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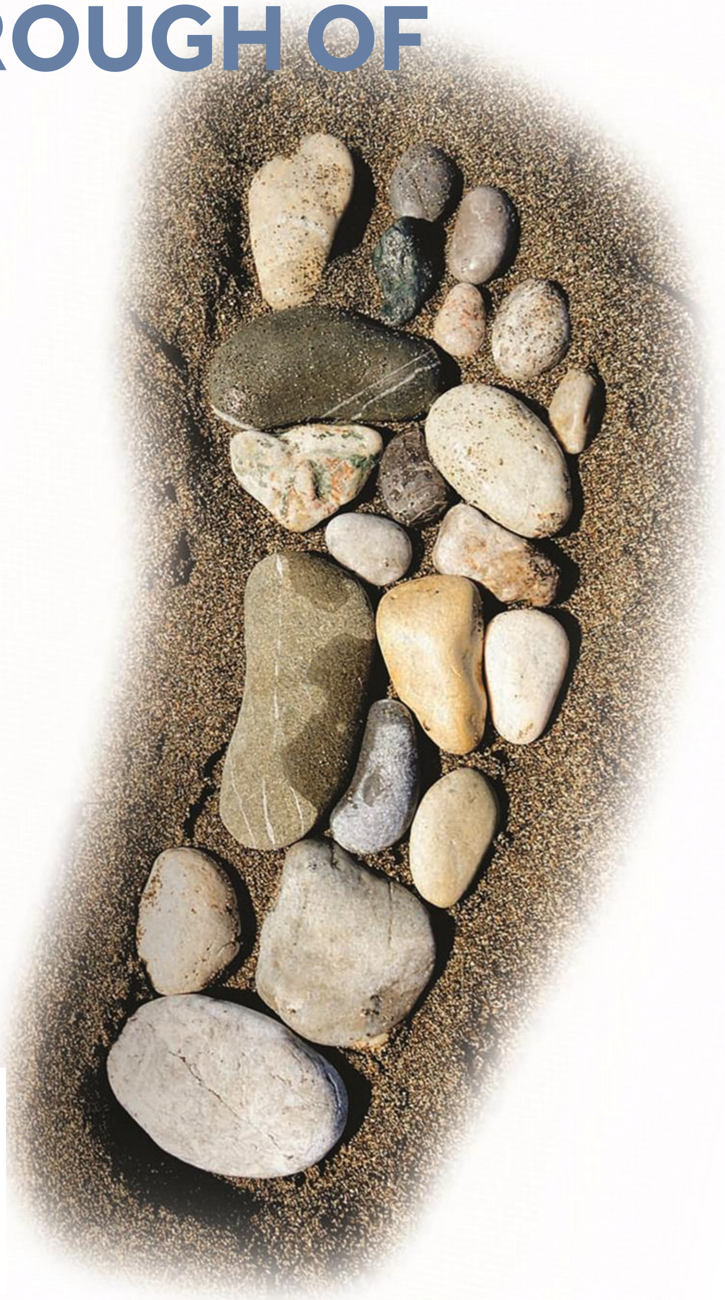
ALCATEL-LUCENT TELEGRAPH WORKS, LONDON BOROUGH OF GREENWICH

Geoarchaeological & Palaeoenvironmental Analysis Report



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1. NON-TECHNICAL SUMMARY

The geoarchaeological and palaeoenvironmental analysis report was aimed at fully addressing the six original project aims, with particular emphasis on considering the dissimilarities between the Alcatel-Lucent and Enderby Wharf sites.

The site appears to lie within a large trough in the Shepperton Gravel surface, representative of at least one major former palaeochannel traversing Greenwich Peninsula from west to east. Alcatel-Lucent and neighbouring Enderby Wharf are located towards the western end where the Shepperton Gravel surface reaches depths of around -4 to -5m OD. At its eastern end, the Shepperton Gravel surface reaches ranges between -4 and -8m OD. Towards the south, the Gravels rise to over 0m OD, most likely representative of the earlier Kempton Park Gravel. Towards the north, the Gravels also rise, but not to the same high level. Within the confines of the channel, the Shepperton Gravel is overlain by a sequence of Alluvium and Peat as recorded elsewhere in the Lower Thames Valley. In most cases, the Peat is actually a complex of alluvial and peat layers, reflective of changing hydrological conditions during the infilling of the channel. In the analysed Alcatel-Lucent sequence, the Peat is relatively thin (0.5m) and seemingly accumulated from the beginning to the end of the Neolithic. At Enderby Wharf, the complex of Peat units is around 2m thick dating from the middle Neolithic to late Bronze Age.

Despite the location of archaeological structures on edge of the channel to the south at Bellot Street, there is no definitive evidence of human activity within the sequences analysed. The Alcatel-Lucent peat deposits do however predate the archaeological remains at Bellot Street, which may explain the lack of evidence for activity.

At Alcatel-Lucent, the Peat surface was occupied by limited alder-willow carr woodland, with sedge fen, reed swamp and areas of standing/slowly moving water; by contrast, at Enderby Wharf, a greater amount of alder woodland is indicated. Both sites indicate a dryland occupied by oak-lime dominated mixed deciduous woodland that post-dates the well-documented Neolithic elm decline, however, this woodland signal is stronger at Alcatel-Lucent. Towards the end of the Neolithic a shift towards sedge fen, reed swamp and salt-marsh communities is recorded on the floodplain with evidence for a drastic shift from freshwater-dominated to estuarine-dominated conditions resulting from a rise in relative sea level. At the same time, a large reduction in mixed deciduous woodland took place on the dryland, probably as a result of human activity from the late Neolithic onwards. Whether the decline of the floodplain and dryland woodland is linked is uncertain, but does seem to be a common feature of woodland within pollen-stratigraphic records from the Lower Thames Valley.

The aims and objectives of the project are considered to have been successfully achieved, providing an important record from this area of the Lower Thames Valley. The results are significant, and the stratigraphic data has already been incorporated into a Greenwich Peninsula based case-study as part of forthcoming Historic England deposit modelling guidance. In addition, academic publication(s) are being prepared on the deposits of Greenwich Peninsula, the Isle of Dogs & south-west Newham.

2. INTRODUCTION

2.1 Site context

This report summarises the findings arising out of the geoarchaeological and palaeoenvironmental analysis undertaken by Quaternary Scientific (University of Reading) in connection with the proposed development of land at the Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10 (National Grid Reference centred on: TQ 3841 7866; Figures 1 and 2). The site is located towards the south-western corner of Greenwich Peninsula, bounded to the west by the River Thames and to the east by Blackwall Lane (Figure 1). Greenwich Peninsula is formed and bounded by a meander of the Thames to the west, east and north of the site, and lies opposite the confluence of the River Lea. The ground across the area originally formed part of the natural floodplain of the Thames, and is underlain by river alluvium (British Geological Survey 1:50,000 sheets 256 North London 1993, 257 Romford 1996, 270 South London 1998, 271 Dartford 1998). This alluvium consists of fine-grained mineral-rich deposits and peat, and is mapped to the south to approximately the position of the A206 where it meets higher drier ground. Beneath the alluvium, sand and gravel is present and is assigned by Gibbard (1994) to the Late Devensian Shepperton Gravel. The bedrock beneath this is mapped as the Palaeogene Lambeth Group – Clay, Silt and Sand. Ground level at the site is recorded at between 1 and 2m OD (CgMs Consulting, 2014).

Recent fieldwork and assessment of the Alcatel-Lucent site itself indicates that the surface of the Shepperton Gravel rests between -3.54 and -4.93m OD. This is overlain by a sequence of Holocene alluvial and peat deposits capped by Made Ground (Young & Batchelor, 2015a, b). The Peat ranges between 0.61 and 1.67m in thickness, and represents a period of semi-terrestrial conditions. Radiocarbon dating of this horizon suggests it accumulated during the Neolithic, however, the dates are in reverse order (4825-4570 to 5300-4980 cal BP). On the adjacent Enderby Wharf site the Gravel surface is recorded between approximately -2.75 and -5.0m OD, with an overlying peat ranging between 0.5 and 3.0m thick, and dating from 5450-5070 to 3390-3230 cal BP, (Neolithic and Bronze Age) (Batchelor *et al.*, 2015). The results of the palaeobotanical assessment indicate that the environment across the Alcatel-Lucent site was relatively open during the accumulation of the peat. This differs somewhat from Enderby Wharf, where a much stronger wetland woodland signal is recorded. These differences may reflect localised variations in environment and vegetation at the time the Peat was forming, or given the chronological uncertainty of the Alcatel-Lucent sequence, may indicate that the Peat is of a different age to that recorded at the Enderby Wharf site.

Previous geoarchaeological deposit modelling across the wider area suggests that both Alcatel-Lucent and the adjacent Enderby Wharf site (Batchelor *et al.*, 2015) are located at the western end of a significant depression (>-4m OD) in the Gravel surface that traverses Greenwich Peninsula from west to east. 20 Horn Lane is located towards the eastern end of this channel (Batchelor & Young 2017). Elsewhere on the peninsula, low gravel surfaces are recorded at various sites, representing localized hollows and/or interconnected palaeochannels. High gravel surfaces (between *ca.* -1 and -1.7m OD) have also been recorded representing small but important former islands. Peat has also been identified at numerous sites across Greenwich Peninsula, including Enderby Wharf (Batchelor *et al.*, 2015), Alcatel-Lucent (Young & Batchelor, 2015) and Bellot Street (Branch et al., 2005). The horizons recorded vary in date, but generally accumulated within the same general age range of 6700 to 3000 cal BP (late Mesolithic to late Bronze Age).

2.2 Geoarchaeological, archaeological and palaeoenvironmental significance

As above, on the basis of ongoing research that incorporates the area of Greenwich Peninsula, including the results of the investigations at the sites listed above and data from the British Geological Survey online database (www.bgs.ac.uk/opengeoscience), the site is thought to lie within the approximate area of a deep, broadly east-west aligned palaeochannel that may have formed either a tributary or subsidiary channel of the Thames (see Batchelor *et al*., 2015; Young & Batchelor, 2015a, b). In addition, the peat recorded at the site represents a period of semi-terrestrial conditions that may date from the Neolithic to Bronze Age periods. The palaeoenvironmental potential of the sequences at the site is therefore considered to be high. Significantly, on the basis of the radiocarbon dates from sites elsewhere on the Peninsula, it is possible that the peat at the present site may have been accumulating at the same time as trackway construction occurred on the nearby 72-88 Bellot Street (Mclean, 1993; Philp, 1993) and the Garage Site, Bellot Street (Branch *et al*., 2005) sites (Bronze Age) approximately 1km to the west. The existing records from the nearby area indicate a variable sequence of Holocene alluvial deposits resting, on a highly variable Shepperton Gravel surface.

The different deposits recorded are significant as they represent different environmental conditions that would have existed in a given location. For example: (1) variations in the topography of the River Terrace Gravels could indicate the position of former channels and islands on the floodplain; (2) the presence of soils and peat represent former terrestrial or semi-terrestrial land-surfaces, and (3) the less organic alluvial deposits of sands/silts/clays represent periods of varying hydrological conditions on the floodplain. By studying the sub-surface stratigraphy across the site in greater detail, it will be possible to build a greater understanding of the former landscapes and environmental changes that took place over space and time at this location of Greenwich Peninsula.

Organic-rich sediments (in particular peat) also have high potential to provide a detailed reconstruction of prehistoric environments on both the wetland and dryland. In particular, there is the potential to increase knowledge and understanding of the interactions between hydrological change, human activity, vegetation succession and climate in this area of the Middle Thames Valley. Significant vegetation changes include the early Holocene/early Mesolithic transition from pine-dominated to mixed-deciduous dominated woodland; the late Mesolithic/Neolithic decline of elm woodland, the Neolithic colonisation and decline of yew woodland; the late Neolithic/early decline of wetland and dryland woodland. Such investigations are carried out through the assessment/analysis of palaeoecological remains (e.g. pollen, plant macrofossils & insects) and radiocarbon dating. So called palaeoenvironmental reconstructions have been carried out on the sedimentary sequences from elsewhere in this general area, including at Alcatel-Lucent (Young & Batchelor, 2015, and Enderby Wharf (Batchelor *et al*., 2015).

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 structure) and palaeoenvironmental record (e.g. changes in vegetation composition). As stated above, such evidence was identified in the form of a Bronze Age trackway at the nearby 72-88 Bellot Street (Mclean, 1993; Philp, 1993) and Garage Site, Bellot Street (Branch *et al*., 2005) sites (Bronze Age) approximately 1km to the west.

2.3 Aims and objectives

The Geoarchaeological Written Scheme of Investigation originally outlined the following research aims for the site (Batchelor, 2015):

1. To clarify the nature of the sub-surface stratigraphy in these areas of the site;
2. To determine the age of the main peat horizon(s) recorded on the site;
3. To investigate whether the geoarchaeological records contain any evidence for natural and/or anthropogenic changes to the landscape (wetland and dryland) throughout the duration of the geoarchaeological sequence;
4. To establish whether the geoarchaeological records provide evidence for prehistoric and historic occupation locally to the site;
5. To establish evidence and possible causes for changes in woodland composition on the wetland and dryland surfaces during the different periods of Peat formation;
6. To integrate the new geoarchaeological record with other recent work in the local area for publication in an academic journal.

The preceding geoarchaeological fieldwork and assessment reports have either in part or fully addressed aims 1 to 5; aim 6 is yet to be considered. The following report therefore aims to fully address the original project aims, with particular emphasis on considering the dissimilarities between the Alcatel-Lucent and Enderby Wharf sites. This analysis consists of: (1) two additional radiocarbon dates, to resolve the age reversal recorded in the current radiocarbon dates and provide a more detailed chronological model for the environmental changes recorded; (2) analysis of 12 pollen samples to examine the changes in vegetation recorded at the site in more detail; and (3) analysis of four diatom samples to examine the hydrological history of the infilling channel.

