In both boreholes the upper silty beds are probably truncated by historic ground modification. The peat units recorded in archaeological Boreholes 1, 2 and 3 (Tables 4 to 6) were similarly thick (around 2m) either directly lying on the gravel surface, or separated by a thin layer of alluvium. The gravel surface was recorded at -3.95m OD in Borehole 1 and -2.95m OD in Borehole 3. Frequent wood fragments were recognised within the new geoarchaeological boreholes, a find analogous to the vast majority of peat sequences in the Lower Thames Valley, and also highlighted during the archaeological watching brief. These remains suggest that the peat surface was colonised by fen carr woodland.

The results of the organic matter content determinations (Table 7; Figure 5) indicate that the organic matter content is low (throughout units 1 (gravel; <2%), 2 (sand; <3%), 3 (lower alluvium; <10%) and 5 (upper alluvium; <25%) as would be expected. Through the peat, organic matter content varies between 20% and 70% suggesting large variability in the amount of flooding occurring during its accumulation.

RESULTS AND INTERPRETATIONS OF THE RADIOCARBON DATING & AGE-DEPTH MODELLING

The results of the radiocarbon dating and age-depth modelling are displayed in Tables 8 & 9 and Figure 5. At the base of the peat sequence, three contiguous 10cm samples were processed by wet sieving in an attempt to obtain terrestrial macrofossil remains suitable for radiocarbon dating. Unfortunately these samples derived no waterlogged wood, and all the seed remains were aquatic (and thus potentially derived). It was therefore decided to submit a sample of bulk peat (-4.13 to -4.18m OD) to the radiocarbon laboratory and radiocarbon date the extractable plant remains. Whilst not an ideal situation, this at least allowed a determination to be gained from the base of the sequence which could be tested at a later stage of work (if necessary). The sample was radiocarbon dated to 10,130-9690 cal BP.

The macrofossil remains were processed from two samples of peat at -3.79 to -3.89 and -3.08 to -3.18m OD. *Alnus* catkins and waterlogged wood respectively were extracted from these samples and submitted for radiocarbon dating. The sample at -3.79 to -3.89m OD provided a date of 7410-7250 cal BP, whilst sample -3.08 to -3.18m OD provided a date of 6210-6000 cal BP. Towards the top of the peat between -2.50 and -2.55m OD, an unidentifiable twig was extracted and radiocarbon dated to 4840-4640 cal BP.

The δ13C (‰) values for both samples are consistent with that expected for peat sediment, and there is no evidence for mineral or biogenic carbonate contamination. The results indicate that the Peat in borehole BH4 dates from the Early Mesolithic to Late Neolithic, and provides an interesting comparison to the peat recorded at nearby 65 Southwark Street, which it mostly predates (Batchelor *et al*., 2011b). The results of the age-depth modelling indicate a slower sedimentation rate between the two lowermost radiocarbon dates. Above this, the sedimentation rate appears to have remained relatively constant until the transition to alluvial sedimentation.

Table 2: Lithostratigraphic description of Borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m BGL)	Depth (m OD)	Unit	Description
0 to 2.00	1.40 to -0.60	-	Made Ground
2.00 to 3.00	-0.60 to -1.60	5	5Y3/1 very dark grey; very well sorted silt; horizontally bedded alternations of plant-rich and mineral-rich sediment; common to very common detrital plant remains; wood debris including round wood to 10mm Ø; moderate acid reaction.
3.00 to 3.61	-1.60 to -2.21	5	2.5Y5/1 grey to 2.5Y3/1 very dark grey; well sorted organic silt; horizontally bedded alternations of plant-rich and mineral-rich sediment; common to very common detrital plant remains; vivianite; moderate acid reaction; well-marked transition to:
3.61 to 3.73	-2.21 to -2.33	5	2.5Y3/1 very dark grey to black; well sorted organic silt with irregular peaty inclusions; massive; very common detrital plant remains; common broken mollusc shell with concentration at base of ubit (-2.29 to -2.33m OD); moderate acid reaction; gradual transition to:
3.73 to 4.00	-2.33 to -2.60	4	Black; peat, slight visible mineral content decreasing downward; scattered broken mollusc shell.
4.00 to 5.00	-2.60 to -3.60	4	Black; woody peat including roundwood to 10mm Ø, with large piece of wood at 3.89-4.02m OD, no acid reaction.
5.00 to 5.58	-3.60 to -4.18	4	Black; peat with slight visible mineral content below -4.80m OD; massive; no acid reaction; sharp contact with:
5.58 to 5.69	-4.18 to -4.29	3	2.5Y4/1 dark grey and 2.5Y5/4 olive brown; very well sorted marly silt; weakly developed horizontal bedding; strong acid reaction; sharp contact with:
5.69 to 5.95	-4.29 to -4.55	2	Black, dark grey and olive brown, moderately sorted very slightly silty sand with scattered flint granules; horizontally bedded; scattered detrital plant rermains; no acid reaction; sharp contact with:
5.95 to 6.00	-4.55 to -4.60	1	Dark brown, moderately well sorted clast-supported gravel of well-rounded and sub-angular flint (with very sparse sand matrix); no acid reaction.

Table 3: Lithostratigraphic description of Borehole BH5, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m BGL)	Depth (m OD)	Unit	Description
0 to 2.50	2.80 to 0.30		Made Ground
2.50 to 3.50	0.30 to -0.70	5	10YR4/1 dark grey with black specks; very well sorted silt with inclusion of 10YR3/2 very dark greyish brown peaty silt at -0.03 to -0.11m OD; massive; common Fe-stained root channels becoming less common downward; scattered root remains; common detrital plant remains (black specks); very scattered broken

			mollusc shell.
3.50 to 3.79	-0.70 to -0.99	5	2.5Y3/1 very dark grey; very well sorted organic silt; massive becoming laminated towards base of unit (below -0.90m OD); very common detrital plant remains increasing downward especially below -0.90m OD; no acid reaction; sharp contact with:
3.79 to 4.48	-0.99 to -1.68	4	Black; peat with scattered twigs.
4.48 to 4.50	-1.68 to -1.70	4a	10YR3/1 very dark grey; very well sorted silt enclosing piece of wood.
4.50 to 4.84	-1.70 to -2.04	4	Black; peat with scattered twigs; sharp contact with:
4.84 to 4.98	-2.04 to -2.18	3	10YR3/1 very dark grey; very well sorted silt; massive, common detrital plant remains; common detrital wood fragments; sharp contact with:
4.98 to 5.44	-2.18 to -2.64	2	Black; woody peat; sharp contact with:
5.44 to 5.50	-2.64 to -2.70	1	Dark grey passing down to olive brown; poorly sorted gravelly sand with clasts of sub-angular flint (up to 30mm).

Table 4: Archaeological watching brief description of Borehole 1, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m BGL)	**Depth (m OD)**	**Description**	**Archaeological interpretation**
0 to 1.70	3.00 to -1.30	Concrete and asphalt	
1.70 to 3.00	-1.30 to 0	Grey gravelly clay with ash and brick fragments	Made Ground
3.00 to 3.10	0 to -0.10	Fibrous peat	Peat
3.10 to 3.72	-0.10 to -0.72	Silty clay with black organic rootlets	Alluvium
3.72 to 3.75	-0.72 to -0.75	Burnt gravels, <5mm sub-angular with black charcoal/silt matrix	Possible Fire
3.75 to 6.09	-0.75 to -3.09	Silty clay fibrous peat with frequent twigs and wood fragments	Peat
6.09 to 6.35	-3.09 to -3.35	Silty clay, light brownish grey	Alluvium
6.35 to 6.70	-3.35 to -3.70	Fibrous peat	Peat
6.70 to 6.95	-3.70 to -3.95	Silty clay, light brownish grey, silty clay	Alluvium
6.95 to 9.00	-3.95 to -6.00	Medium density grey gravel	Sand and Gravel

Table 5: Archaeological watching brief description of Borehole 2, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m BGL)	**Depth (m OD)**	**Description**	**Archaeological interpretation**
0 to 0.74	3.08 to 2.34	Concrete and asphalt	
0.74 to 2.70	2.34 to 0.38	Dark brown silty sand with brick, concrete and occasional shell fragments	Made Ground
2.70 to 3.50	0.38 to -0.42	Firm, greyish brown clay with occasional fine to medium gravel	Alluvium
3.50 to 3.65	-0.42 to -0.57	Fibrous peat with frequent twigs/brushwood and wood fragments	Peat
3.65 to 3.95	-0.57 to -0.87	Silty clay, light grey	Alluvium
3.95 to 6.00	-0.87 to -2.92	Dark brown fibrous peat with occasional twigs	Peat

Table 6: Archaeological watching brief description of Borehole 3, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m BGL)	Depth (m OD)	Description	Archaeological interpretation
0 to 0.60	3.00 to 2.40	Concrete and asphalt	
0.60 to 1.50	2.40 to 1.50	Brown clayey sand with gravel, concrete and brick fragments	Made Ground
1.50 to 2.50	1.50 to 0.50	Firm, dark grey clay	Alluvium
2.50 to 3.50	0.50 to -0.50	Dark brown silty sand, slightly peaty with modern brick fragments	Made Ground
3.50 to 4.00	-0.50 to -1.00	Silty clay, light grey	Alluvium
4.00 to 4.70	-1.00 to -1.70	Fibrous peat with occasional twigs	Peat
4.70 to 4.90	-1.70 to -1.90	Silty clay fibrous peat, greyish brown with occasional twigs	Peat
4.90 to 5.70	-1.90 to -2.70	Silty clay, mid grey and slightly peaty	Peat
5.70 to 5.95	-2.70 to -2.95	Fibrous peat with occasional twigs	Peat
5.95+	-2.95+	Medium density grey gravel	Sand and Gravel

Table 7: Results of the organic matter determinations from borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m OD)	Organic matter content (%)
-1.64	11.34
-1.72	21.60
-1.80	12.89
-1.88	13.91
-1.96	15.46
-2.04	25.83
-2.12	12.26
-2.20	19.02
-2.28	15.30
-2.36	24.29
-2.44	37.32
-2.52	38.97
-2.60	41.60
-2.68	36.17
-2.76	30.88
-2.84	33.74
-2.92	40.97
-3.00	41.87
-3.04	48.77
-3.08	63.13
-3.12	77.34
-3.16	64.35

Depth (m OD)	Organic matter content (%)
-3.20	68.41
-3.24	57.60
-3.28	48.93
-3.32	39.26
-3.40	53.06
-3.48	44.08
-3.56	23.76
-3.64	25.58
-3.72	36.31
-3.80	58.79
-3.88	68.29
-3.96	58.76
-4.04	69.37
-4.12	49.26
-4.16	20.29
-4.20	7.02
-4.28	3.05
-4.36	0.77
-4.44	0.54
-4.52	0.79
-4.59	1.96

Table 8: Results of the radiocarbon dating of borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

Laboratory code / Method	Borehole number	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-316286	BH4	Unidentified twig extracted from bulk peat	-2.50 to -2.55	4200 ± 30	2890-2700 cal BC (4840-4640 cal BP)	-26.8
Beta-322060	BH4	*Alnus glutinosa* waterlogged wood	-3.08 to -3.18	5370 ± 30	4260-4050 cal BC (6210-6000 cal BP	-27.2
Beta-321894	BH4	*Alnus glutinosa* catkins	-3.79 to -3.89	6360 ± 30	5460-5300ca BC (7410-7250 cal BP)	-28.3
Beta-316287	BH4	Unidentified plant remains extracted from bulk peat	-4.13 to -4.18	8810 ± 40	8180-7740 cal BC (10,130-9690 cal BP)	-28.6

Table 9: Results of the age-depth modelling of borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

Boundary/^{14}C Date/LPAZ	**Unmodelled (BP)**		**Modelled (BP)**		**Individual Agreement Index**
	95.4% (2 sigma)		**95.4% (2 sigma)**		
	from	**to**	***from***	***to***	
Boundary: Base of Peat			*10060*	*9630*	
R_Date: Beta-316827	10150	9680	*9920*	*9600*	92.2
Base of LPAZ LVI-1			*9840*	*9070*	
Base of LPAZ LVI-2			*8490*	*7490*	
R_Date: Beta-321894	7420	7180	*7420*	*7260*	60.5
Base of LPAZ LVI-3			*7020*	*6580*	
R_Date: Beta-322060	6280	6020	*6270*	*6000*	83.3
Base of LPAZ LVI-4			*6200*	*5820*	
R_Date: Beta-316286	4840	4630	*4840*	*4620*	95.2
Boundary: Top of Peat			*4540*	*3690*	
Agreement index of Model - A= 65.8% (A'c= 60.0%) **Agreement index Overall = 66.5% (A'c= 60.0%)**					

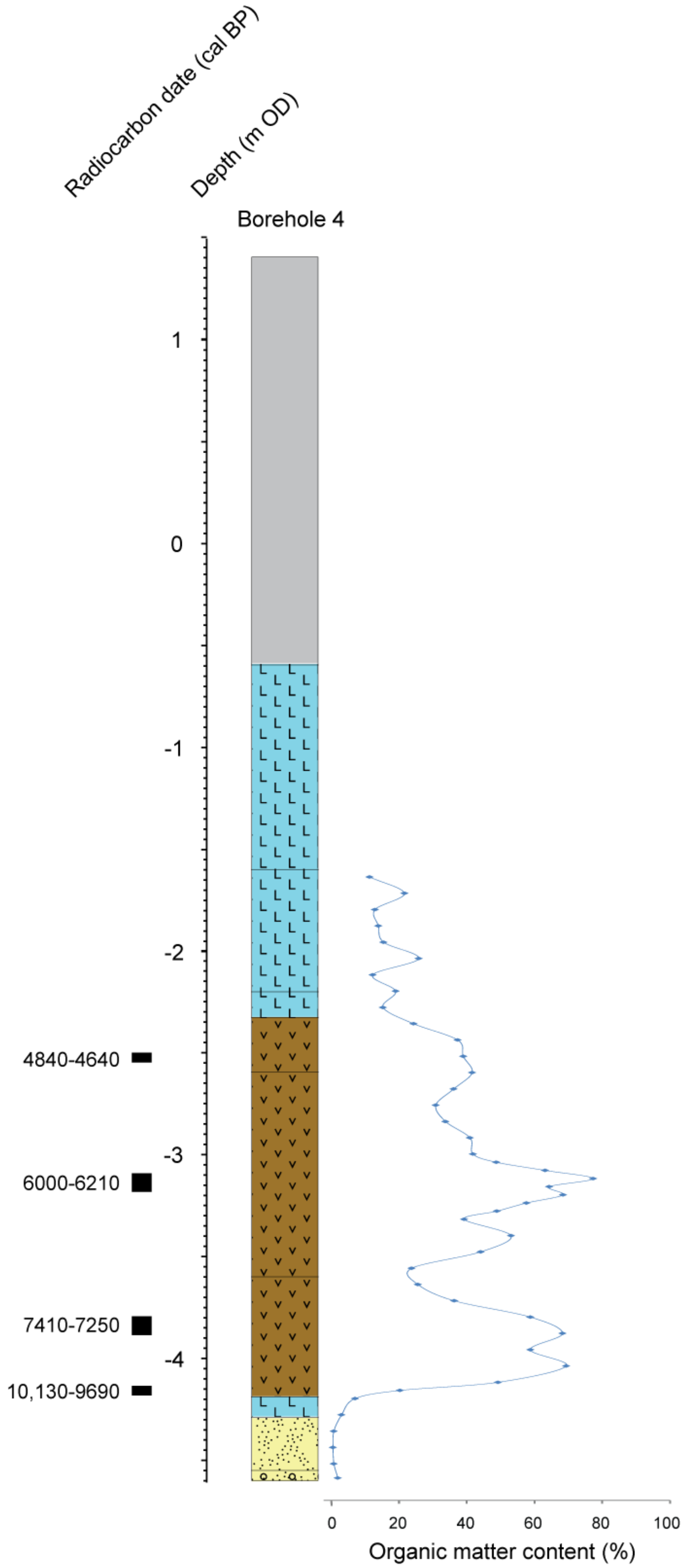


Figure 5: Results of the organic matter determinations and radiocarbon dating for borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

RESULTS AND INTERPRETATIONS OF THE POLLEN-STRATIGRAPHIC ANALYSIS

Results of the pollen-stratigraphic analysis

Figure 6 has been divided into five local pollen assemblage zones (LPAZs) based upon the results of the pollen-stratigraphical analysis: LPAZ LVI-1 to LPAZ LVI-5. The assemblage zones are summarised below followed by their interpretation.