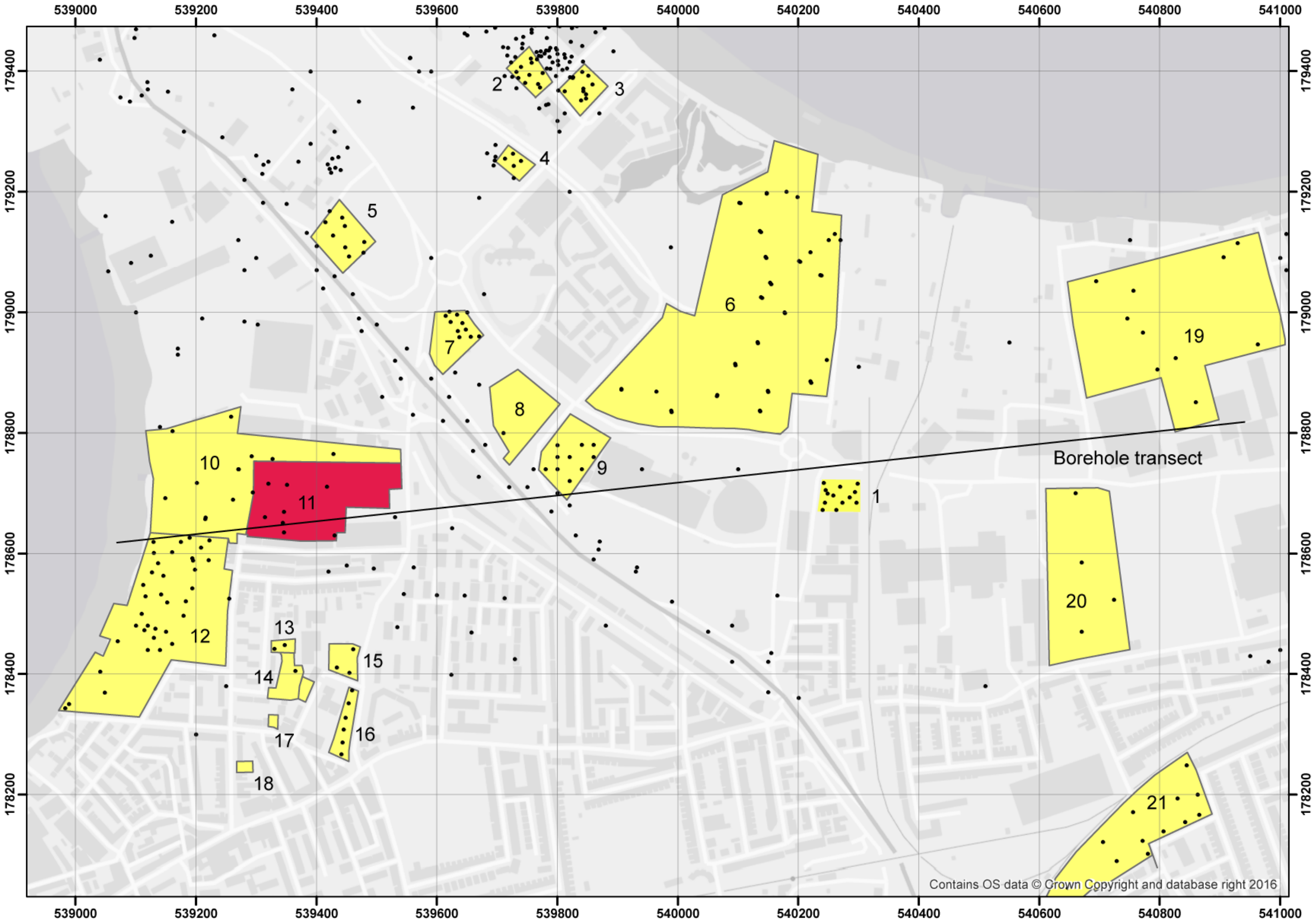

Figure 1: Location of (1) 20 Horn Lane, Royal Borough of Greenwich and selected other geoarchaeological and archaeological sites nearby: (2) Plot MO115 (Young & Batchelor, 2013b); (3) Plot MO117 (JHW13; Young & Batchelor, 2013a); (4) Plot 19.05 (Batchelor & Young 2017); (5) Plot MO401 (Batchelor, 2014); (6) Greenwich Millennium Village (Miller & Halsey, 2011); (7) Land between A102(M) & Bugsby's Way (GPN98); (8) The Leisure Site, Bugsby's Way (BW99); (9) Land between A102(M) & Bugsby's Way (GPN98); (10) Enderby Wharf (Batchelor *et al.*, 2015); (11) Alcatel-Lucent Telegraph Works (Young & Batchelor, 2015); (12) Greenwich Wharf (Batchelor, 2016); (13) Bellot Street (GLB05; Branch *et al.*, 2005); (14) 72-88 Bellot Street (BSG93; McLean, 1993; Philp, 1993); (15) & (16) 1-3, 9, 27 Blackwall Lane & 109 Pelton Street (MoLA, 2011); (17) St Josephs Community Centre; (18) 4 Christchurch Way (Hart, 2011); (19) Lombard Wall (Young *et al.*, 2011); (20) Greenwich Industrial Estate (GIE02; Morley, 2003); (21) Victoria Way (MoLA, 1993).

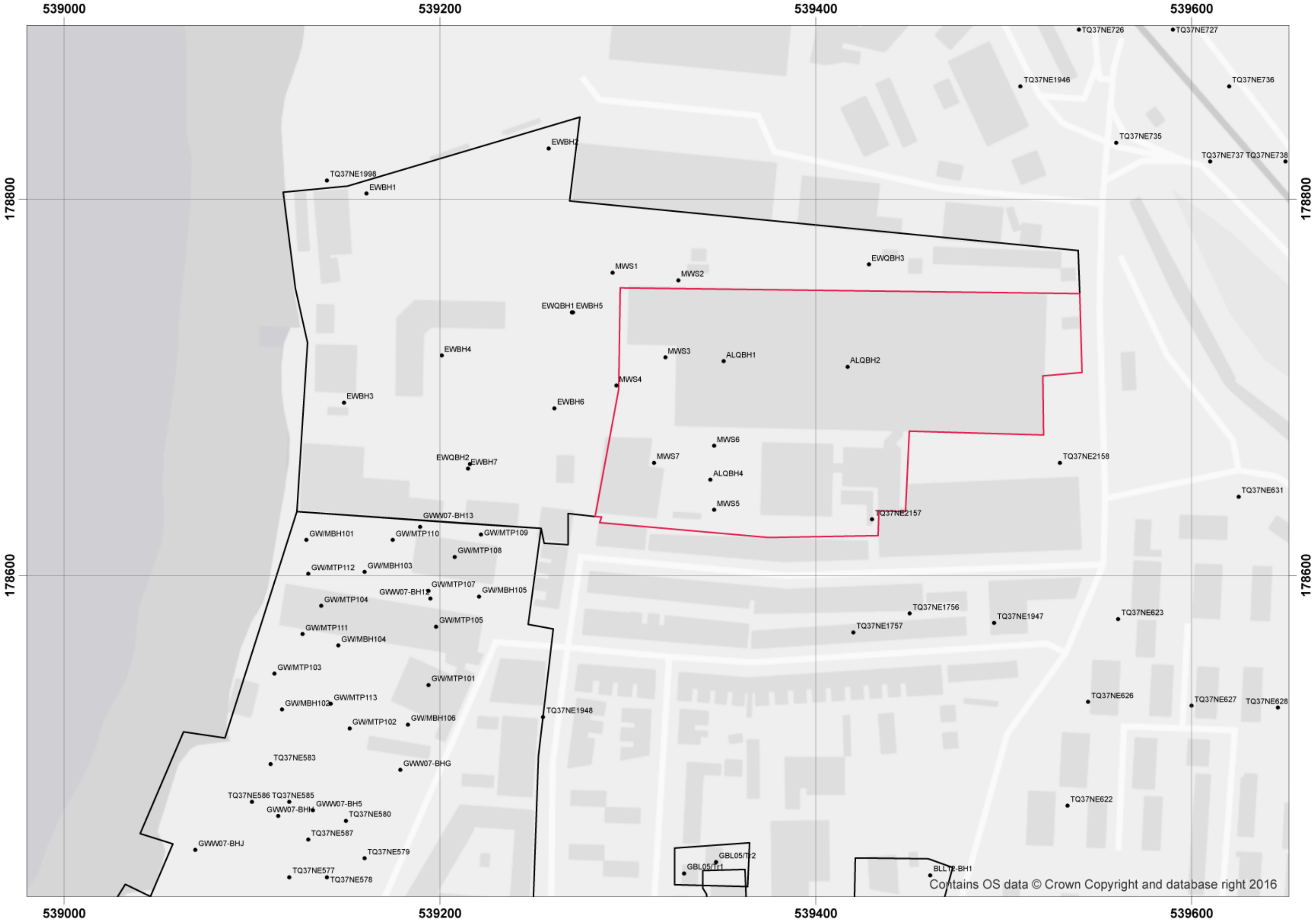

Figure 2: Location of the new geoarchaeological boreholes at the Alcatel-Lucent Telegraph Works site (red outline) and existing geoarchaeological, geotechnical and BGS archive boreholes in the area of the deposit model, including those at Enderby Wharf (Batchelor *et al.*, 2015a; black outline).

3. METHODS

3.1 Field investigations

Three geoarchaeological boreholes (boreholes QBH1, QBH2 and QBH4) were put down at the site in August 2015 by Quaternary Scientific. One of the boreholes proposed in the WSI for the site (QBH3; Batchelor, 2015) could not be put down since this area of the site was still in use at the time of the fieldwork. Borehole core samples were recovered using an Eijkelkamp window sampler and gouge set using an Atlas Copco TT 2-stroke percussion engine. This coring technique is 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. The borehole locations were recorded using a Leica GS09 Differential GPS (Table 1).

Table 1: Borehole attributes for the boreholes from Alcatel-Lucent Telegraph Works

Borehole	Easting	Northing	Elevation (m OD)
Geoarchaeological boreholes (present site)			
QBH1	539351	178714	1.80
QBH2	539417	178711	1.80
QBH4	539344	178651	2.02
Geotechnical boreholes (present site; Merebrook Consulting, 2012)			
MWS1	539292	178761	1.40
MWS2	539327	178757	1.50
MWS3	539320	178716	1.80
MWS4	539294	178701	2.00
MWS5	539346	178635	2.10
MWS6	539346	178669	1.90
MWS7	539314	178660	2.10

3.2 Lithostratigraphic description

The lithostratigraphy of the retained core samples was described in the laboratory using standard procedures for recording unconsolidated sediment and organic sediments, noting the physical properties (colour), composition (gravel, sand, clay, silt and organic matter) and inclusions (e.g. artefacts) (Tröels-Smith, 1955). The procedure involved: (1) cleaning the sample using a scalpel; (2) recording the physical properties, most notably colour using a Munsell Soil Colour Chart; (3) recording the composition; gravel (Grana glareosa; Gg), fine sand (Grana arenosa; Ga), silt (Argilla granosa; Ag) and clay (Argilla steatoides); (4) recording the degree of peat humification and (5) recording the unit boundaries e.g. sharp or diffuse. The results of the geoarchaeological descriptions of the boreholes are displayed in Tables 2 to 4. The spatial attributes of the boreholes are displayed in Table 1 and in Figure 2.

3.3 Deposit modelling

The local deposit model was based on a review of 121 borehole records, including the three geoarchaeological boreholes and seven existing geotechnical boreholes (Merebrook Consulting, 2012) from the site, and records from Enderby Wharf (Batchelor *et al*., 2015), Greenwich Wharf

(Batchelor, 2016), Bellot Street (Branch *et al*., 2005) and 27 BGS archive boreholes (www.bgs.ac.uk/opengeoscience) (Figure 2; Table 1). Sedimentary units from the boreholes were classified into seven groups: (1) Bedrock, (2) Gravel, (3) Sand, (4) Lower Alluvium. (5) Peat, (6) Upper Alluvium and (7) Made Ground. In addition, 857 geoarchaeological, archaeological and geotechnical records were collated to examine key deposits across the wider area. The classified data for groups 1-7 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 & 8-9). Thickness of the Peat, total Holocene alluvium (incorporating the Lower Alluvium, Peat and Upper Alluvium) and Made Ground (Figures 6-7, 10-12) were also modelled (also using an Inverse Distance Weighted algorithm). Borehole transects are displayed in Figures 13 (Alcatel-Lucent & Enderby Wharf) & 14 (wider area).

Because the boreholes are not uniformly distributed over the area of investigation, the reliability of the models generated using RockWorks is variable. In general, reliability improves from outlying areas where the models are largely supported by scattered archival records towards the core area of commissioned 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 deposit models from the Alcatel-Lucent site; for the models of the wider area (Figures 4, 7 & 12), a 100m radius is used. In addition, it is important to recognise that multiple sets of boreholes are represented, put down at different times and recorded using different descriptive terms and subject to differing technical constraints in terms of recorded detail including the exact levels of the stratigraphic boundaries.

3.4 Organic matter determinations

A total of 37 subsamples from borehole QBH2 were taken for determination of the organic matter content (Table 5; Figure 13). 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 and Enell, 1986).

3.5 Radiocarbon dating

Four subsamples of unidentified twig wood (<2-3 years old) were extracted from the Peat in borehole 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 v4.0.1 (Bronk Ramsey, 1995; 2001 and 2007) and the IntCal13 atmospheric curve (Reimer *et al*., 2013). The results are displayed in Figure 13 and in Table 6.

3.6 Diatom analysis

0.5g of sediment was required for the diatom sample preparation. Visual inspection of five samples, revealed that the uppermost and- and lower two samples (-2.18m, -2.84m, -3.20m) were silt and clay rich, with the basal sample containing a high sand content. In contrast, the two middle samples were essentially pure organic samples, with a mixture of humic and herbaceous organic remains present. Samples were first treated with hydrogen peroxide (30% solution) and/or weak ammonia (1% solution) depending on organic and/or calcium carbonate content, respectively. The higher organic content encountered in the peat samples required prolonged hydrogen peroxide pre-treatment to remove the majority of organic material from the sample in advance of analysis. Only the mineral rich samples (samples -2.18m, -2.84m and -3.20m) were subsequently 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 15.

3.4 Pollen analysis

Ten sub-samples from the peat in borehole 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. The analysis procedure consists of counting the pollen and spores present until a count of 300 total land pollen is (TLP) was reached. This consists of tree, shrub and herb taxa; aquatics and spores are counted as a percentage of total land pollen. 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 concentration of microscopic charred particles is also recorded. The results are displayed in Figure 16.

3.5 Macrofossil assessment

A total of six small bulk samples from borehole QBH2 were extracted for the recovery of macrofossil remains including waterlogged plant macrofossils, wood, insects and Mollusca. The extraction process involved the following procedures: (1) removing a sample of either 5 or 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. Preliminary identifications of the waterlogged seeds have been made using modern comparative material and reference atlases (Cappers *et al.* 2006). Nomenclature used follows Stace (2005) (Table 9).

4. RESULTS, INTERPRETATION & DISCUSSION OF THE GEOARCHAEOLOGICAL BOREHOLE INVESTIGATIONS ANALYSIS

The results of the lithostratigraphic descriptions and deposit modelling have been reporting previously (Young & *Batchelor, 2015a, b)*), and are summarised and updated below, based upon the results of the most recent radiocarbon dating (Table 6). A summary of the borehole spatial data used from the site are shown in Table 1, with the geoarchaeological lithostratigraphic descriptions shown in Tables 2 to 5. The results of the deposit modelling are displayed in Figures 3 to 14: Figures 3 to 12 are surface elevation and thickness models for each of the main stratigraphic units; Figures 13 & 14 are borehole transects. The results of the organic matter determinations and radiocarbon dating are displayed in Tables 5-6 & Figure 12.

The results of the deposit modelling indicate that the number and spread of sedimentary logs is sufficient to permit modelling with a high level of reliability across most of the modelled area, but not the eastern part of the Alcatel-Lucent site itself. The full sequence of sediments recorded in the boreholes comprises:

The full sequence of sediments recorded in the boreholes comprises:

Made Ground
Upper Alluvium – widely present
Peat – widely present
Lower Alluvium – widely present
Sand – intermittently present
Gravel – widely present

4.1 Gravel

Gravel was present in all the boreholes that penetrated to the bottom of the Holocene sequence. It was deposited during the Late Glacial (15,000 to 10,000 years before present) 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 surface of this unit is recorded in the three geoarchaeological boreholes at -4.15 (QBH1), -3.54 (QBH2) and -3.91m OD (QBH4), similar to the levels recorded at the Enderby Wharf site immediately to the west (-3.5 to -4.0m OD; Batchelor *et al.*, 2015a). The Gravel surface falls towards the southeast of the site to -4.93m OD in BGS borehole TQ37NE2157, -6.81m OD in TQ37NE2158 and -5.4m OD in TQ37NE631. To the south towards Greenwich Wharf (Batchelor, 2016) and Bellot Street (Branch et al., 2005) the Gravel rises to between -2 and 0m OD, whilst to the northwest and northeast of these sites the Gravel surface generally lies above -3m OD.

According to the wider modelling exercise (Figures 4 & 13), the site does appear to lie within a large trough in the Shepperton Gravel surface, representative of at least one former palaeochannel traversing Greenwich Peninsula from west to east. At its western end beneath Alcatel-Lucent & Enderby Wharf the channel reaches depths of around -4 to -5m OD. Towards its eastern end at 20 Horn Lane and Greenwich Millennium Village (Miller & Halsey, 2011), the Shepperton Gravel is lower, ranging between -4 and -8m OD. Similarly towards the south-east, a deep depression is evident beneath the Greenwich Industrial Estate site (Morley, 2003), potentially representing a channel draining off the terrace edge towards the present day River Thames. Towards the north of Alcatel-Lucent and further onto the main area of Greenwich Peninsula, the Shepperton Gravel surface is recorded in various places down to -4 representing the presence of further smaller, but important channels.

Beyond the confines of the channel to the south, the Gravel surface rises to between -2 and 0m OD as it nears the margin of the floodplain. The Gravel surface also rises to a similar height towards the east beneath the Lombard Wall site (Young *et al.*, 2011). To the north, Gravel surface is patchily recorded above -2m OD, representing small, but important former islands. Wherever the Gravel surface reaches such elevations, it is more likely to represent the former River Terrace of the Kempton Park Gravel, deposited during the middle-late Pleistocene. Such terraces have negligible potential for Palaeolithic remains since the Kempton Park Gravel was deposited during a period when hominid remains have not previous been recorded in the British Isles. They do however, represent areas of greater archaeological potential as they would have been raised above the surrounding floodplain during the Holocene period. This is demonstrated by prehistoric trackway remains found within the overlying Peat at Bellot Street (e.g. Branch *et al.*, 2005).

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.

Within the local model, it is recognised in seven sequences: QBH4, EWQBH1, EWQBH2, EWBH7, TQ37NE2157, TQ37NE1756 and TQ37NE623 (Figure 13). 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 (see below), due to the nature of the coring methods and less precise method of description. In the case of the modelling exercise, differentiation between the Sand and Shepperton Gravel is made based upon the presence 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 deposits of the

Lower Alluvium are described as a predominantly silty or clayey tending to become increasingly sandy downward in most sequences. The Lower Alluvium frequently contains detrital wood or plant remains, and in many cases is described as organic and with occasional Mollusca remains. 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. In borehole QBH2 the organic content in this unit is recorded at between *ca*. 5 and 10% (Figure 12). The surface of this unit across the site lies at between *ca*. -3.5 and -2.0m OD (Figures 5 & 13), generally sloping downwards from west to east from Enderby Wharf to Alcatel-Lucent.

4.4 Peat

In boreholes QBH1 and QBH2 the Lower Alluvium is overlain by a horizon of woody Peat with occasional herbaceous remains, indicative of a transition to semi-terrestrial conditions supporting the growth of wetland vegetation in this area of the site. In borehole QBH2 the organic content within this horizon is consistently recorded at between 80 and 85%. In borehole QBH4 no Peat is recorded, but a horizon of organic-rich alluvium is present at the same elevation as the Peat identified elsewhere. In QBH1 Peat is recorded at between -0.85 and -2.52m OD, separated by a horizon of organic alluvium between -1.35 and -1.94m OD; in QBH2 the Peat is recorded at between -2.20 and -2.81m OD. Towards the southeast of the site, Peat was recorded in BGS borehole TQ37NE2157 (-0.38 and -3.68m OD). No Peat was recorded in the majority of the existing geotechnical boreholes; however, none of these boreholes penetrated beyond 4m depth, and only in MWS5 was the surface of the Peat recorded (-0.7m OD). The thickness of the Peat is therefore variable across the site, recorded as 1.67m in QBH1 (inclusive of the intervening organic Alluvium), 0.61m in QBH2 and 3.3m in TQ37NE2157 (Figure 6).

Two radiocarbon determinations were undertaken on the top & base of the Peat to ascertain when accumulation commenced / ceased (i.e. four in total). Unfortunately the dates are reversed providing 4830-4570 cal BP, 6000-5900 cal BP (both from the base of the peat), 4840-4580 cal BP & 5300-5030 cal BP (both from the top of the peat). It is not possible to confidently ascertain the reason for this, it may be due to an erroneous date on one or more of these samples, or may represent the reworking of older sediment (by fluvial activity) as the channel infilled. However, high organic-matter values of >75% are more likely to represent an in situ origin for the radiocarbon dated twigs; as such 6000-5900 cal BP is considered most likely from the base of the peat, and 4840-4580 cal BP for the top of the peat. Radiocarbon determinations 4830-4570 and 5300-5030 cal BP from the top/base of the peat were undertaken on sediment of lower organic matter values and thus are more likely to be derived material.

Peat is frequently recorded across much of the wider area in thicknesses of up to 3m (Figures 7 & 14). Greater thicknesses tend to be recorded in areas where the Shepperton Gravel surface is lowest. Thus, thick horizons have been recorded at Alcatel-Lucent, Enderby Wharf (Batchelor *et al.*, 2015) and 20 Horn Lane (Batchelor & Young, 2017) for example. Similarly to Alcatel-Lucent, the Peat at Enderby Wharf is actually a complex of interdigitating alluvial and peat layers, most likely reflective of changing hydrological conditions during the infilling of the channel.

As above, in the analysed Alcatel-Lucent QBH2 sequence, the Peat is relatively thin (0.5m) and seemingly accumulated between 6000-5900 and 4840-4580 cal BP (beginning to end of the Neolithic). At Enderby Wharf, the complex of Peat units is around 2m thick dating from 5450-5070 to 3290-3230 cal BP (middle Neolithic to late Bronze Age) (Figure 13). More widely, even in areas of high gravel topography (e.g. Bellot Street & Lombard Wall), important Peat horizons have been recorded. In these higher locations, the Peat tends to date from the Bronze Age period onwards (Branch *et al.*, 2005; Young *et al.*, 2011). Indeed it is such locations that are more likely to contain archaeological remains on the basis of previous findings.

4.5 Upper Alluvium

The Upper Alluvium rests on the Peat and was recorded in all records across the site. 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 deposits of the Upper Alluvium are described as predominantly silty or clayey which are very occasionally organic-rich. The surface of the Upper Alluvium is relatively even, generally lying at between 0.5 and 1m OD (Figures 9 & 13).

The Total Alluvium thickness (incorporating Sand, Lower Alluvium, Peat and Upper Alluvium) is displayed in Figures 10 (local area) and 11 (wider area). The thickness of the Total Alluvium tends to reflect the model of the Gravel surface, with greater thicknesses recorded in areas of low Gravel topography and vice versa as might be expected.

4.6 Made Ground

The sequence at the site is capped by between 1.0 and 1.5m of Made Ground (Figure 12), so that the modern surface of the site lies at between *ca*. 1.5 and 2.0m OD.

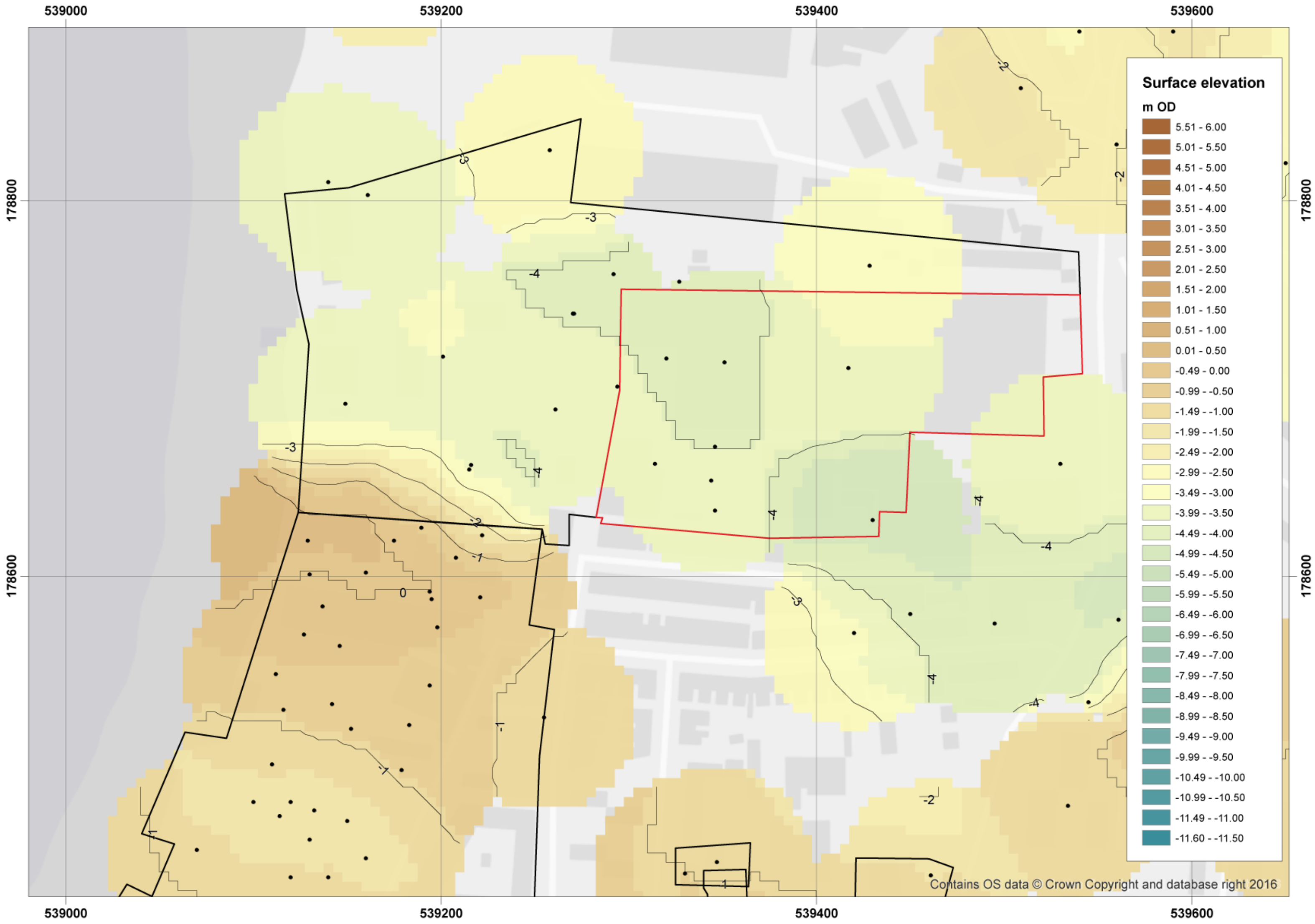

Figure 3: Surface of the Shepperton Gravel (m OD)

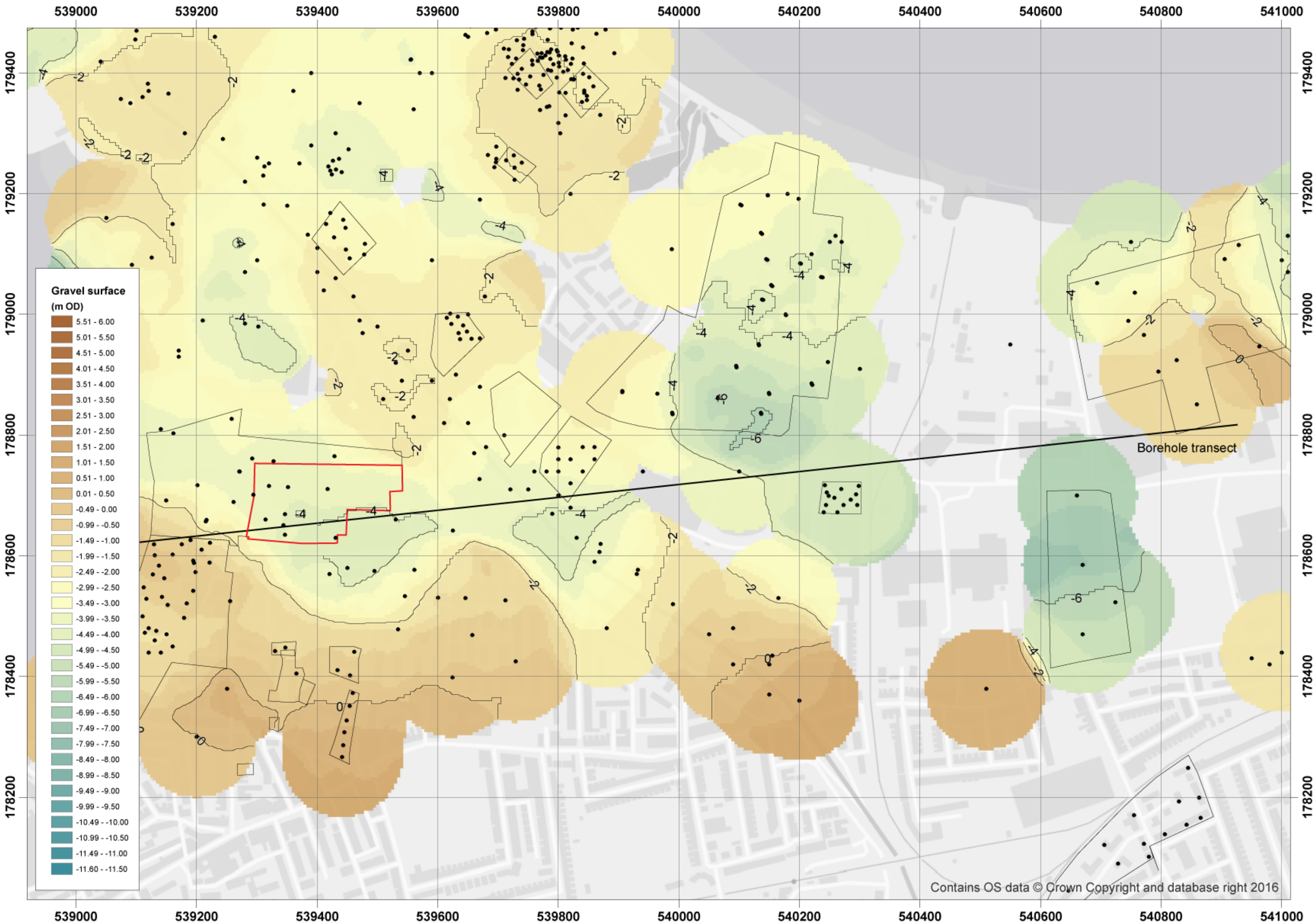

Figure 4: Wider surface of the Shepperton Gravel (m OD)