LPAZ LVI-1 -4.12 to -3.92m OD ***9480-9070*** **to** ***8490-7490*** **cal BP**

Poaceae – Cyperaceae - ***Betula***

This zone is characterised by high values of herbaceous pollen (65%) dominated by Poaceae (35%) and Cyperaceae (20%) with *Artemisia* (<10%) and others including Asteraceae, cf *Thalictrum*, *Filipendula*, *Galium* type, *Rumex* undifferentiated and Apiaceae (<3%). Tree (30%) and shrub (4%) pollen was dominated by *Betula* (declining from 16% to <2%) and *Pinus* (increasing from 5% to 32%) with *Salix* and *Corylus* type (both <3%) and trace values of *Alnus*, *Quercus* and *Fraxinus* (<1%). Aquatic values were high (16%) but declined through the zone (to 6%) and included *Sparganium* type (up to 12%), *Myriophyllum* type (up to 6%) and *Potamogeton* type (<3%). Spores comprised Pteropsida only (<8%). Pollen concentration was moderately high, ranging around 100,000 grains per cm^3.

Between -4.45 and -4.12m OD, it was only possible to assess the pollen samples; only *Pinus* Poaceae, Cyperaceae and possibly *Quercus* were recorded (Table 9). These taxa are generally the dominant taxa recorded within the overlying samples.

LPAZ LVI-2 -3.92 to -3.52m OD ***8490-7490*** **to** ***7020-6580*** **cal BP**

Pinus **–** ***Corylus*** **type –** ***Quercus***

This zone is characterised by high values of tree (up to 80%) and shrub pollen (up to 50%). *Pinus* dominates initially (75%) but declines through the zone. *Corylus* type does the opposite, increasing through the zone from 2% to 52%. Similarly, *Quercus* increases from absence to *ca*. 15%. *Alnus* values are high (62%) in a single sample only, otherwise are generally <1%. Other tree and shrub taxa with a continual presence include *Ulmus*, *Tilia* and *Salix*. Herb pollen values are low (<12%) dominated by Poaceae and Cyperaceae with others including Lactuceae, *Rumex* undifferentiated, Apiaceae and *Ranunculus* type. Aquatic values are sporadic, including only trace values of *Menyanthes trifoliata* and *Sparganium* type. Spore values almost comprise *Pteropsida* and *Polypodium vulgare*. Total pollen concentration remains high, generally around 100,000 grains/cm^3.

LPAZ LVI-3 -3.52 to -3.08m OD ***7020-6580*** **to** ***6200-5820*** **cal BP**

***Alnus – Quercus – Tilia – Corylus* type**

This zone is characterised by a change in the arboreal pollen assemblage, with Alnus increasing to dominance (40%) with *Quercus* (*ca*. 20%), *Tilia* (10%), *Corylus* type (10-20%), *Ulmus*, *Pinus* (both <5%), *Fraxinus* and *Betula* (both <1%). Herbaceous pollen values remain low (<10%) including Poaceae, Cyperaceae (both <4%), Caryophylllaceae, *Ranunculus* type, *Chenopodium* type, *Filipendula* and Lactuceae (all <2%). Aquatic taxa are only present sporadically, and spore values are low (<10%) comprising *Pteropsida, Polypodium vulgare* and *Pteridium aquilinum*. Total pollen concentration decreases from *ca*. 100,000 to <20,000 grains per cm^3. Within the uppermost sample, a full count was not attainable; instead the assessment values are displayed in Table 9. The only taxa recorded (*Alnus*, *Quercus* and *Corylus* type), were the most commonly recorded through this zone.

LPAZ LVI-4 -3.08 to -2.24m OD ***6200-5820*** **to >4840-4640 cal BP**

Alnus – Quercus – Corylus* type - *Tilia

This zone is characterised by a decline in *Ulmus* pollen values at its base. Otherwise, the assemblage remains unchanged from LPAZ LVI-3. The exact position of this transition is not entirely clear due to the limited number of grains possible to count in the two samples towards the base of the zone (Table 9). Total pollen concentration also remains low (<20,000 grains/cm^3) with the exception of two spikes of 100,000 and 250,000 grains/cm^3 at -2.76 and -2.52m OD respectively.

LPAZ LVI-5 -2.24 to -1.64m OD **>4840-4640 cal BP**

***Alnus* – Poaceae - *Quercus – Corylus* type**

This zone is characterised by a decline *Alnus* (to *ca*. 20%) and *Tilia* (to <2%) pollen. All other tree and shrub taxa maintain similar percentage values to the preceding zone, with the exception of *Pinus* which increases slightly (<5%), and *Calluna vulgaris* which appears in the record (<1%). The decline in *Alnus* and *Tilia* is reflected by an increase in the diversity and overall percentage values of herbaceous pollen. Poaceae dominates (<20%) with Cyperaceae, Asteraceae, *Plantago lanceolata*, Lactuceae, Caryophyllaceae and *Rumex* undifferentiated. *Cereale* type, *Centaurea nigra* and *Polygonum aviculare* are further notable taxa recorded in trace values. Aquatic values are low but present throughout the zone including *Sparganium* type, *Myriophyllum* type, *Typha latifolia* and *Menyanthes trifoliata*. Spores comprise *Pteridium aquilinum*, *Pteropsida* (both <3%) and *Polypodium vulgare* (decreasing to <2%). Total pollen concentration is low (*ca*. 50,000 grains/cm^3).

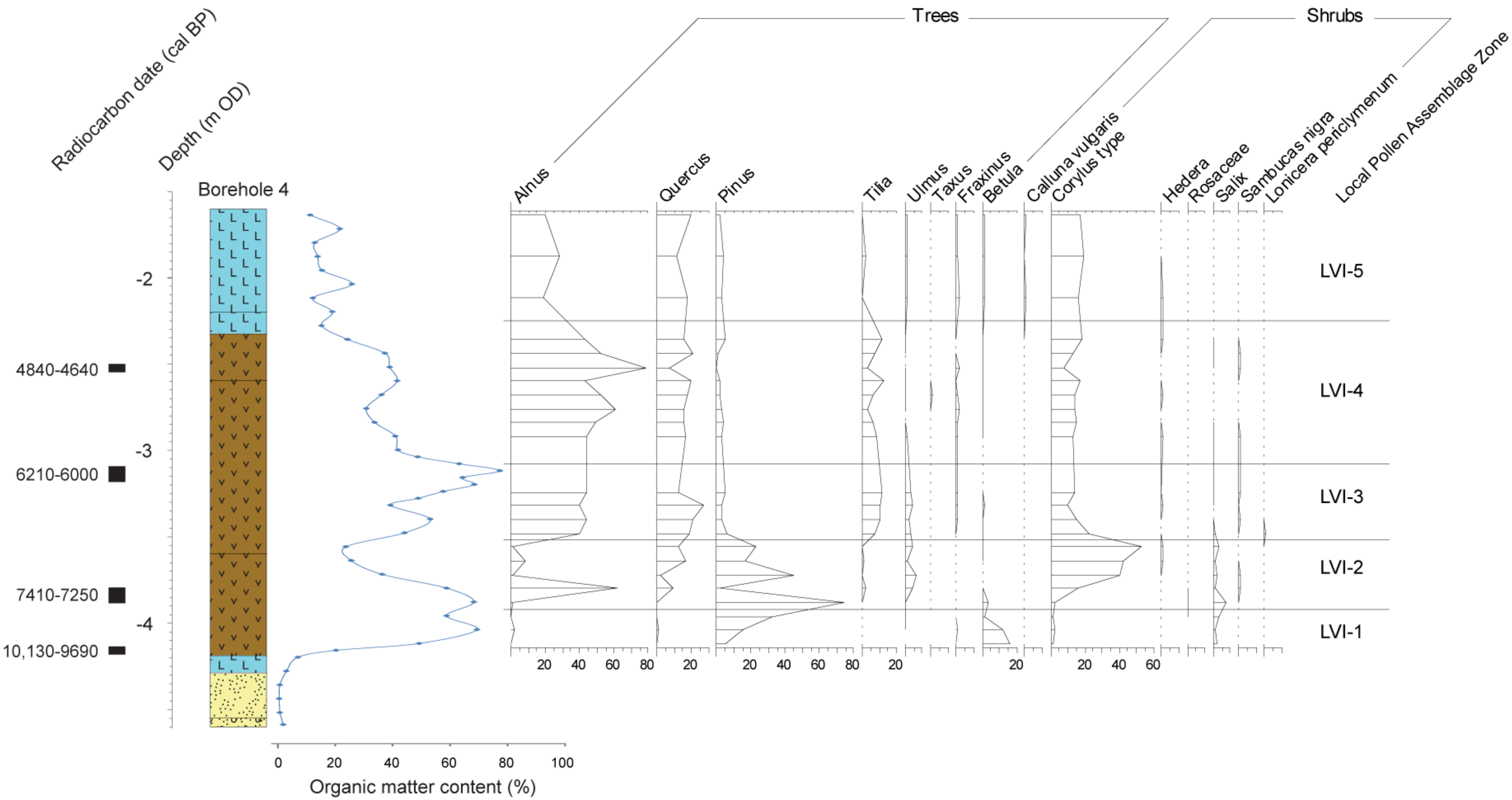


Figure 6: Pollen-stratigraphic diagram, Surrey House, London Borough of Southwark (site code: LVI11)