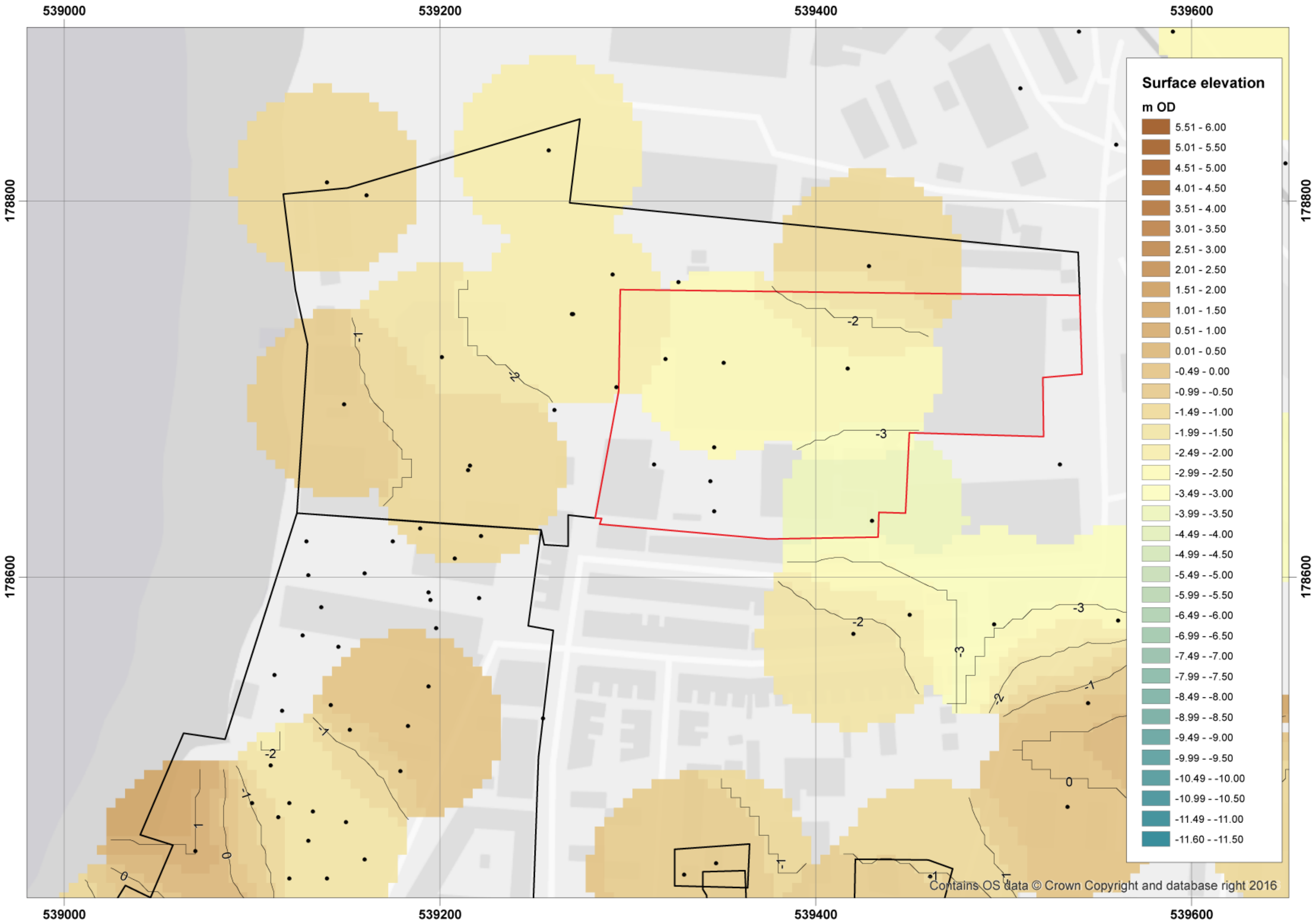

Figure 5: Surface of the Lower Alluvium (m OD).

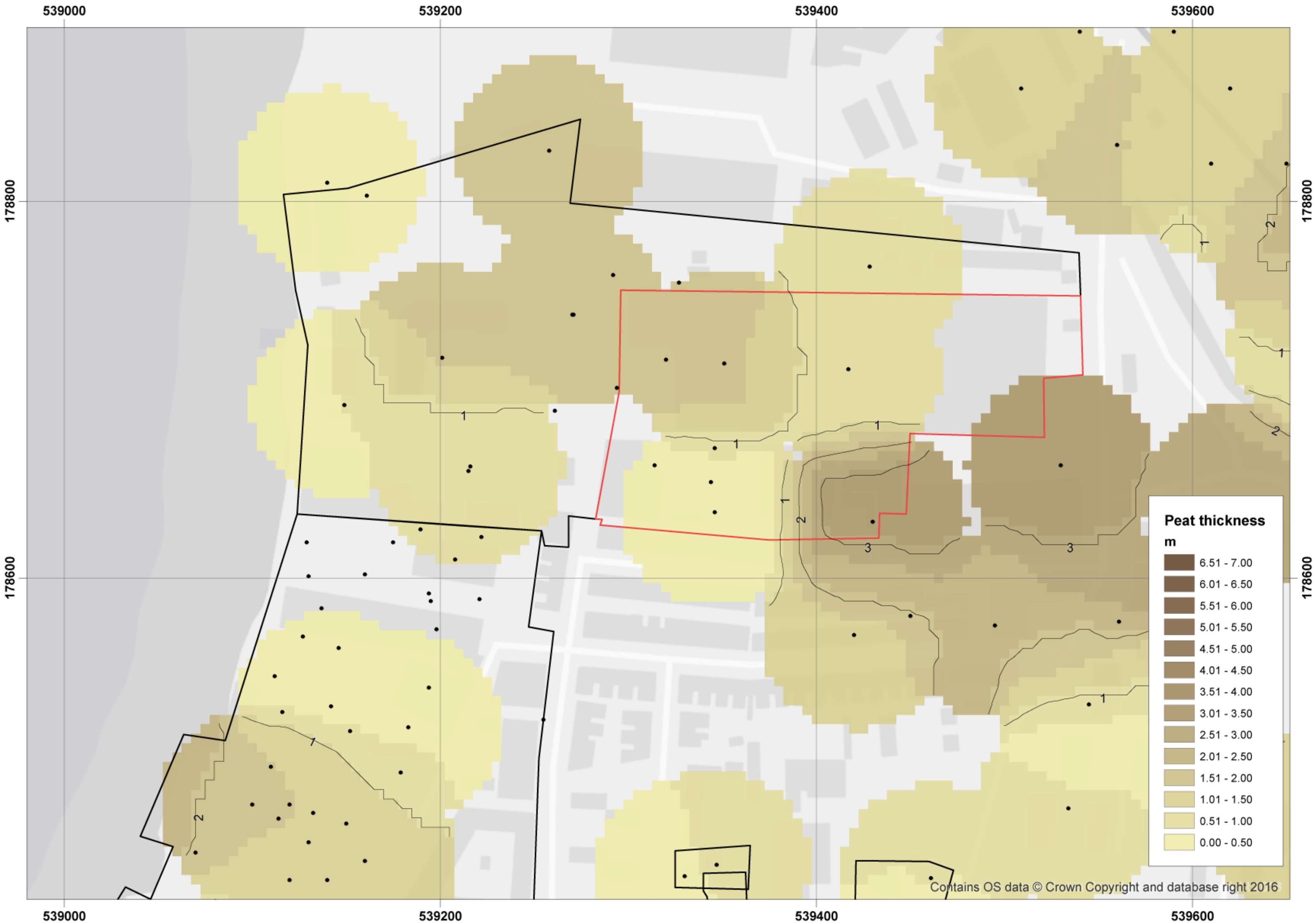

Figure 6: Thickness of the Peat (m)

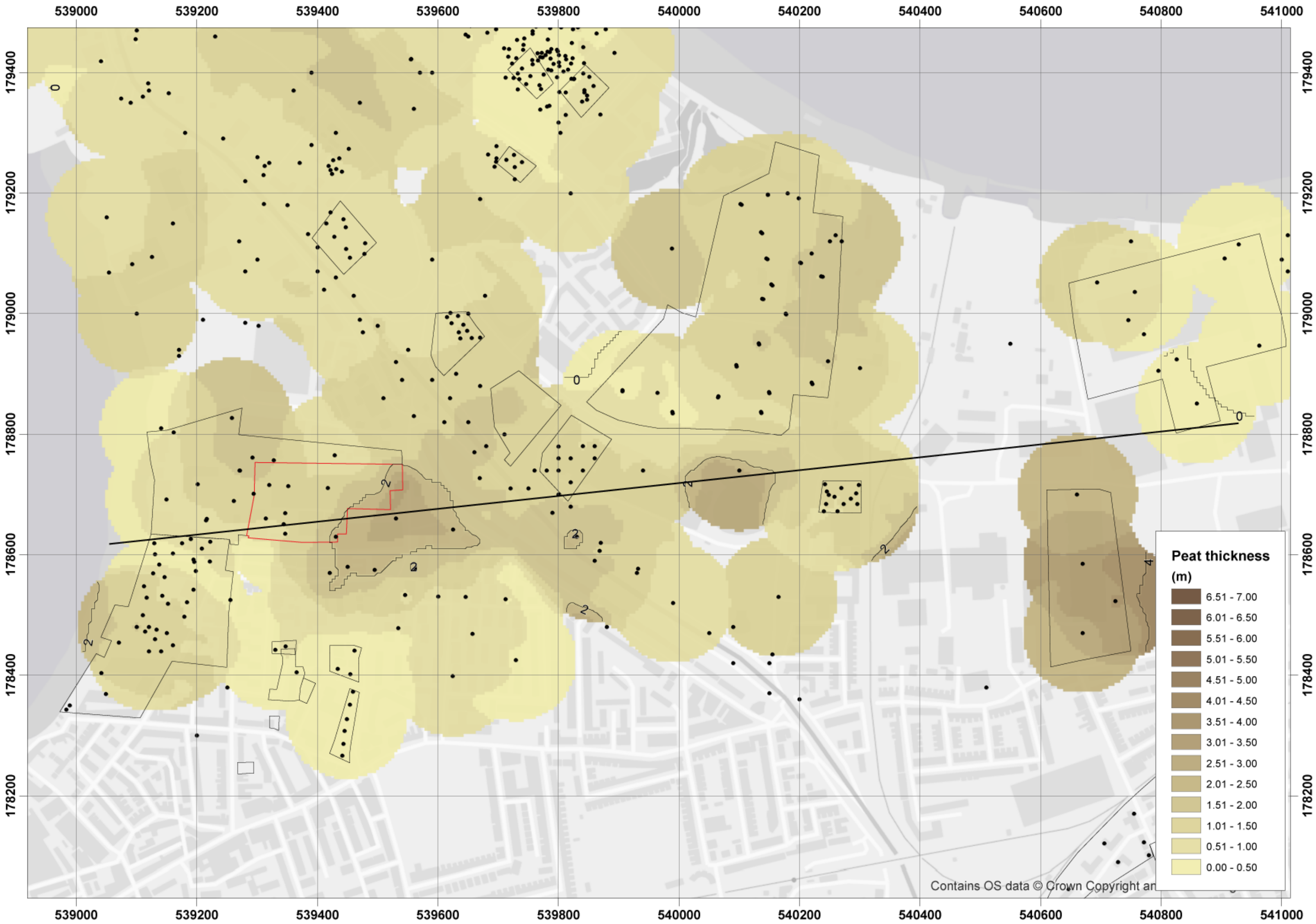

Figure 7: Wider thickness of the Peat (m)

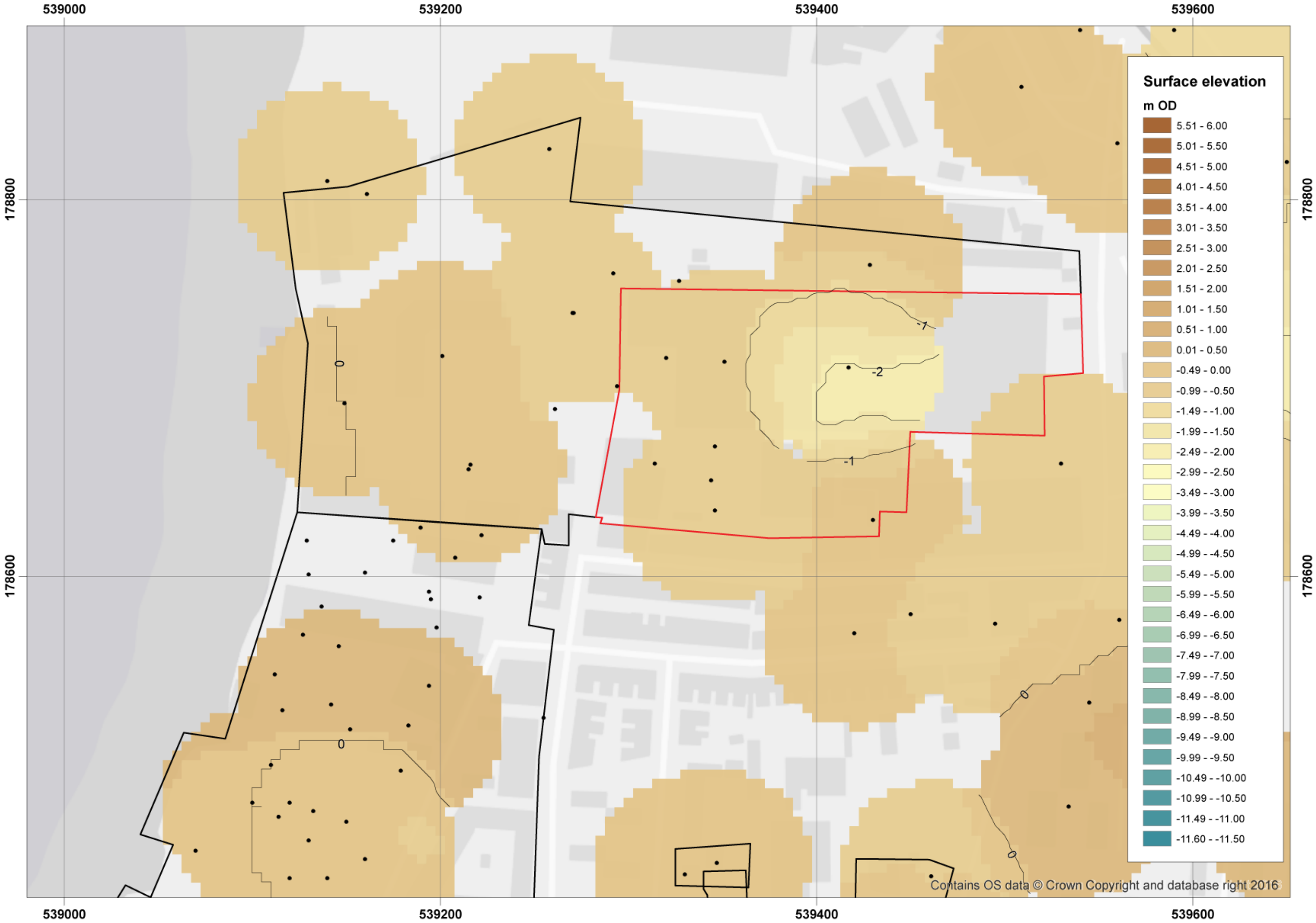

Figure 8: Surface of the Peat (m OD).

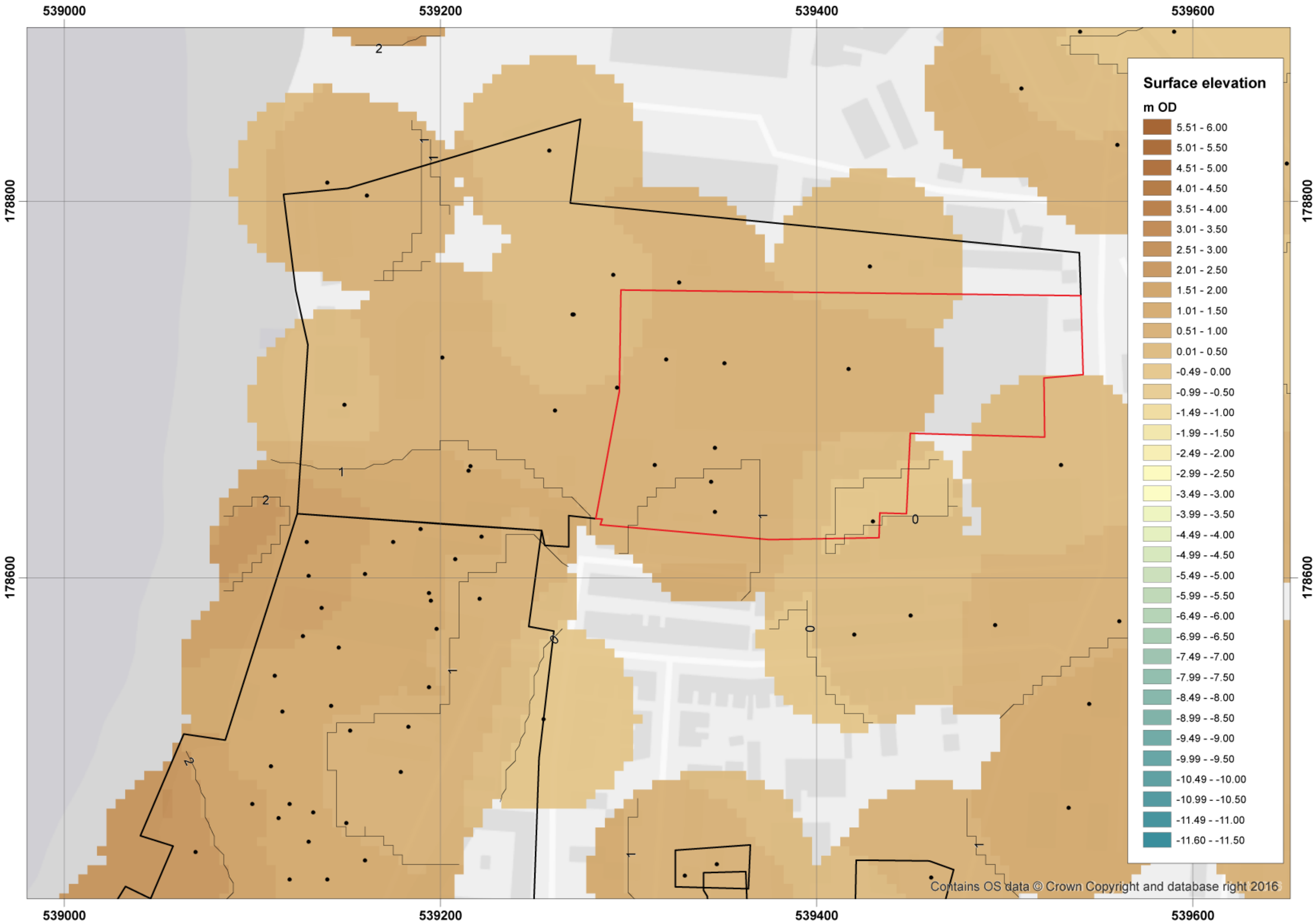

Figure 9: Surface of the Upper Alluvium (m OD)

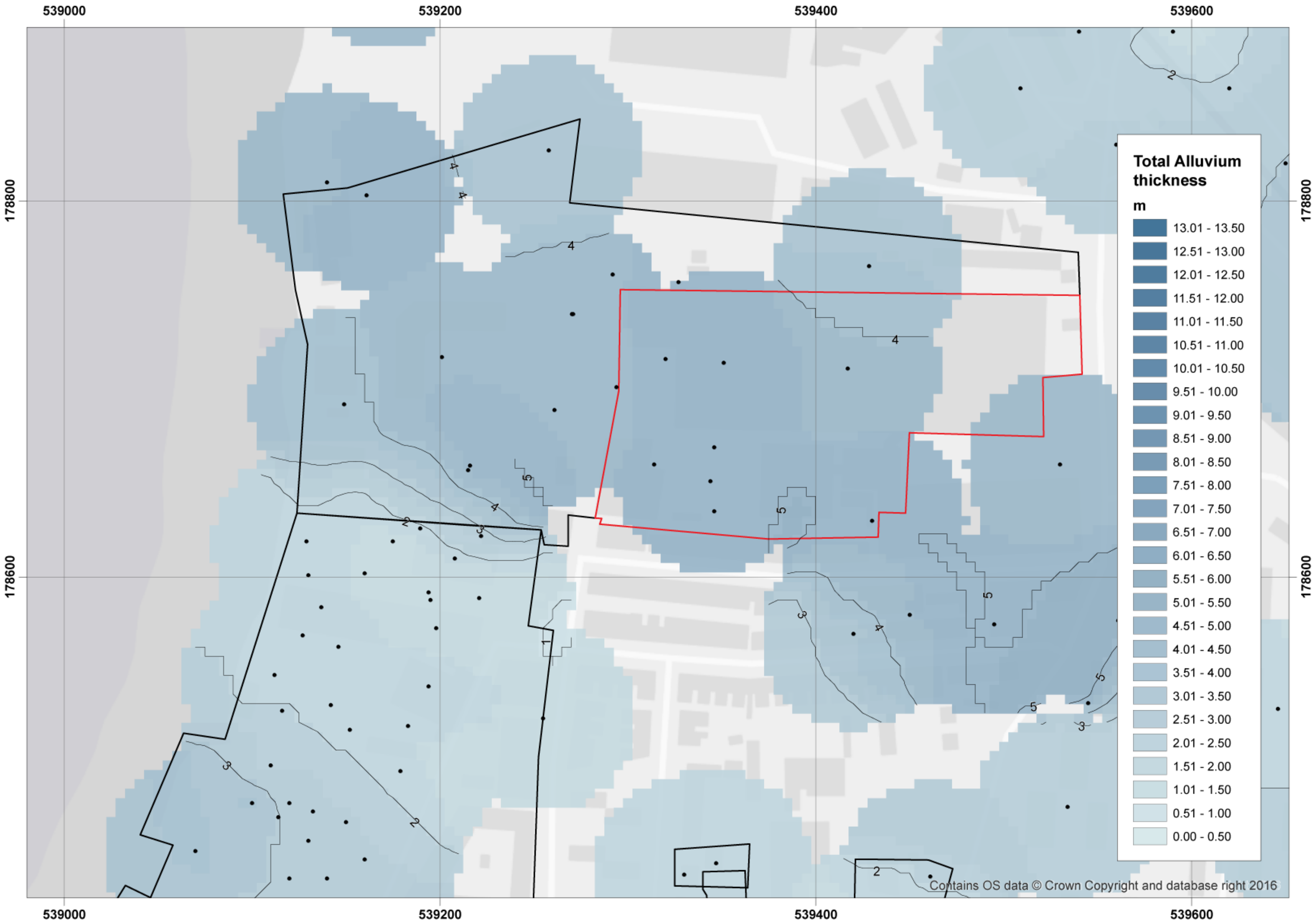

Figure10: Thickness of the Total Alluvium (incorporating the Sand, Lower Alluvium, Peat and Upper Alluvium) (m)

Figure 11: Wider thickness of the Total Alluvium (incorporating the Sand, Lower Alluvium, Peat and Upper Alluvium) (m)

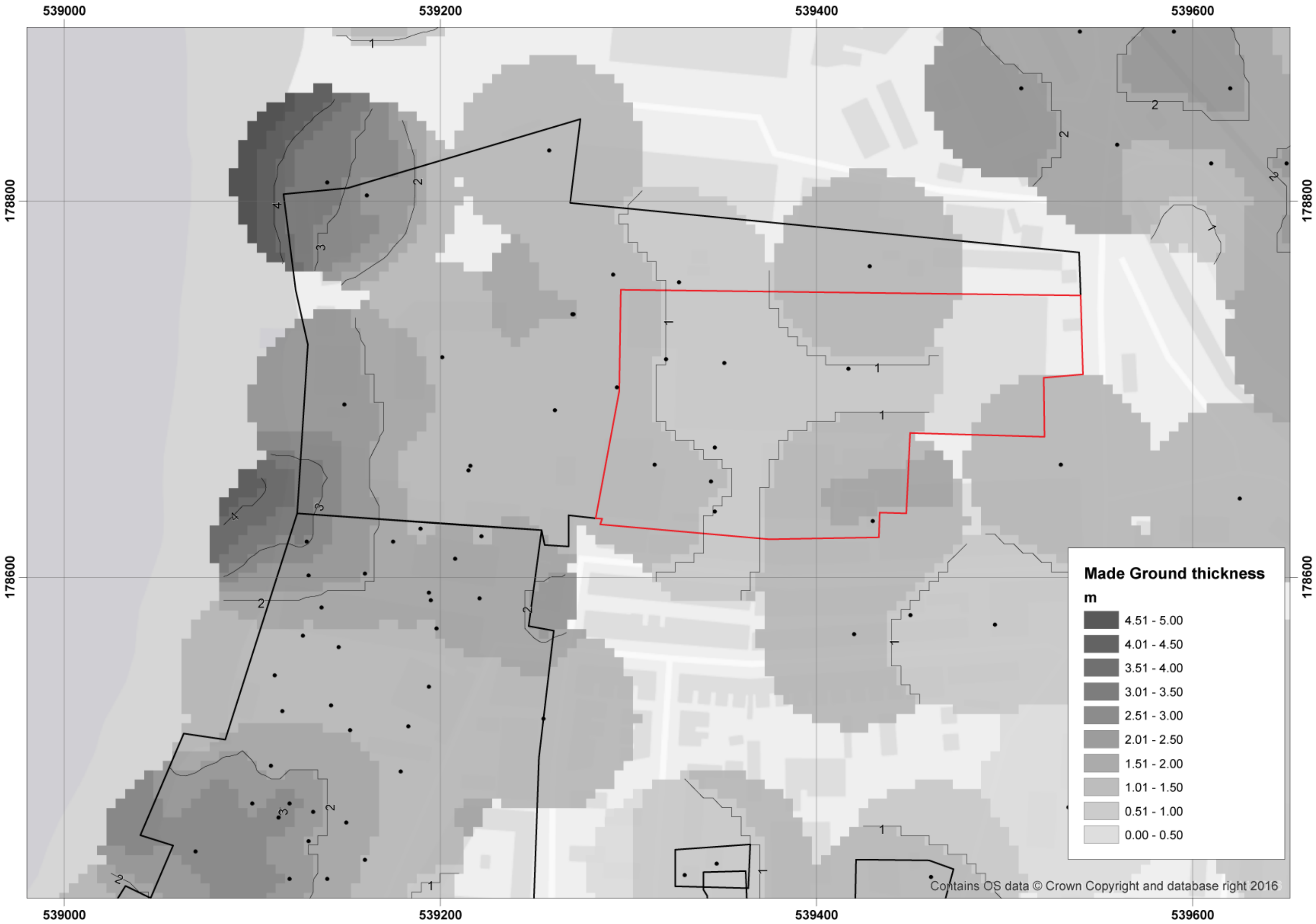

Figure 12: Thickness of the Made Ground (m)

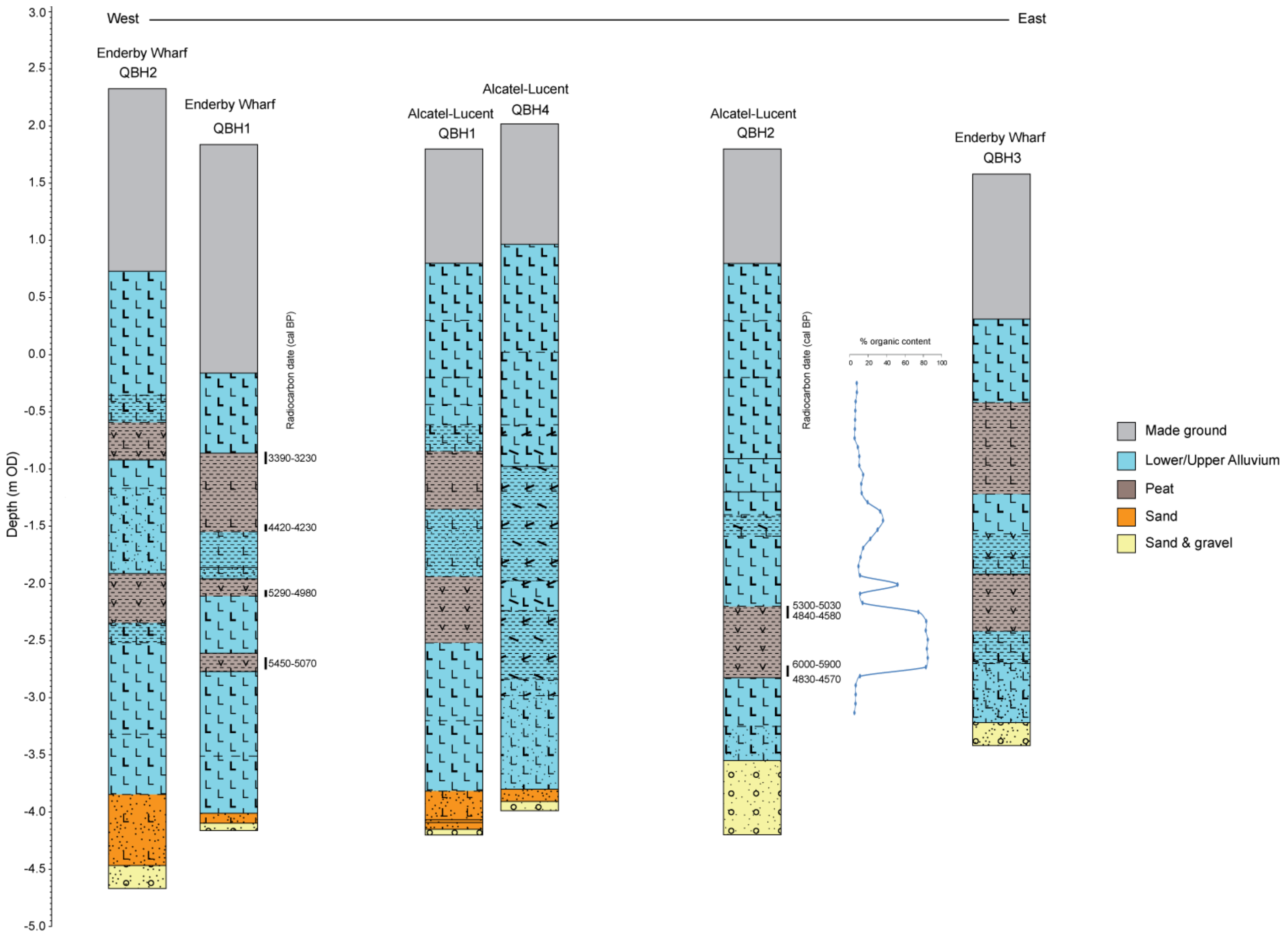

Figure 13: Transect of boreholes across the Alcatel-Lucent & Enderby Wharf sites, including the results of the radiocarbon dating and organic matter determinations