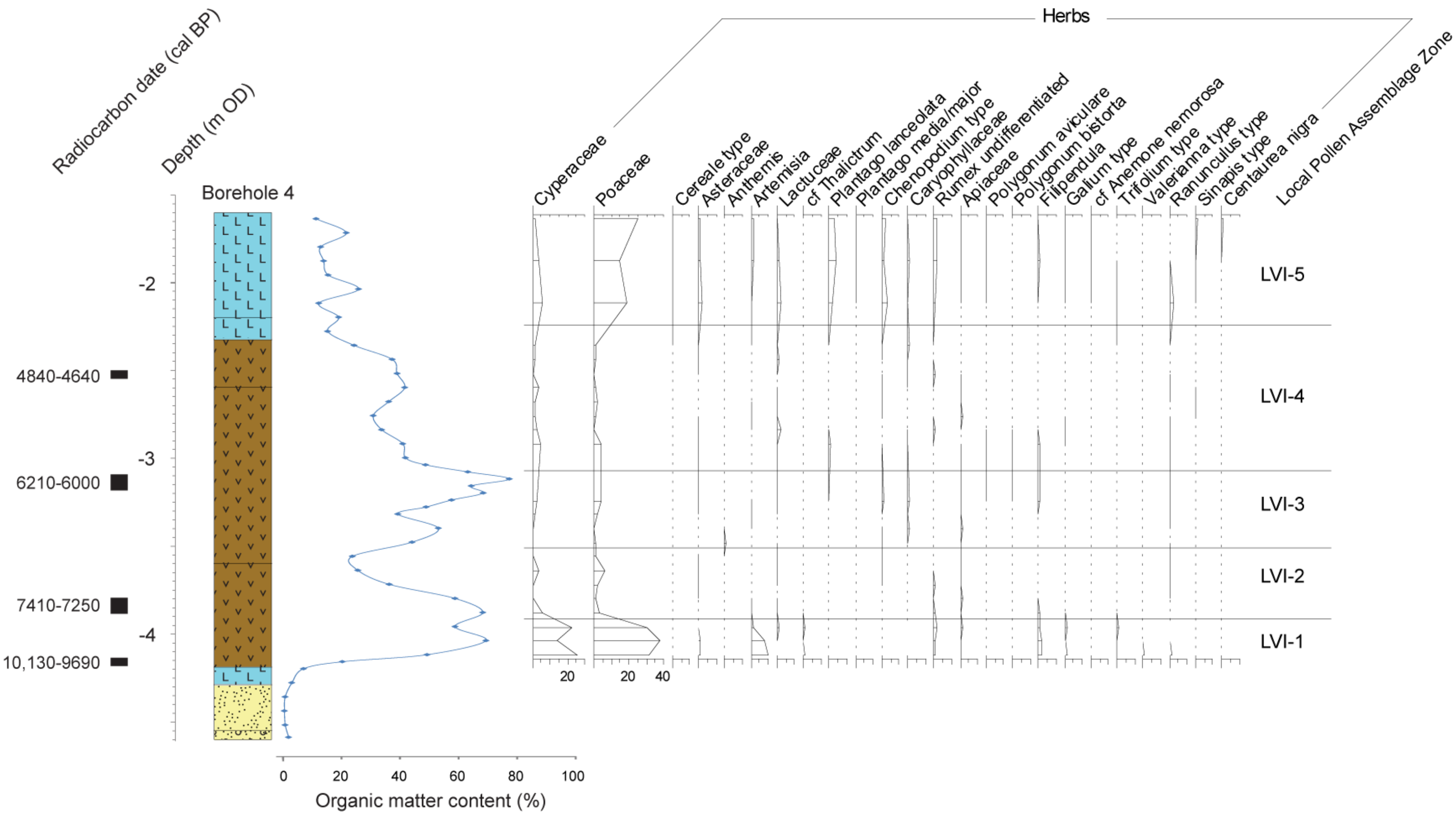


Figure 6: Pollen-stratigraphic diagram, Surrey House, London Borough of Southwark (site code: LVI11)

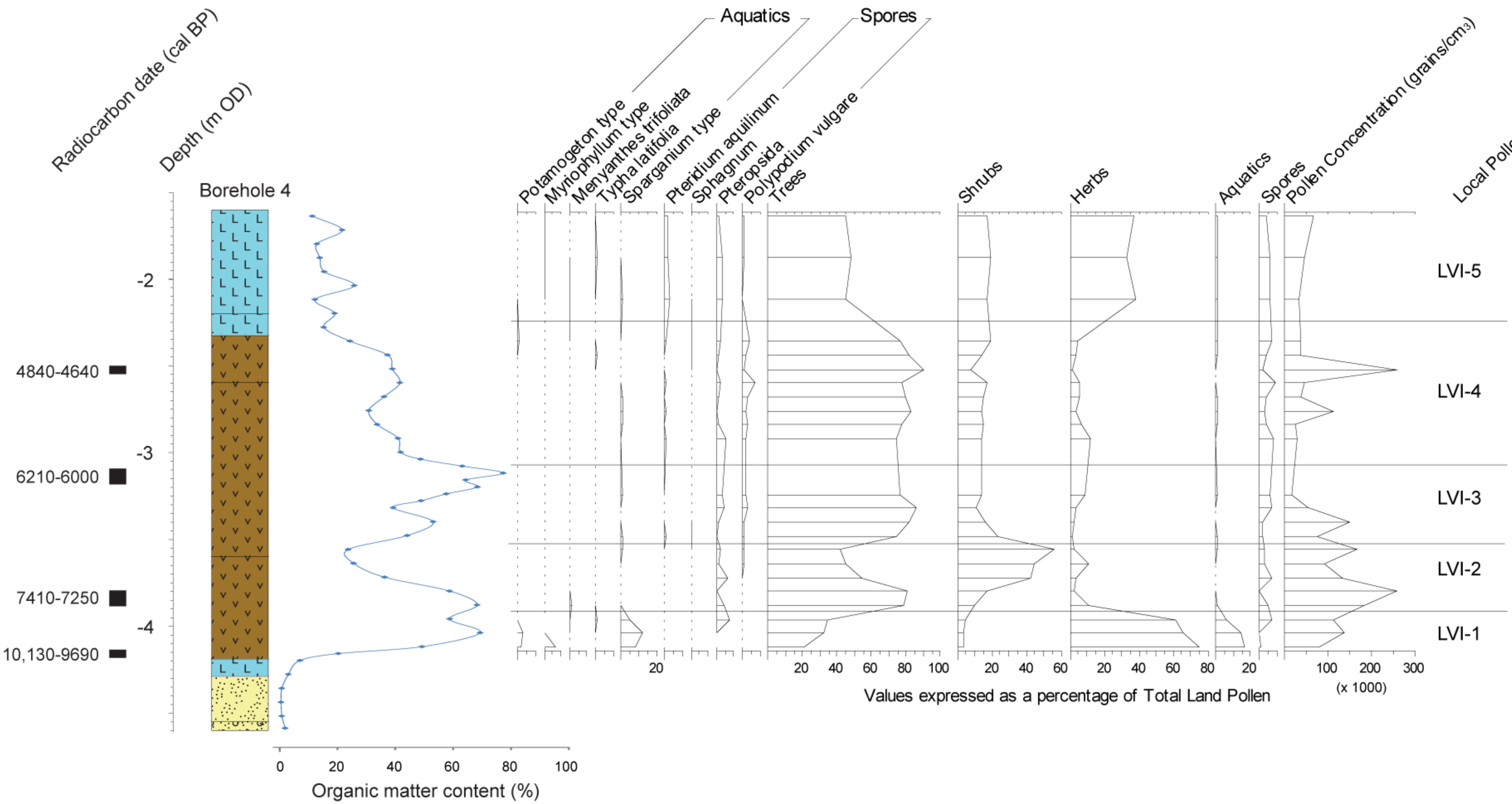


Figure 6: Pollen-stratigraphic diagram, Surrey House, London Borough of Southwark (site code: LVI11)

Table 10: Results of the borehole BH4 pollen assessment, Surrey House, London Borough of Southwark (site code: LVI11)

Sample number	Unit number	Main pollen taxa			Concentration 0-5	Concentration grains/cm^3	Preservation 0- 5	Microcharcoal 0 - 5
		Latin name	**Common name**	**Number**				
-3.00 to -3.01	4	*Alnus* *Quercus* *Pinus* *Tilia*	alder oak pine lime	4 1 1 1	2	4564	3	-
-3.08 to -3.09	4	*Alnus* *Quercus* *Tilia* *Ulmus* *Corylus type*	alder oak lime elm e.g. hazel	5 1 1 1 2	2	11263	3	-
-3.16 to -3.17	4	*Alnus* *Quercus* *Corylus type*	alder oak e.g. hazel	7 1 1	2	19667	3	-
-4.25 to -4.26	3	*Pinus* cf *Quercus* Poaceae Cyperaceae	pine oak grass family sedge family	3 1 3 3	2	3790	3	1
-4.44 to -4.45	1	*Pinus* Poaceae	pine grass family	2 1	1	1303	2-3	1

Key:
Concentration: 0 = 0 grains; 1 =1-75 grains, 2 = 76-150 grains, 3 = 151-225 grains, 4 = 226-300, 5 = 300+ grains per slide
Preservation: 0 = none, 1 = very poor, 2 = poor, 3 = moderate, 4 = good, 5 = excellent
Charcoal: 0 = none, 1 = negligible, 2 = occasional, 3 = moderate, 4 = frequent, 5 = abundant

Interpretation of the pollen-stratigraphic analysis

The results of the pollen-stratigraphical analysis indicate that during LPAZ LVI-1, grasses (Poaceae), sedges (Cyperaceae) and mugwort (*Artemisia*) dominated the wetland environment, with other herbaceous and aquatic taxa such as bur-reed (*Sparganium* type), water-milfoil (*Myriophyllum* type), pondweed (*Potamogeton* type) buttercup/water crowfoot (*Ranunculus* type), meadowsweet (*Filipendula* type) and dock/sorrel (*Rumex* undifferentiated). Woodland taxa included birch (*Betula*) and pine (*Pinus*) which were present throughout, whilst alder (*Alnus*), oak (*Quercus*), ash (*Fraxinus*), hazel (*Corylus* type) and willow (*Salix*) were present in low concentrations and/or rarely. Where these woodland taxa were growing is more difficult to establish. Birch and Pine produce high quantities of pollen which are well documented for travelling long distances, and thus may have travelled some distance from source as opposed to originating from the wetland. Alder and willow most likely grew on the wetland when they appeared, whilst ash, hazel, oak, elm may have grown either within a wetland community, or on the dryland with lime (and probably birch and pine). Radiocarbon age-depth modelling indicates that this period of vegetation history spanned from at least 9480-9070 to 8490-7490 cal BP equating to the Early Mesolithic cultural period.

During LPAZ LVI-2, the pollen-stratigraphical analysis indicates an initial transition to a local dryland and possibly wetland environment dominated by pine, whilst alder, willow, grasses and sedges indicate the continuance of wetland habitats. Birch also declines significantly at the transition from LPAZ LVI-1 to LVI-2. From midway through the zone (*ca*. 7360-7060 cal BP), pine woodland steadily declines and is replaced by mixed deciduous woodland dominated by hazel and oak with elm and lime. The dominance of hazel during this period is suggestive of a relatively open woodland, whilst the simultaneous increase of oak and lime, suggests the change in woodland took place on the dryland. On the wetland, with the exception of a single large spike in values, the concentration of *Alnus* pollen remains low, suggesting a limited presence of alder-willow carr woodland throughout the entire zone (8490-7490 to 7020-6580; Late Mesolithic cultural period).

The transition to LPAZ LVI-3 is characterised by the development of alder-dominated carr woodland on the wetland. The surface of the wetland was also populated by trees, shrubs and plants typical of marsh/fen environments such as willow, grasses, sedges, bur-reed and possibly ash. Woodland also underwent a further change on the dryland, with the decline of hazel and pine and expansion of oak and lime. This suggests closure of the woodland canopy, forcing reduced opportunities for the flowering of shrubs such as hazel. Radiocarbon age-depth modelling indicates that this period of vegetation history spanned from 7020-6580 to 6200-5820 cal BP, equating to the Late Mesolithic/Early Neolithic cultural periods.

During LPAZ LVI-4, alder dominated woodland continued to grow on the wetland, and mixed deciduous woodland on the dryland. However, this period is characterised by a decline in *Ulmus* (elm) pollen at the beginning of the zone, which represents the decline of elm within the dryland, and possibly wetland woodland community. The elm decline is well recorded in pollen diagrams across the British Isles representing the large-scale decline of elm populations during the Early Neolithic. At Surrey House, the decline occurs around 7020-6580 cal BP which is within the range of dates calculated for the British Isles by Parker *et al* (2002) where the reduction in pollen is recorded as commencing between 6343 and 6307 and continuing until 5420 and 5290 cal BP. Multiple reasons have been put forward for cause of the decline in elm populations, including disease and human activity. At Surrey House, a minor decline in lime is noted alongside an increase in the quantity and diversity of herbaceous pollen, including grasses, ribwort plantain (*Plantago lanceolata*) and knotgrass (*Polygonum aviculare*) which suggests that temporary clearance on the dryland may well have been the primary cause of the decline. However, it is also noted that alder increases gradually through the zone (with grasses and sedges), which might also indicate that paludification (the expansion of wetland onto areas of former dryland) was a causal factor.

Also of note during LPAZ LVI-4 was the minimal occurrence of *Taxus* (yew) pollen midway through the zone, the timing of which coincides with the known expansion of yew woodland along the Lower Thames Valley between *ca*. 5000 and 4000 cal BP (Batchelor, 2009). Following the decline of elm, sporadic grains of *Taxus* (yew) pollen are recorded midway through the zone, most likely representing its growth nearby on the wetland or dryland surface. Yew is commonly recorded as a component of the wetland woodland along the Lower Thames Valley during the Neolithic cultural period (Batchelor, 2009).

During the final period LPAZ LVI-5, the pollen-stratigraphic record indicates changes in woodland structure on both the wetland and dryland surfaces. On the wetland, alder dominated woodland declines, as grasses, sedges and various herbaceous plants expand, most likely in response to wetter conditions. The increase in diversity of aquatic taxa (bur-reed, pondweed, bulrush, water-milfoil and bog bean) enhances the indication of wetter conditions. On the dryland, lime (which will only grow on well drained soils) declines, whilst other mixed deciduous trees and shrubs (including oak, hazel, elm and ash) maintain constant values. The apparent contemporaneous change in wetland and dryland woodland is a phenomenon commonly recorded in pollen diagrams from the Lower Thames Valley, although often this is recorded later during the Bronze Age cultural period. The decline in woodland on both surfaces is coincidental with the occurrence of grass pollen grains with a similar morphology to cereals, as well as grasses, docks/sorrel and ribwort plantain (*Plantago lanceolata*), black knapweed (*Centaurea nigra*) and knotgrass (*Polygonum aviculare*). These species may be associated with activities such as clearance, cultivation and/or pastoralism, suggesting that the transition in wetland and dryland woodland communities may be associated with anthropogenic processes. However, because of the early date of the decline in dryland woodland, and since it is only the more hydrologically sensitive lime that appears to be affected, it is considered more likely that the transition in both dryland and wetland communities has been mainly caused by the expansion of wetland onto former areas of dryland.