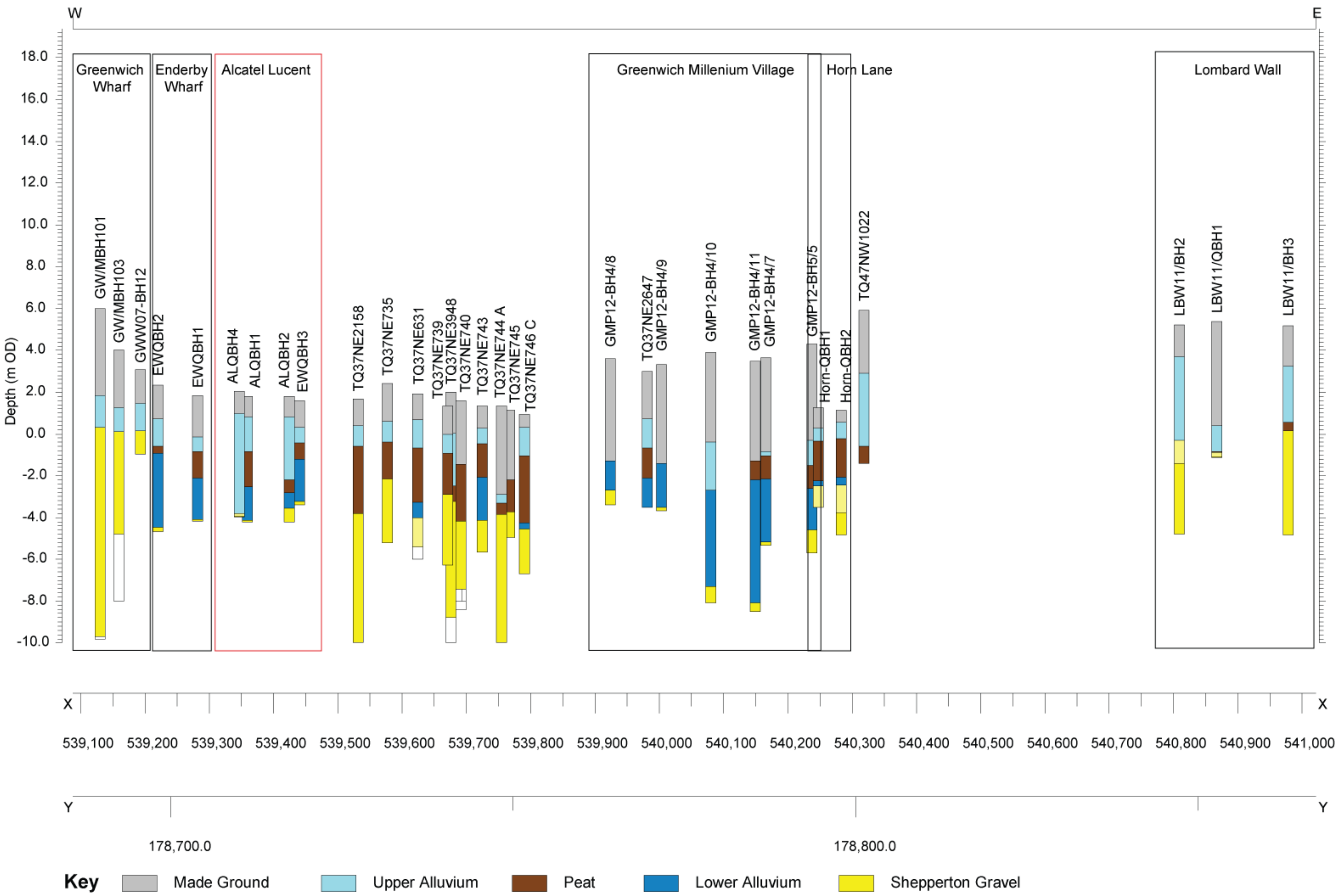

Figure 14: East-west transect across the site and wider area.

Table 2: Lithostratigraphic description of borehole QBH1, Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10.

Depth (m OD)	Depth (m bgs)	Composition	Stratigraphic Unit
1.80 to 0.80	0.00 to 1.00	Made Ground	MADE GROUND
0.80 to 0.30	1.00 to 1.50	As3 Ag1; brown silty clay with frequent iron staining particularly in worm and root hollows. Diffuse contact in to:	UPPER ALLUVIUM
0.30 to -0.20	1.50 to 2.00	As3 Ag1; blue grey silty clay with some iron staining.	
-0.20 to -0.44	2.00 to 2.24	Gley 1 4/10Y; Ag2 As2; dark greenish grey clay and silt with iron staining. Diffuse contact in to:	
-0.44 to -0.61	2.24 to 2.41	Gley 1 5/N; Ag3 As1; grey clayey silt with less frequent iron staining. Diffuse contact in to:	
-0.61 to -0.85	2.41 to 2.65	7.5YR 4/1; Ag2 As1 Sh1 Dl+ Dh+; dark grey organic clayey silt with traces of detrital wood and detrital herbaceous material. Diffuse contact in to:	
-0.85 to -1.35	2.65 to 3.15	7.5YR 3/1; Sh3 Ag1 Th+ Tl+; humo. 2/3; very dark grey moderately to well humified silty peat with traces of wood and herbaceous material. Diffuse contact in to:	PEAT
-1.35 to -1.94	3.15 to 3.74	10YR 4/1; Ag2 Ga1 Sh1 Dl+ Dh+; dark grey organic sandy silt with traces of detrital wood and detrital herbaceous material. Some more organic or sandy horizons within this unit. Diffuse contact in to:	
-1.94 to -2.52	3.74 to 4.32	10YR 2/1; Sh3 Tl^{2}1 Ag+; humo. 2; black woody moderately humified peat with a trace of silt.	
-2.52 to -3.20	4.32 to 5.00	Gley 1 5/10Y; Ag3 As1 Dl+; greenish grey clayey silt with a trace of detrital wood.	LOWER ALLUVIUM
-3.20 to -3.82	5.00 to 5.62	Gley 1 6/10Y; Ag3 As1 Ga+ Dl+; greenish grey clayey silt with a trace of sand and detrital wood. Diffuse contact in to:	
-3.82 to -4.07	5.62 to 5.87	Gley 1 5/10Y; Ga2 Ag2; greenish grey sand and silt. Sharp contact in to:	
-4.07 to -4.09	5.87 to 5.89	Gg3 Ga1; sandy gravel. Clasts are flint, up to 20mm in diameter, sub-angular to sub-rounded. Sharp contact in to:	SHEPPERTON GRAVEL
-4.09 to -4.15	5.89 to 5.95	Gley 1 5/10Y; Ga2 Ag2; greenish grey sand and silt. Sharp contact in to:	
-4.15 to -4.20	5.95 to 6.00	Gg3 Ga1; sandy gravel. Clasts are flint, up to 30mm in diameter, sub-angular to sub-rounded.	

Table 3: Lithostratigraphic description of borehole QBH2, Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10.

Depth (m OD)	Depth (m bgs)	Composition	Stratigraphic unit
1.80 to 0.80	0.00 to 1.00	Made Ground	MADE GROUND
0.80 to 0.30	1.00 to 1.50	As3 Ag1; brown silty clay with frequent iron staining particularly in worm and root hollows. Diffuse contact in to:	UPPER ALLUVIUM
0.30 to -0.20	1.50 to 2.00	As3 Ag1; blue grey silty clay with some iron staining.	
-0.20 to -0.92	2.00 to 2.72	10YR 5/2; As3 Ag1; greyish brown silty clay with some iron staining. Diffuse contact in to:	
-0.92 to -1.20	2.72 to 3.00	10YR 4/2; Ag3 As1 Sh+ Dl+; dark greyish brown clayey silt with traces of organic matter and detrital wood.	

Depth (m OD)	Depth (m bgs)	Composition	Stratigraphic unit
-1.20 to -1.40	3.00 to 3.20	2.5Y 4/1; Ag3 As1 Dh+; dark grey clayey silt with a trace of detrital wood. Diffuse contact in to:	
-1.40 to -1.59	3.20 to 3.39	2.5Y 3/1; Ag2 Sh1 Dl1 Ga+; very dark grey organic silt with detrital wood and a trace of sand. Diffuse contact in to:	
-1.59 to -2.20	3.39 to 4.00	Gley 1 4/10Y; Ag3 As1 Sh+ Dl+; dark grey clayey silt with traces of organic matter and detrital wood.	
-2.20 to -2.81	4.00 to 4.61	10YR 2/1; Sh2 Tl^{2}2 Th+ Ag+; humo. 2; black moderately humified wood peat with traces of herbaceous material and silt. Sharp contact in to:	PEAT
-2.81 to -3.20	4.61 to 5.00	Gley 1 4/10Y; Ag2 As2 Dh+ Ga+; dark greenish grey clay and silt with traces of detrital herbaceous material and sand.	LOWER ALLUVIUM
-3.20 to -3.54	5.00 to 5.34	Gley 1 5/10Y; Ag2 As1 Ga1 Dh+; greenish grey sandy clayey silt with a trace of detrital herbaceous material. Some vertical sedge rooting. Sharp contact in to:	
-3.54 to -4.20	5.34 to 6.00	Gg3 Ga1; sandy gravel. Clasts are flint, up to 40mm in diameter, sub-angular to well-rounded.	SHEPPERTON GRAVEL

Table 4: Lithostratigraphic description of borehole QBH4, Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10.

Depth (m OD)	Depth (m bgs)	Composition	Stratigraphic unit
2.02 to 1.02	0.00 to 1.00	Made Ground	MADE GROUND
1.02 to 0.97	1.00 to 1.05	Disturbed Alluvium (Made Ground)	
0.97 to 0.02	1.05 to 2.00	As3 Ag1; blue grey silty clay with some iron staining.	UPPER ALLUVIUM
0.02 to -0.61	2.00 to 2.63	Gley 1 5/10Y; Ag2 As2; greenish grey clay and silt. Diffuse contact in to:	
-0.61 to -0.98	2.63 to 3.00	10YR 3/1; Ag2 As1 Dl1 Dh+ Sh+; very dark grey clayey silt with detrital wood and traces of detrital herbaceous material and organic matter.	
-0.98 to -1.98	3.00 to 4.00	10YR 4/1; Ag2 Sh1 Dl1 Dh+; dark grey organic silt with detrital wood and a trace of detrital herbaceous material.	
-1.98 to -2.24	4.00 to 4.26	10YR 3/1; Ag2 As1 Dl1 Sh+ Ga+; very dark grey clayey silt with detrital wood and traces of organic matter and sand. Diffuse contact in to:	
-2.24 to -2.84	4.26 to 4.86	10YR 2/1; Ag2 Sh1 Dl1 Ga+; black organic silt with detrital wood and a trace of sand. Some more sandy horizontal beds. Diffuse contact in to:	
-2.84 to -2.98	4.86 to 5.00	Gley 1 5/10Y; Ag2 Ga1 Dl1; greenish grey sandy silt with detrital wood. Frequent Mollusca.	LOWER ALLUVIUM
-2.98 to -3.80	5.00 to 5.82	Gley 1 5/10Y; Ag2 As1 Ga1 Gg+; greenish grey sandy clayey silt with occasional gravel clasts. Very sharp contact in to:	
-3.80 to -3.91	5.82 to 5.93	Gley 1 4/10Y; Ga4 Ag+; dark greenish grey sand with a trace of silt. Sharp contact in to:	SAND
-3.91 to -3.98	5.93 to 6.00	Gg3 Ga1; sandy gravel. Clasts are flint, up to 40mm in diameter, sub-angular to well-rounded.	SHEPPERTON GRAVEL

Table 5: Results of the borehole QBH2 organic matter determinations, Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10.

Depth (m OD)		Organic matter content (%)
From	To	
-0.25	-0.26	7.67
-0.33	-0.34	7.81
-0.41	-0.42	6.46
-0.49	-0.50	6.07
-0.57	-0.58	5.86
-0.65	-0.66	5.58
-0.73	-0.74	5.33
-0.81	-0.82	8.84
-0.89	-0.90	10.44
-0.97	-0.98	10.45
-1.05	-1.06	14.55
-1.13	-1.14	12.57
-1.21	-1.22	12.96
-1.29	-1.30	19.41
-1.37	-1.38	33.20
-1.45	-1.46	36.19
-1.53	-1.54	30.30
-1.61	-1.62	22.38
-1.69	-1.70	14.55
-1.77	-1.78	11.73
-1.85	-1.86	9.54
-1.93	-1.94	11.19
-2.01	-2.02	51.98
-2.09	-2.10	11.25
-2.17	-2.18	13.95
-2.25	-2.26	74.62
-2.33	-2.34	83.09
-2.41	-2.42	82.59
-2.49	-2.50	84.80
-2.57	-2.58	83.86
-2.65	-2.66	84.76
-2.73	-2.74	82.75
-2.81	-2.82	11.14
-2.89	-2.90	6.51
-2.97	-2.98	6.47
-3.05	-3.06	6.28
-3.13	-3.14	5.14

Table 6: Results of the borehole QBH2 radiocarbon dating, Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10.

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)	**δ**13C (‰)
BETA 423497	Twig wood; top of peat	-2.20 to -2.25	4490 ± 30 BP	3350-3090 cal BC 5300-5030 cal BP	-31.0
BETA 461556	Twig wood; top of peat	-2.25 to -2.30	4170 ± 30 BP	2890-2630 cal BC 4840-4580 cal BP	-25.1
BETA 461555	Twig wood; base of peat	-2.71 to -2.76	5180 ± 30 BP	4050-3950 cal BC 6000-5900 cal BP	-28.0
BETA 423496	Twig wood; base of peat	-2.76 to -2.81	4150 ± 30 BP	2880-2620 cal BC 4830-4570 cal BP	-26.1

5. RESULTS AND INTEPRETATION OF THE DIATOM ANALYSIS

Diatom analysis was targeted on the Alluvial and Peat sediments with the aim of ascertaining the nature of the hydrological conditions during infilling of the large palaeochannel. A summary of the diatom results are provided in Table 7 and Figure 15. Only a single sample (-2.18m OD) contained diatoms in sufficient abundance to achieve a full count. Diatoms were absent in the lowermost three samples, and only occasional diatom frustules were encountered in the upper peat sample (-2.22m OD). When encountered, in the majority of cases, taxa were identifiable to species level, but in some instances, identifications were only possible to genera level.

Table 7 displays the diatom species present within each sample. The diatoms are divided into 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. Tychoplankton are species encountered in both planktonic and benthic settings. 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.

In addition, benthic taxa are considered to provide a more reliable indicator of palaeoenvironmental conditions. 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 transported after death.

Due to the fact that the vast majority of taxa encountered in sample -2.18m OD were marine and brackish species, the assemblage 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 therefore summarises the diatom assemblage compositions that are associated with differing elevations within the littoral zone and Figure 15 summarises the categories when applied to the diatom sequence.

4.1 Results of the diatom analysis

Diatom preservation was very good in sample -2.18m OD from the Upper Alluvium. There was evidence of some frustule dissolution, especially on the diatoms that could not be unidentifiable to species level (commonly the larger taxa, such as *Pinnularia*), but overall, those taxa present are commonly associated with one another to suggest the assemblage survived any significant post-depositional modification. In the sample from the top of the Peat at -2.22m OD, only isolated marine planktonic and tychoplanktonic taxa were present. The assumed 'semi-terrestrial' nature of these peat deposits means that post-depositional fluctuations in the water table can result in silica dissolution by redox and the associated presence of humic acids. The lowermost three samples from the Peat and Lower Alluvium contained no diatoms. The abundance of sand in the basal sample may contribute towards explaining this absence, due to the much higher depositional energy conditions often associated with sandy substrates, but post-depositional sediment oxidation is also a likely contributing factor.

Analysis and discussion therefore focuses on the single assemblage from the Upper Alluvium. The diatom assemblages display a clear dominance of marine, marine brackish and brackish taxa, with planktonic, tychoplanktonic and benthic species contributing to the floral diversity. Of the benthic taxa present, most are typically associated with muddy substrates, and some are aerophilous taxa (and hence require periods of sub-aerial exposure). Taking into account the diatom assemblage and stratigraphic context, the vertical shift from a peat into an upper alluvium would therefore be indicative of a rise in relative sea level.

The assemblage is characterised by planktonic taxa (*ca*. 25% TDV - Total Diatom Valves), with the key taxa being *Paralia sulcata*, *Pseudomelosira westii*, *Pseudopodosira stelligera*. Tychoplanktonic taxa, represented by *Rhaphoneis amphiceros* and *Delphineis surirella*, contribute a further *ca*. 20% TDV. The benthic taxa comprise *ca*. 45% TDV, primarily through the abundance of the marine brackish species *Nitzschia navicularis, Nitzschia punctata, Diploneis didyma* and *Diploneis interrupta*.

Figure 15 summarises the interpretation of the ecological groupings encountered within the sample from -2.18m OD, in accordance with the scheme of Vos and de Wolf (1993), which provides a greater insight into both the ecological and lifeform affiliations of the species, specifically describing the variations in benthic groups. Taking into account the abundance/dominance of marine brackish epipelon and aerophilious species, the scheme interprets the diatom assemblage encountered at -2.18m OD as having been deposited on a 'saltmarsh around MHW' (mean high water) .

4.2 Interpretation & discussion of the diatom analysis

The diatom assemblages present within borehole QBH2 were restricted to a single sample at -2.18m OD. Whilst unfortunate, the small data set still provides valuable information about the transition from Peat to Upper Alluvium to contribute to our palaeoenvironmental understanding of the site.

The presence of peat interbedded with minerogenic units (sands, silts and clays), mirror interbedded sequences encountered throughout much of the Lower Thames Valley. When preserved, diatom flora associated with more 'freshwater' depositional settings would be expected to be encountered in organic-rich/Peat units, whilst by marine-brackish taxa are associated with the overlying/underlying Upper/Lower Alluvium. The presence of isolated marine diatoms within the peat unit can be disregarded; the taxa present (*Pseudomelosira westi*, *Rhaphoneis amphiceros*) are both live as plankton/tychoplankton and hence live much of their life cycle floating in the water column. Their presence is therefore likely indicative of inundation of an essentially freshwater setting by isolated extreme high tides. The absence of any minerogenic component to the sediment, alongside the absence of other diatoms further supports this as the depositional setting is likely to have been semi-terrestrial, ensuring water tables were sufficiently low to prevent diatom preservation of any of the expected freshwater flora.

The subsequent shift from freshwater Peat into Upper Alluvium can be interpreted as evidence of a rise in relative sea level, based on the diatom flora encountered. An alternative explanation could have been that a shift to floodplain deposition occurred as a result of a migrating river channel; however, the near exclusive presence of marine, marine brackish and brackish taxa (and absence of freshwater epipelon or aerophilous taxa) indicates the dominance of estuarine conditions.

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. Unfortunately, since only a single sample could be analysed, the ability to infer change over time is restricted. However, the Vos and de Wolf (1993) scheme suggests that, very soon after the shift from biogenic to minerogenic sedimentation, deposition was taking place in the intertidal zone, on a saltmarsh elevated proximal to MHW. The assemblage indicates that, very soon after the shift to minerogenic sedimentation had occurred, deposition was already taking place down the tidal frame towards the saltmarsh-mudflat transition. The fact that deposition higher up on the saltmarsh is not suggested, infers that the shift from terrestrial to estuarine conditions was relatively rapid. Radiocarbon determinations from the top of the underlying Peat indicates that the transition into the Upper Alluvium took place shortly after 4840-4580 cal BP. The earlier shift from the Lower Alluvium into the Peat has been dated to sometime before 4050-3950 cal BC (6000-5900 cal BP).

It is unfortunate that diatoms were absent from the remaining stratigraphic archive, and hence the single diatom assemblage in which diatoms were encountered in abundance only provides a snapshot of the environmental conditions that prevailed at Alcatel-Lucent during the Bronze Age. However, the diatom assemblages does confirm the influence of relative sea level on the Thames lowlands at this time, by recording the drastic shift from freshwater-dominated to estuarine-dominated conditions, sometime after 4840-4580 cal BP.

Table 7: Diatom flora encountered during analysis of QBH2, Alcatel-Lucent Telegraph Works, London Borough of Greenwich

	Species		Sample Depth (m O.D.)				
			-2.18	-2.22	-2.84	-2.8	-3.2
Planktonic	*Actinoptychus senarius*	M Plank	4	0	0	0	0
	Paralia sulcata	M Plank	32	0	0	0	0
	Pseudomelorira westii	M Plank	42	5	0	0	0
	Pseudopodosira stelligera	M Plank	19	0	0	0	0
	Thalassiosira sp.	M Plank	3	0	0	0	0
	Triceratium favus	M Plank	5	0	0	0	0
	Delphineis surirella	M Tych	19	0	0	0	0
	Rhaphoneis amphiceros	M Tych	64	1	0	0	0
	Cyclotella striata	B Plank	9	0	0	0	0
	Cyclotella meneghianina	BF Plank	2	0	0	0	0
	Diploneis ovalis	MB Aero	12	0	0	0	0
	Diploneis interrupta	MB Aero	43	0	0	0	0
	Campylodiscus echeneis	MB Epipel	9	0	0	0	0
	Diploneis didyma	MB Epipel	50	0	0	0	0
	Nitzschia hungarica	MB Epipel	2	0	0	0	0
	Nitzschia navicularis	MB Epipel	81	0	0	0	0
	Nitzschia punctata	MB Epipel	23	0	0	0	0
	Epithemia adnata	F Epiphyt	5	0	0	0	0
	Pinnularia sp.	unknown	4	0	0	0	0
	Total		428	6	0	0	0

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

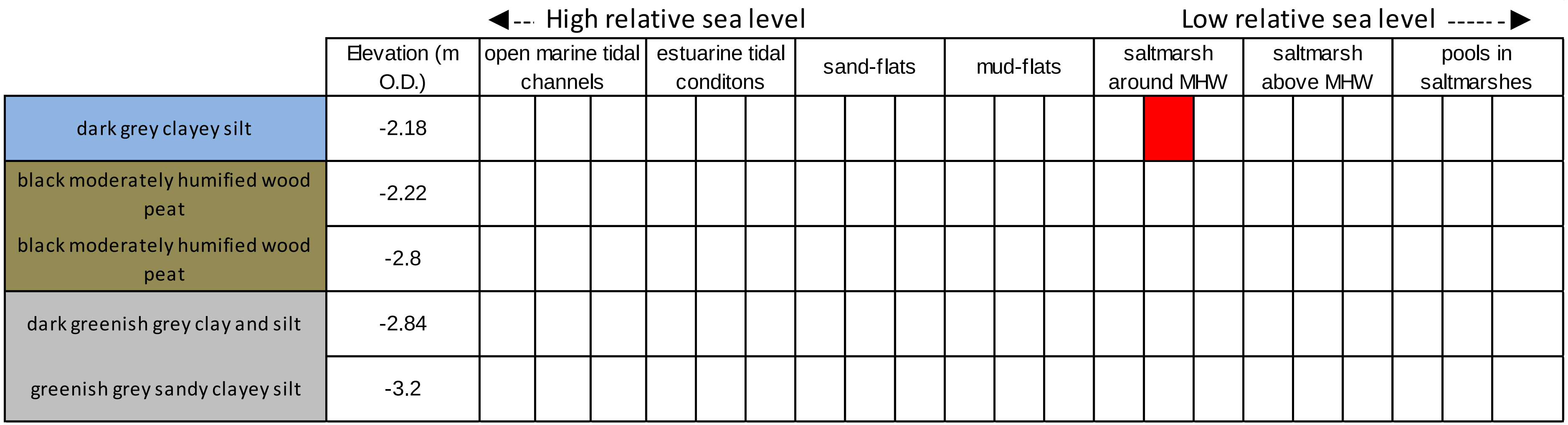

Figure 15: Summary of diatom salinity & lifeform classifications in accordance with the classification scheme of Vos & de Wolf (1993), associated with assemblages encountered Borehole QBH2, Alcatel-Lucent Telegraph Works, London Borough of Greenwich

6. RESULTS, INTERPRETATION & DISCUSSION OF THE POLLEN ANALYSIS

6.1 Results of the pollen analysis

Figure 16 has been divided into two local pollen assemblage zones (LPAZs BLW-1 & 2) based upon the results of the pollen-stratigraphical analysis.

LPAZ BLW-1 -2.74 to -2.20m OD *Quercus* – Cyperaceae - *Alnus*

This zone is characterised by moderate to high values of tree pollen (50%): Quercus dominates (35%) with *Alnus* (15%), *Tilia (5%)*, and sporadic occurrences of *Pinus* and *Fraxinus* (both <5%). Shrubs (10%) are dominated by *Corylus* type with sporadic occurrences of *Salix*. Herbs are dominated by Cyperaceae (increasing from 20 to 50%) with Poaceae, Apiaceae, and *Chenopodium* type (all <4%). Aquatic taxa are represented by *Sparganium* type only (<2%) with a spike in *Potamogeton* type towards the top of the zone (5%). Spores are dominated by *Filicales* (increasing from 20 to 50%) with *Pteridium aquilinum* and *Polypodium vulgare*.

LPAZ BLW-2 -2.20 to –0.66m OD *Quercus* – Cyperaceae – *Alnus* – *Pinus*

This zone is characterised by a general decrease in arboreal pollen percentage values (ca. 70%-30%): *Quercus* (20%), *Alnus* and *Pinus* (both 10%) dominate with sporadic occurrences of *Betula*, *Ulmus* and *Tilia*. Shrubs (10%) are dominated by *Corylus* type (10%) with *Salix, Sambucas nigra and Calluna vulgaris*. Herbs increase in diversity, dominated by Cyperaceae (20%) with Poaceae, Lactuceae, *Chenopodium* type, *Artemisia*, *Plantago lanceolata, Asteraceae, Ranunculus* type and *Cereale* type. Aquatic values are limited including sporadic occurrences of *Sparganium* type, *Potamogeton* type and *Nymphaea*. Spores are dominated by *Filicales* (50-<5%) with *Pteridium aquilinum* and *Polypodium vulgare*.

6.2 Interpretation and discussion of the pollen analysis

LPAZ BLW-1 -2.74 to -2.20m OD *Quercus* – Cyperaceae - *Alnus*

The results of the pollen-stratigraphical analysis indicate that during LPAZ BLW-1 (6000-5900 to 4840-4580 cal BP), *alder (Alnus)* and willow (Salix) occupied the peat surface forming carr woodland. The presence of sedges (Cyperaceae), grasses (Poaceae - e.g. *Phragmites australis* - reeds), bur-reed (*Sparganium* type) and pondweed (*Potamogeton* type) also indicate the presence of sedge fen, reed swamp and areas of standing/slowly moving water. The environment indicated is therefore one of damp, swamp-like conditions rather than mature and dry fen-carr woodland. In addition, the *Chenopodium* type pollen is recorded throughout the zone, perhaps indicating the influence of saline conditions at the site; genera of the family Chenopodiaceae (goosefoot family) may be found growing 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).

Quercus (oak), *Betula* (birch) and *Corylus* type (e.g. hazel) may have accompanied alder on the floodplain surface. However, these taxa more commonly occur on the dryland where they would have formed a mosaic of mixed deciduous woodland with *Tilia* (lime). The entomophilous (insect pollinated) nature of *Tilia* suggests that even low percentages of pollen can represent the considerable growth of lime on the dryland. *Ulmus* pollen however is absent indicating that the sequence post-dates the well-documented middle Holocene (early Neolithic) elm decline that occurred across the Lower Thames Valley and British Isles between 6347 and 5281 cal BP (Parker *et al*., 2002; Batchelor *et al*., 2014).

No definitive evidence of human activity is recorded during this period. The presence of *Cereale*-type pollen might represent either cereal cultivation, a possibility which is enhanced by the nearby location of the archaeological activity on the channel margins to the south during the later Bronze Age. However, due to its isolated occurrence within a pollen sequence from an infilling channel exuding a strong swamp-like signal, it is more probable that this represents the growth of coastal grasses, which produce pollen with a similar morphology and size to that of cereal pollen grains (e.g. Andersen, 1979). Microcharcoal values are not recorded in sufficient values to indicate nearby burning.

The reconstructed vegetation on both the floodplain and dryland in the location of QBH2 on Alcatel-Lucent during LPAZ BLW-1 is very similar to that recorded during the same period on adjacent site Enderby Wharf (Batchelor *et al*., 2015). The main difference in the floodplain vegetation signal is the greater concentration of alder over sedges, grasses and aquatics in the Enderby Wharf sequence. And on the dryland, the stronger woodland signal in the Alcatel-Lucent sequence. These recorded variations could reflect either: (1) differing distances of each sequence from the dryland edge, or (2) variations in the hydrological conditions within the channel during its infilling.

LPAZ BLW-2 -2.20 to –0.66m OD *Quercus* – Cyperaceae – *Alnus* – *Pinus*

The transition to LPAZ BLW-2 (after 4840-4580 cal BP) is characterised by changes on both the floodplain and dryland. On the floodplain, a large increase in grasses, sedges, dandelions (Lactuceae), *Chenopodium* type and various herbs and aquatics are recorded. This assemblage is suggestive of a shift towards sedge fen, reed swamp and salt-marsh communities with an estuarine influence, most likely as a consequence of an increase in relative sea level rise (RSL). *Pinus* (pine) and *Pteridium aquilinum* (bracken) also increase during this period; these are taxa frequently over-represented in alluvial environments as a consequence of its morphology, which allows them to float long distances (e.g. Campbell, 1999). On the dryland, the decline of oak is suggestive of a large reduction in mixed deciduous 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. This would be supported by the nearby occurrence of archaeological remains close to the channel edge at Bellot Street (e.g. Branch *et al*., 2005; Philp & Garrod, 1994). An increase of microcharcoal, suggestive of nearby burning, is also recorded. *Cereale* taxa continue to be recorded, but as above, within the stratigraphic context, it is more likely that these represent the nearby growth of coastal grasses. Whether the decline of the floodplain and dryland woodland is linked is uncertain, but does seem to be a common feature of woodland within pollen-stratigraphic records from the Lower Thames Valley.