RESULTS AND INTERPRETATION OF THE MACROFOSSIL RAPID ASSESSMENT

A total of eighteen small bulk samples from units 4 (peat) and 5 (upper alluvium) of borehole BH4 were extracted for the recovery of macrofossil remains including waterlogged plant macrofossils, waterlogged wood, insects and Mollusca (Table 11). The results of the macrofossil rapid assessment indicated that waterlogged seeds were present in ten of the samples, while waterlogged wood was present in fourteen samples. Fragments of insects were present in three samples (-2.21 to -2.31, -2.60 to -2.70 and -3.55 to -3.65m OD); however, these lacked the diagnostic features necessary for identification. Fragments of Mollusca were present in the uppermost sample in the sequence (-2.21 to -2.31m OD). No charred seeds, charcoal or bone were found during the assessment.

RESULTS AND INTERPRETATION OF THE WATERLOGGED PLANT MACROFOSSIL ANALYSIS (SEEDS)

The results of the borehole BH4 waterlogged seed analysis are displayed in Table 12. The waterlogged seeds in borehole BH4 are characterised by two different assemblages; below *ca*. -3.93m OD the assemblage is dominated entirely by aquatic taxa including *Ranunculus* cf. *fluitans*/*aquatilis* (water crowfoot), *Scirpus* sp. (bulrush) and *Potamogeton* sp. (pondweed). Above *ca*. -3.93m OD the assemblage is dominated by tree and shrub taxa including *Alnus glutinosa* (alder), *Cornus sanguinea* (dogwood) and cf. *Rubus* sp. (bramble). Herbaceous taxa were present, and included *Ranunculus* cf. *repens* (creeping buttercup). Aquatic or damp ground vegetation including *Sparganium erectum* (bur-reed) and *Apium nodiflorum* (fool's watercress) were present in two samples (-2.21 to -2.31 and -2.80 to -2.90m OD); these taxa are indicative of shallow, still or slow-flowing water. The assemblage in borehole <BH4> is thus indicative of wet conditions below -3.93m OD, with more terrestrial conditions (indicated by the growth of vegetation typical of fen woodland) above -3.93m OD.

RESULTS AND INTERPRETATION OF THE WATERLOGGED WOOD ANALYSIS

The results of the BH4 waterlogged wood analysis are displayed in Table 12. Those samples analysed below -3.88m OD did not reveal any identifiable remains as a consequence of being either too small; having no visible clear anatomical structures, or appearing fused. These features may be a result of drying (not necessarily modern drying). The other sample analysed between -3.08 and -3.18m OD contained fragments of *Alnus glutinosa* (alder) wood.

Table 11: Results of the macrofossil rapid assessment of borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

			Charred					Waterlogged		Mollusca		Bone			Insects	
Depth (m OD)	Volume sampled (ml)	Volume processed (ml)	Charcoal (>4mm)	Charcoal (2-4mm)	Charcoal (<2mm)	Seeds	Chaff	Wood	Seeds	Whole	Fragments	Large	Small	Fragments	Whole	Fragments
-2.21 to -2.31	50	50	-	-	-	-	-	4	1	2	2	-	-	-	-	-
-2.40 to -2.50	50	50	-	-	-	-	-	1	-	-	-	-	-	-	-	-
-2.50 to -2.55	25	25	-	-	-	-	-	1	1	-	-	-	-	-	-	-
-2.55 to -2.60	25	25	-	-	-	-	-	1	1	-	-	-	-	-	-	-
-2.60 to -2.70	50	50	-	-	-	-	-	2	1	-	-	-	-	-	-	2
-2.80 to -2.90	100	100	-	-	-	-	-	1	1	-	-	-	-	-	-	-
-3.08 to -3.18	50	50	-	-	-	-	-	5	-	-	-	-	-	-	-	-
-3.17 to -3.27	150	150	-	-	-	-	-	4	-	-	-	-	-	-	-	-
-3.35 to -3.45	125	125	-	-	-	-	-	1	-	-	-	-	-	-	-	-
-3.55 to -3.65	100	100	-	-	-	-	-	1	-	-	-	-	-	-	-	-
-3.65 to -3.75	75	75	-	-	-	-	-	1	-	-	-	-	-	-	-	-
-3.79 to -3.89	125	125	-	-	-	-	-	2	1	-	-	-	-	-	-	-
-3.88 to -3.93	50	50	-	-	-	-	-	3	-	-	-	-	-	-	-	-
-3.93 to -3.98	25	25	-	-	-	-	-	1	1	-	-	-	-	-	-	-
-3.98 to -4.03	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
-4.03 to -4.08	25	25	-	-	-	-	-	-	1	-	-	-	-	-	-	-
-4.08 to -4.13	25	25	-	-	-	-	-	-	1	-	-	-	-	-	-	-
-4.13 to -4.18	25	25	-	-	-	-	-	-	2	-	-	-	-	-	-	-

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 12: Results of the waterlogged plant macrofossil (seeds) analysis of borehole BH4, Surrey House, London Borough of Southwark (site code: LVI11)

Depth (m OD)	Waterlogged seeds			Waterlogged wood		
	Latin name	**Common name**	**Number**	**Latin name**	**Common name**	**Number**
-2.21 to -2.31	*Cornus sanguinea* *Alnus glutinosa* catkin *Apium nodiflorum* *Sparganium erectum* cf. *Rubus* sp. Unidentified	dogwood alder fool's watercress bur-reed e.g. bramble -	1 1 2 1 1 1			
-2.50 to -2.55	*Ranunculus* cf. *repens*	creeping buttercup	1			
-2.55 to -2.60	*Alnus glutinosa* catkin *Ranunculus* cf. *repens*	alder creeping buttercup	1 2			
-2.60 to -2.70	*Alnus glutinosa* catkin *Ranunculus* cf. *repens*	alder creeping buttercup	2 2			
-2.80 to -2.90	*Sparganium erectum*	bur-reed	1			
-3.08 to -3.18				*Alnus glutinosa*	alder	
-3.79 to -3.89	*Alnus glutinosa* catkin	alder	3			
-3.88 to -3.93				Unidentifiable	-	
-3.93 to -3.98	*Scirpus* sp.	bulrush	1	Unidentifiable	-	
-4.03 to -4.08	*Scirpus* sp.	bulrush	2			
-4.08 to -4.13	*Ranunculus* cf. *fluitans/aquatilis* *Scirpus* sp. *Potamogeton* sp.	water crowfoot bulrush pondweed	1 8 1			
-4.13 to -4.18	*Scirpus* sp. *Potamogeton* sp.	bulrush pondweed	44 1			

RESULTS AND INTERPRETATION OF THE MOLLUSCA ANALYSIS

One sample from unit 5 (-2.21 to -2.31m OD) was identified during the macrofossil assessment as having a moderate concentration of Mollusca remains. This sample was submitted for analysis in order to provide further information on the hydrological conditions that led to the cessation of peat formation. The results of the analysis indicated that the sample contained very few Mollusca shells, but a good number of opercula as follows:

Gyraulus acronicus	1
Valvata piscinalis	1
Pisidium milium	2 valves
Bythinia tentaculata opercula	30
Bythinia leachi opercula	15

This is an odd assemblage in that there are no identifiable shell fragments of either species of *Bythinia* (some small shell fragments are present which are not identifiable). It is uncertain why there should be so many opercula without the corresponding shells; perhaps the opercula have survived some degree of acidity which has destroyed the shells.

Gyraulus acronicus is at present time a rare shell living only in the upper reaches of the River Thames and tributaries, although it was somewhat more widespread in the early Postglacial period, being recorded from the lower Thames and River Lea (Kerney 1999: 65).

The shells/opercula in the assemblage are all freshwater species associated with well-oxygenated moving water (Boycott 1936). The sample is likely to be from a river or ditch with rather slow moving water and does not suggest a pond or lake or other more stagnant water.

DISCUSSION & CONCLUSIONS

Sedimentary and hydrological history

The sedimentary sequences recorded at Surrey House provide an important insight into the processes by which the Bankside Channel was progressively infilled during the Holocene. The Bankside Channel itself originated as a substantial topographic feature on the surface formed during the final stage of the Late Devensian Shepperton Gravel aggradation. Throughout the valley of the Lower and Middle Thames this surface is characterised by the presence of longitudinal gravel bars aligned approximately parallel with the axis of the valley and representing high energy deposition. These bars are separated by intervening channels in which evidence of lower energy deposition (sands, silts and clays) may be present. The local amplitude of the relief on this surface is generally about 3-4m but the scale of the Bankside Channel is indicated by a relief amplitude of >7m: from -4.55m OD at Surrey House to 2.67m OD at 231-241 Blackfriars Road on the crest of the gravel bar to the north of the channel, separating the channel from the River Thames (Batchelor *et al* 2008).

The combined results of the archaeological watching brief, geoarchaeological fieldwork and analysis at Surrey House indicate a dipping Shepperton Gravel surface from south (-2.95m OD; Borehole 3) to north (-4.55m OD; Borehole BH4; Figure 3). Significantly, the depths towards the northern edge of the site are the lower than recorded elsewhere in the Bankside Channel, at -3.49m OD at the South Point site (Branch *et al*., 2002); and -3.64m OD at Anchor Terrace (Thompson *et al*., 1998); and substantially below the levels recorded in two sites immediately to the north and south of the Surrey House site, respectively at -2.95m OD at St Christopher House (Howell 2003) and at -1.60m OD at 65 Southwark Street to the east (Batchelor *et al*., 2011b; Figure 4). The low level of the base of the Holocene sediment sequence at the Surrey House site may indicate the presence of a continuous deep narrow channel occupying the axis of the Bankside depression or, and perhaps more likely, a localised scour hollow in the surface of the Shepperton Gravel.

Deposition in the Bankside Channel was aggradational, reflecting in response to the intermittently rising Holocene sea level. There is no clear indication of in-channel deposition at Surrey House. The lower part of the sequence consists mainly of peat, but no mineral sediment coarser than silt was recorded. This suggests that any fluvial deposition was from still or very slow-moving water. Thus the sediments represent either deposition in a Bankside Channel occupied by a very slow-moving distributary; or deposition on the floodplain of the Bankside Channel; or, that by the time these sediments were being deposited, there was no permanent water body occupying the Bankside Channel and therefore that aggradation within the channel as a whole was being achieved solely as a result of episodic flooding and peat accumulation. The accumulation of peat at Surrey House commenced around 10,130-9690 cal BP and continued until sometime after 4840-4640 cal BP. Initially, the rate of sedimentation was slow, but increased to a more rapid rate after 7410-7250 cal BP. The lowermost date was questioned during the assessment stage, but is now considered accurate since: (1) all other dates are in chronological order; (2) pollen concentration is higher during the earlier stages of peat accumulation, which might be expected if the rate of accumulation was lower, (3) the compressed/dry nature of the waterlogged wood also suggests a slower period of peat accumulation, and (4) the highest values of organic-matter content were recorded during this period suggesting drier conditions. During the latter period of peat accumulation, variations in organic matter content suggest that the peat surface was prone to frequent episodes of flooding and fine-grained mineral input. This however, does not appear to have had an impact upon the rate of sedimentation.

The results from Surrey House clearly confirm that accumulation was not contemporaneous across the entirety of the Bankside Channel. At Surrey House, peat accumulation took place during the Early Mesolithic and Late Neolithic; at 65 Southwark Street, peat accumulation took place during the Middle and Late Neolithic, whilst at Bear House & Bear Lane, it didn't commence until the Late Neolithic and continued until the Late Bronze Age. Elsewhere, at sites towards the middle of the projected course of the Bankside Channel, such as St Christopher House (*ca*. 100m northeast of the site; Maloney, 2004) radiocarbon dating indicates that the channel dated from at least 10,650-10,250 cal yr BP and included both peat and alluvial deposits (Maloney, 2004), whilst historic records indicate it had infilled by the Late 17th Century (Turner, 2009). One possible explanation for this is that during the Holocene, the course of the Bankside migrated, with channels formed and abandoned at different times. Another possibility is that peat accumulation actually continued for some time after the Late Neolithic at Surrey House and 65 Southwark Street, but the sequence has since been truncated.

The preliminary indications from the Mollusca record at Surrey House are that the water conditions resulting in alluvial deposition after peat accumulation were of slow moving freshwater. This result is similar to that from 65 Southwark Street which provides a diatom record of shallow freshwater immediately prior to, and after peat formation. Higher up in the 65 Southwark Street sequence, are indications for the influence of tidal waters.

Vegetation history

The new radiocarbon dated palaeoenvironmental record from Surrey House indicates that LPAZ LVI-1 can be equated to the Early Mesolithic (9840-9070 to 8490-7490 cal BP). During this period, grasses, sedges and other herbaceous taxa typical of grasslands dominated the wetland environment with willow, whilst birch and pine woodland grew either nearby, or as part of the regional vegetation. This assemblage is very similar to that of other similarly dated pollen-stratigraphic records such as the Cable Car North Tower (Batchelor *et al*., 2012b), West Silvertown (Wilkinson *et al*., 2000) and Bramcote Green (Thomas and Rackham, 1996), and is indicative of cold weather conditions of the Early Holocene. Trace pollen values of alder, oak, elm and hazel suggest deciduous trees were beginning to become established nearby. Unfortunately, the plant macrofossil records are unable to provide further insight as to the nature of the onsite woodland due to the unidentifiable nature of the wood fragments recorded.

The transition to LPAZ LVI-2 is characterised by the initial dominance of pine (*ca*. 75%TLP), an occurrence not reflected in the plant macrofossil record, but is strongly suggestive of onsite woodland. This peak is dated between 8490-7490 and 7360-7060 cal BP, which is much later than the Early Holocene age recorded for similar peaks at West Silvertown (between 12,080-11230 and 11,035-10,290 cal BP) and other sites in London such as Bramcote Green (Thomas and Rackham, 1996). However, a peak in pine has recently been recorded at other sites in London (Sidell, pers. comm.), including the Cable Car North Tower (Batchelor *et al*., 2012b), where it was dated slightly later around 6850-6670 cal BP (also *ca*. 75% TLP). These dates potentially indicate the expansion of pine within the Lower Thames Valley during the Late Mesolithic cultural period.

From *ca*. 7360-7060 cal BP, pine woodland steadily declines and is replaced by mixed deciduous woodland dominated by hazel and oak with elm and lime. The dominance of hazel during this period is suggestive of a relatively open woodland, whilst the simultaneous increase of oak and lime, suggests the change in woodland took place on the dryland. Furthermore, these warmth-loving trees (especially elm and lime), are suggestive of warmer conditions since they became established during a period of Early Holocene climatic amelioration, forming a mixed deciduous forest ecosystem. This forest would have been present throughout the Lower Thames Valley, and probably formed excellent areas for human occupation during the Mesolithic/Neolithic cultural periods, with rich plant and animal resources, including hazel nuts and acorns, and probably *Cervus elaphus* (red deer) and *Bos primigenius* (auroch) (see Thomas and Rackham, 1996; Sidell *et al.,* 2002).

LPAZ LVI-2 is also characterised by definitive evidence for the moderate onsite growth of alder-willow carr woodland according to the pollen and plant macrofossil records. This community would have grown alongside a range of grasses, sedges, ferns and aquatics, which combined with the alder and willow is indicative of a damp surface incorporating standing water habitats such (e.g. ponds).

Between 7020-6580 and 6200-5820 cal BP (LPAZ LVI-3) alder-dominated carr woodland expanded on the wetland. Woodland also underwent a further change on the dryland, with the decline of hazel and pine and expansion of oak and lime. Lime is entomophillous (insect pollinated) and thus frequently under-represented in pollen records. The high values of *Tilia* pollen therefore suggest that lime was the dominant component of the mixed deciduous woodland with oak. Furthermore, the high values of oak and lime combined with the decline in hazel suggest a closed woodland canopy, preventing the flowering of hazel.

During the period dated 6200-5820 and sometime after 4840-4640 cal BP (LPAZ LVI-4), alder continued to dominate on the wetland, whilst mixed deciduous woodland grew on the dryland. However, this period also incorporates two important events: (1) the decline of elm, and (2) the growth of yew.

<u>The elm decline</u>

The radiocarbon-dated pollen-stratigraphical record from Surrey House indicates a decline in elm woodland somewhere around *ca.* 6200-5820 cal BP. This broadly synchronous, pan-European event was arguably the most significant change in woodland composition and structure during around this time, and started in the British Isles between *ca.* 6343 and 6307 cal yr BP (a period of 36 years), and ended between *ca.* 5420 and 5290 cal yr BP (Parker *et al*., 2002). The reasons for the decline of elm have been of great debate over the years with the following hypotheses made: (1) climate change to cooler conditions (e.g. Smith, 1981); (2) soil deterioration due to e.g. Mesolithic burning (Peglar and Birks, 1993), or waterlogging and peat formation (paludification; Waller, 1994); (3) competitive exclusion (e.g. Huntley and Birks, 1983; Peglar and Birks, 1993); (4) human interference with natural vegetation (e.g. Scaife, 1988; Lamb and Thompson, 2005), and (5) Dutch elm disease (e.g. Perry and Moore, 1987; Girling, 1988). The two most strongly argued causes for the decline are human interference with natural vegetation succession and Dutch elm disease, with a combination of the two, the most likely cause.

The argument for human activity centres on the fact that the decline in *Ulmus* pollen is contemporaneous with the transition from the Mesolithic to Neolithic cultural period and is often accompanied by palynological and/or coleopteran evidence for temporary episodes of clearance for cultivation and animal husbandry (e.g. Scaife, 1988; Wilkinson, 1988; Girling and Grieg, 1985). However, the evidence for a human caused decline is circumstantial with no definitive archaeological proof for the exploitation of *Ulmus* (Garbett, 1981; Rasmussen, 1989a,b), and arguments that the human population at this time would have been too small to cause a long-term reduction in woodland (e.g. Moe and Rackham, 1992).

Elm disease is caused by the fungus *Ophiostoma* (*Ceratocystis*) *ulmi* which is carried by the beetle *Scolytus scolytus*. The discovery of these insects at or near to a decline in elm pollen at sites such as Hampstead Heath (Girling, 1988; Girling and Grieg, 1985) and Red Moss of Candyglirach near Aberdeen (Clark and Edwards, 2004) is widely regarded as strong indication that disease was the main cause of the Neolithic elm decline. Further support for this hypothesis has been provided by the discovery of microscopic anatomical features in elm wood analogous to those found in modern diseased trees (Rasmussen and Christensen, 1997), and by rapid, large-scale declines in elm in both recent and Middle Holocene pollen-stratigraphic records (Perry and Moore, 1987; Peglar and Birks, 1993). However, despite the support for this hypothesis conclusive evidence for a disease-caused Holocene decline remains absent.

It is for this reason that the elm decline is considered most likely to have been caused by the interaction of human activity and disease. Whether farming facilitated the spread of the disease by creating opportunities for its easier transmission through woodland (for example the pollarding of elm branches would have produced cuts within the tree, reducing its natural defences, and allowing the direct attack of insects; Austin, pers comm.), or whether disease created woodland glades suitable for cultivation, or pastoralism, may have varied spatially.

The latest evidence from the Lower Thames Valley include two Late Mesolithic/Early Neolithic records of *Scolytus scolytus* at Horton Kirby (Kent) and Old Seager Distillery (Deptford; Batchelor *et al*., in prep). Both sites also contain elm pollen and waterlogged wood, whilst the latter site contains flint artefacts. These are unique sites, and when combined with other sites in the Lower Thames Valley, may suggest that human activity was the initial factor allowing the spread of disease (Batchelor *et al*., in prep).

At Surrey House, a minor decline in lime is noted alongside an increase in the quantity and diversity of herbaceous pollen, including grasses, ribwort plantain and knotgrass. This suggests that temporary clearance on the dryland for grazing may well have been the primary cause of the decline nearby to the site. However, it is also noted that alder increases gradually through the zone (with grasses and sedges), which might also suggest paludification (the expansion of wetland onto areas of former dryland) may also have been a causal factor.

<u>The colonisation of yew</u>

The pollen-stratigraphic records indicate that yew may have become a component of the woodland in the nearby vicinity sometime after the elm decline. The concentration of pollen is low, and no waterlogged wood was recorded. Yew is well established as growing on the floodplain of the Lower Thames Valley between *ca*. 5000 and 4000 cal BP (Batchelor, 2009), and at present macrofossil records indicate its growth from at least the East India Docks in the west (Pepys, 1665) to Aveley Parish in the east (Wilkinson and Murphy, 1995). Further to the west, yew has been recorded in a few pollen diagrams, including Joan Street, Union Street (both Sidell et al., 2000) and now, Surrey House. There is therefore an increasing number of sites that suggest yew was growing towards central London, but the lack of macrofossil evidence means that its presence is yet to be confirmed, although its presence is certainly less extensive than in other areas to the east.

The final major change in vegetation is recorded sometime after 4840-4640 cal BP (LPAZ LVI-5) and is near contemporaneous with the transition from peat to alluvial sediments. This is characterised by changes in woodland structure on both the wetland and dryland surfaces. On the wetland, alder dominated woodland declines, as grasses, sedges and various herbaceous and aquatic plants expand, most likely in response to wetter conditions. On the dryland, lime (which will only grow on well drained soils) declines, whilst other mixed deciduous trees and shrubs (including oak, hazel, elm and ash) maintain constant values. The apparent contemporaneous change in wetland and dryland woodland is a phenomenon commonly recorded in pollen diagrams from the Lower Thames Valley, although often this is recorded later during the Bronze Age cultural period. The decline in woodland on both surfaces is coincidental with the occurrence of grass pollen grains with a similar morphology to cereals, as well as grasses, docks/sorrel and ribwort plantain, black knapweed and knotgrass. These species may be associated with activities such as clearance, cultivation and/or pastoralism, suggesting that the transition in wetland and dryland woodland communities may be associated with anthropogenic processes. However, because of the early date of the decline in dryland woodland, and since it only appears to be the hydrologically sensitive lime that is affected, it is considered more likely that the transition in both dryland and wetland communities has been mainly caused by the expansion of wetland onto former areas of dryland. This interpretation is enhanced by the record from the adjacent 65 Southwark Street site, at which peat accumulation appears to have continued a little after that of Surrey House and at which all mixed deciduous woodland declined (Batchelor *et al*., 2011b).

CONCLUSIONS

The aim of this analysis report was to provide a quantified reconstruction of the environmental history of the site and its surroundings during the Mesolithic and Neolithic cultural periods. The main findings of the analysis are as follows:

1. The environmental archaeological investigation of the Surrey House site has enhanced knowledge and understanding of the environmental history of Bankside Channel.
2. The basal gravel surface at Surrey House is the lowest thus far recorded in the Bankside Channel, as is the commencement of the subsequent peat formation (10,130-9690 cal BP; Early Mesolithic). Peat formation continued until sometime after 4840-4640 cal BP (Late Mesolithic).
3. The biostratigraphical (pollen and plant macrofossil) records indicate that during the period of peat formation, there were specific important changes in both the wetland and dryland vegetation cover which are analogous to that recorded within the Cable Car North Tower record (Batchelor *et al*., 2012b). This includes the timing and nature of the pine and hazel peaks during the Mesolithic and timing of the elm decline during the Late Mesolithic/Early Neolithic. Yew was also recorded within the Surrey House pollen record although at present macrofossils remain elusive from this area of London.
4. No definitive indications of human activity were recorded on the site, but the following aspects were noted as potentially significant: (1) indications of temporary land clearance around the time of the decline in elm, and (2) indications of human activity around the cessation of peat formation. In both cases (particularly the second), wetland expansion may have caused similar pollen stratigraphic changes.
5. Throughout the analysed period of sedimentation at Surrey House, the site appears only to have been influenced by freshwater processes.
6. The new record from Surrey House is a significant, and warrants collation with other recently investigated sites (e.g. 65 Southwark Street, Bear House/Bear Lane and Great Suffolk Street), for a publication focussed on the environmental history of the Bankside Channel. This publication will incorporate further waterlogged wood identifications from the peat and analysis of diatoms from the overlying alluvium of the Surrey House sequence. These analyses are currently being undertaken to enhance the existing work

already carried out. A significant change to the reconstruction of the environmental history is not anticipated as a consequence of this additional work.

7. Work on the integrated publication is already underway with Surrey Archaeological Collections targeted as a potential destination in late 2013/early 2014.

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