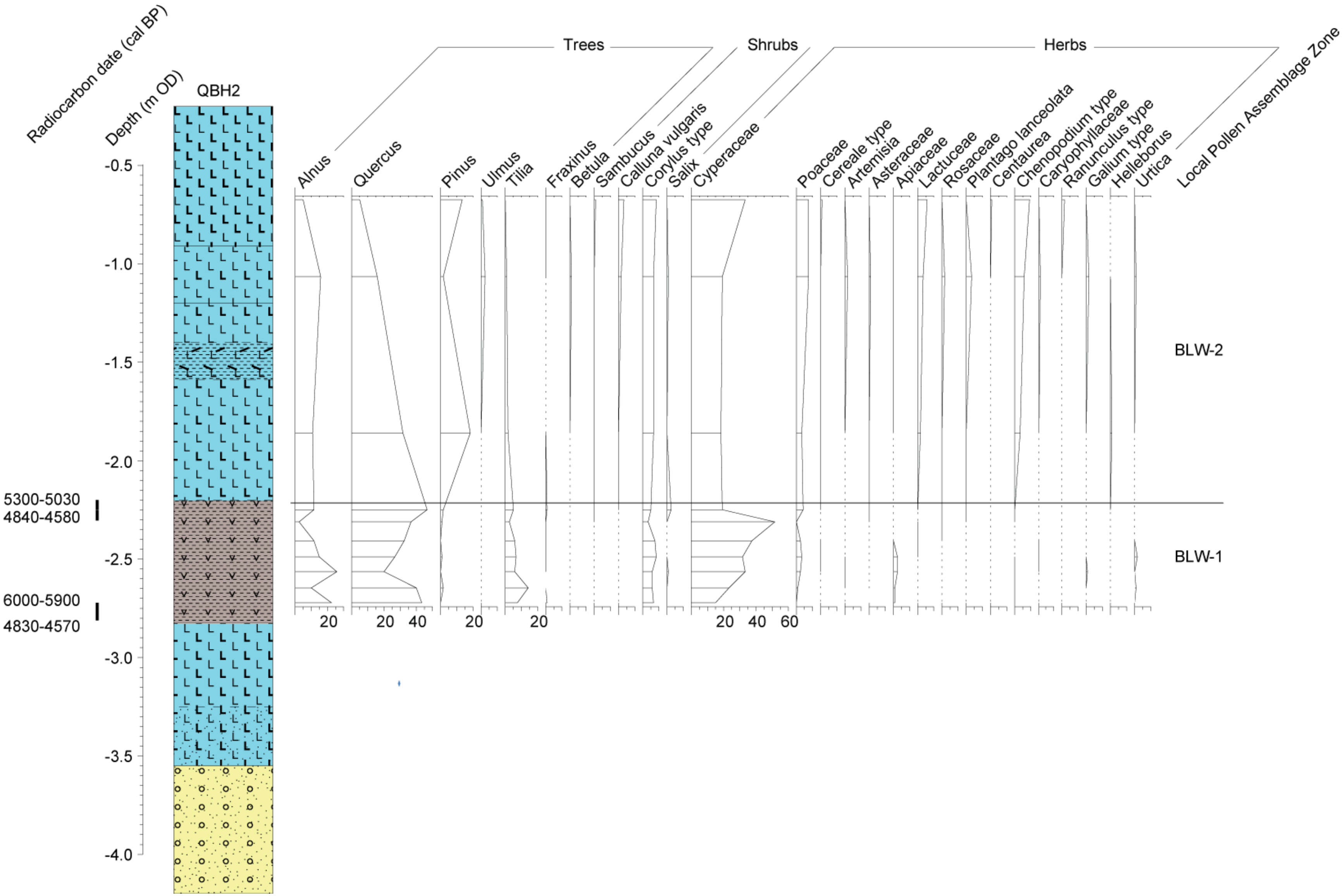

Figure 16: Pollen percentage diagram, QBH2, Alcatel-Lucent Telegraph Works, London Borough of Greenwich

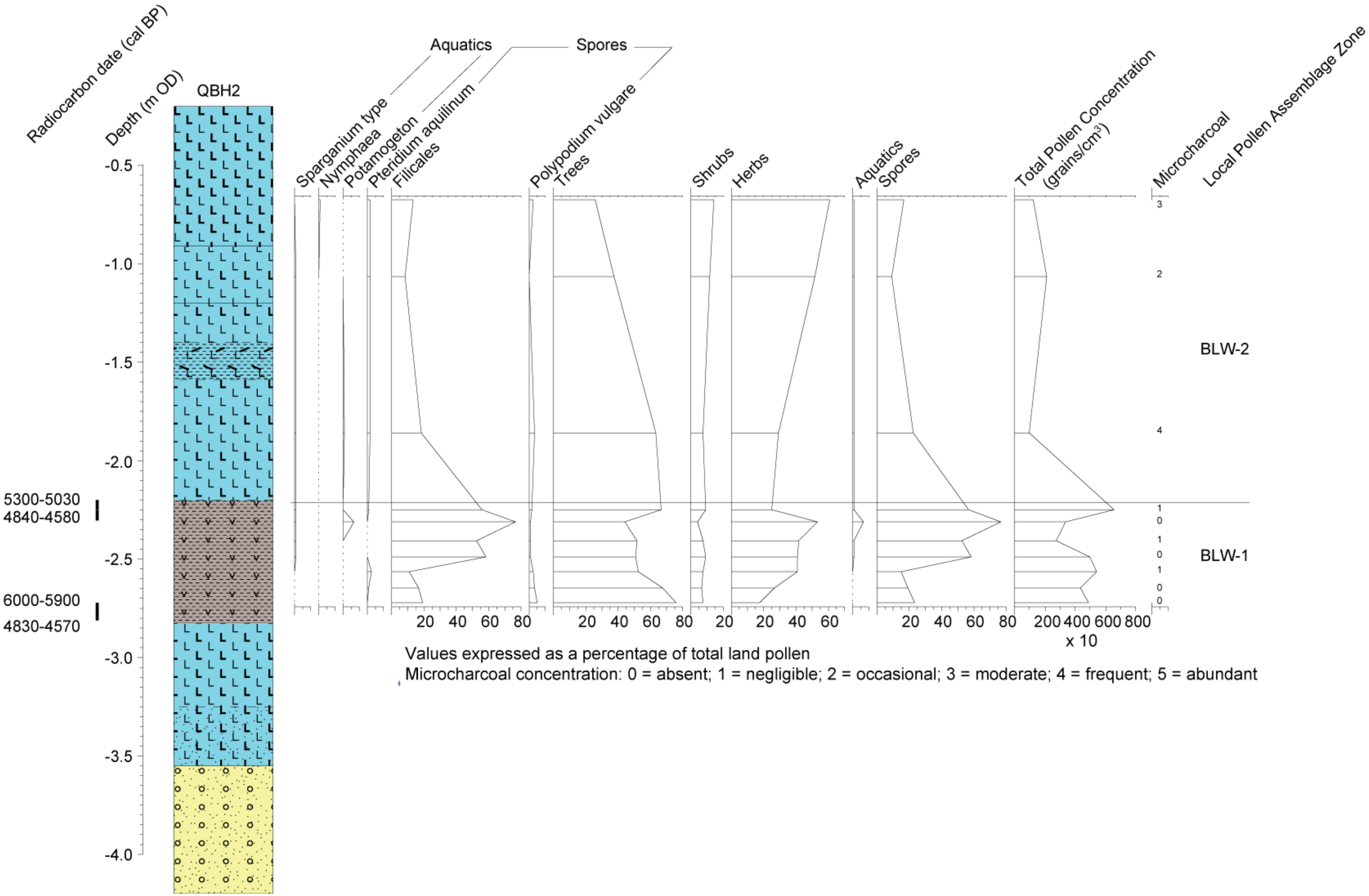

Figure 16: Pollen percentage diagram, QBH2, Alcatel-Lucent Telegraph Works, London Borough of Greenwich

7. RESULTS AND INTERPRETATION OF THE MACROFOSSIL ASSESSMENT

A total of six small bulk samples from borehole QBH2 were extracted for the recovery of macrofossil remains, including waterlogged plant macrofossils, waterlogged wood, insects and Mollusca (Table 9). The samples were focussed on the Peat horizon in borehole QBH2. The results of the macrofossil rapid assessment indicate that waterlogged wood was present in moderate concentrations in all six samples from the Peat in borehole QBH2. Waterlogged seeds were present in low concentrations in two samples (-2.25 to -2.30 and -2.71 to -2.76m OD). Insects were recorded in low concentrations in one sample (-2.56 to -2.66m OD).

No charred plant remains, Mollusca, bone or artefacts were recorded during the assessment. The two samples from borehole QBH2 in which waterlogged seeds were recorded underwent a more detailed assessment (Table 9). The seed assemblage included only one specimen of *Alnus glutinosa* (alder) in each sample. Although too small an assemblage to attempt a full environmental interpretation, the presence of alder in these two samples is consistent with an alder-carr dominated wetland environment.

Table 9: Results of the macrofossil assessment of borehole QBH2, Alcatel-Lucent Telegraph Works, London Borough of Greenwich

				Charred					Waterlogged			Mollusca		Bone				
Depth (m OD)	Volume sampled (ml)	Volume processed (ml)	Fraction	Charcoal (>4mm)	Charcoal (2-4mm)	Charcoal (<2mm)	Seeds	Chaff	Wood	Seeds	Identifications	Whole	Fragments	Large	Small	Fragments	Insects	Artefacts
-2.20 to -2.25	50	50	>300µm	-	-	-	-	-	2	-		-	-	-	-	-	-	-
-2.25 to -2.30	25	25	>300µm	-	-	-	-	-	2	1	*Alnus glutinosa* (alder) x 1	-	-	-	-	-	-	-
-2.35 to -2.45	75	75	>300µm	-	-	-	-	-	3	-		-	-	-	-	-	-	-
-2.56 to -2.66	50	50	>300µm	-	-	-	-	-	3	-		-	-	-	-	-	1	-
-2.71 to -2.76	25	25	>300µm	-	-	-	-	-	3	1	*Alnus glutinosa* (alder) x 1	-	-	-	-	-	-	-
-2.76 to -2.81	25	25	>300µm	-	-	-	-	-	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+

8. CONCLUSIONS

The geoarchaeological and palaeoenvironmental analysis report was aimed at fully addressing the following original project aims, with particular emphasis on considering the dissimilarities between the Alcatel-Lucent and Enderby Wharf sites.

1. To clarify the nature of the sub-surface stratigraphy in these areas of the site;
2. To determine the age of the main peat horizon(s) recorded on the site;
3. To investigate whether the geoarchaeological records contain any evidence for natural and/or anthropogenic changes to the landscape (wetland and dryland) throughout the duration of the geoarchaeological sequence;
4. To establish whether the geoarchaeological records provide evidence for prehistoric and historic occupation locally to the site;
5. To establish evidence and possible causes for changes in woodland composition on the wetland and dryland surfaces during the different periods of Peat formation;
6. To integrate the new geoarchaeological record with other recent work in the local area for publication in an academic journal.

The site appears to lie within a large trough in the Shepperton Gravel surface, representative of at least one major former palaeochannel traversing Greenwich Peninsula from west to east. Alcatel-Lucent and neighbouring Enderby Wharf are located towards the western end where the Shepperton Gravel surface reaches depths of around -4 to -5m OD. At its eastern end, the Shepperton Gravel surface reaches ranges between -4 and -8m OD at 20 Horn Lane (Batchelor & Young, 2017) and Greenwich Millennium Village (Miller & Halsey, 2011). Towards the south, the Gravels rise to over 0m OD on Greenwich Wharf (Batchelor, 2016) and Bellot Street (Branch et al., 2005), most likely representative of the earlier Kempton Park Gravel. Towards the north, the Gravels also rise, but not to the same high level.

Within the confines of the channel at Alcatel-Lucent & Enderby Wharf, the Shepperton Gravel is overlain by a tripartite sequence of Lower Alluvium, Peat and Upper Alluvium as recorded elsewhere in the Lower Thames Valley. In most cases, the Peat is actually a complex of interdigitating alluvial and peat layers, reflective of changing hydrological conditions during the infilling of the channel. In the analysed QBH2 sequence, the Peat is relatively thin (0.5m) and seemingly accumulated between 6000-5900 and 4840-4580 cal BP (beginning to end of the Neolithic). At Enderby Wharf, the complex of Peat units is around 2m thick dating from 5450-5070 to 3290-3230 cal BP (middle Neolithic to late Bronze Age).

Despite the location of archaeological structures on edge of the channel to the south at Bellot Street, there is no definitive evidence of human activity within the sequences analysed. Potential cereal pollen grains were encountered within the peat and overlying alluvium, but these most likely represent coastal grasses which have a similar morphology. In addition, high levels of microcharcoal were recorded in certain samples, but it is not possible to state whether these originate from are an in situ or allocthonous source. Nor is it possible to ascertain whether they are of natural or anthropogenic origin. The Alcatel-Lucent peat deposits do however predate the archaeological remains at Bellot Street, which may explain the lack of evidence for anthropogenic activity.

The reconstructed vegetation on both the floodplain and dryland in the location of QBH2 on Alcatel-Lucent during the Neolithic is similar to that recorded at Enderby Wharf. At Alcatel-Lucent, the Peat surface was occupied by limited alder-willow carr woodland, with sedge fen, reed swamp and areas of standing/slowly moving water; by contrast, at Enderby Wharf, a greater amount of alder woodland is indicated. Both sites indicate a dryland occupied by oak-lime dominated mixed deciduous woodland that post-dates the well-documented Neolithic elm decline, however, this woodland signal is stronger at Alcatel-Lucent. These recorded variations could reflect either: (1) differing distances of each sequence from the dryland edge, or (2) variations in the hydrological conditions within the channel during its infilling.

After 4840-4580 cal BP a shift towards sedge fen, reed swamp and salt-marsh communities is recorded on the floodplain. The diatom record strongly indicates that this transition was caused by a drastic shift from freshwater-dominated to estuarine-dominated conditions consequent of rising relative sea level. Contemporaneously, a large reduction in mixed deciduous woodland took place on the dryland. 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. This is supported by the nearby occurrence of archaeological remains close to the channel edge at Bellot Street. Whether the decline of the floodplain and dryland woodland is linked is uncertain, but does seem to be a common feature of woodland within pollen-stratigraphic records from the Lower Thames Valley.

The aims and objectives of the project are considered to have been successfully achieved, as above, providing an important record from this area of the Lower Thames Valley. The results are significant, and the stratigraphic data has already been incorporated into a Greenwich Peninsula based case-study as part of forthcoming Historic England deposit modelling guidance. In addition, academic publication(s) are being prepared on the deposits of Greenwich Peninsula, the Isle of Dogs & south-west Newham.

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10. APPENDIX 1: OASIS

OASIS ID: quaterna1-248193

Project details

Project name	Alcatel-Lucent Telegraph Works
Short description of the project	The site appears to lie within a large trough in the Shepperton Gravel surface, representative of at least one major palaeochannel traversing Greenwich Peninsula from west to east. Within the confines of the channel, the Gravel is overlain by a sequence of Alluvium and Peat as recorded elsewhere in the Lower Thames Valley. In the analysed Alcatel-Lucent sequence, the Peat is relatively thin (0.5m) and seemingly accumulated from the beginning to the end of the Neolithic. At Enderby Wharf, the complex of Peat units is around 2m thick dating from the middle Neolithic to late Bronze Age. Despite the location of archaeological structures on edge of the channel to the south at Bellot Street, there is no definitive evidence of human activity within the sequences analysed. The Alcatel-Lucent peat deposits do however predate the archaeological remains at Bellot Street, which may explain the lack of evidence for activity. At Alcatel-Lucent, the Peat surface was occupied by limited alder-willow carr woodland, with sedge fen, reed swamp and areas of standing/slowly moving water; by contrast, at Enderby Wharf, a greater amount of alder woodland is indicated. Both sites indicate a dryland occupied by oak-lime dominated mixed deciduous woodland that post-dates the well-documented Neolithic elm decline, however, this woodland signal is stronger at Alcatel-Lucent. Towards the end of the Neolithic a shift towards sedge fen, reed swamp and salt-marsh communities is recorded on the floodplain with evidence for a drastic shift from freshwater to estuarine-dominated conditions resulting from a rise in relative sea level. At the same time, a large reduction in mixed deciduous woodland took place on the dryland, probably as a result of human activity from the late Neolithic onwards. Whether the decline of the floodplain and dryland woodland is linked is uncertain, but does seem to be a common feature of woodland within pollen-stratigraphic records from the Lower Thames Valley.
Project dates	Start: 01-09-2015 End: 20-04-2017
Previous/future work	No / No
Any associated project reference codes	BLW15 - Sitecode
Type of project	Environmental assessment
Monument type	PEAT Neolithic
Significant Finds	POLLEN Neolithic
Significant Finds	DIATOMS Bronze Age
Significant Finds	MACROFOSSILS Neolithic
Survey techniques	Landscape

Project location

Country	England
Site location	GREATER LONDON GREENWICH GREENWICH Alcatel-Lucent Telegraph Works
Postcode	SE10 0TT

Site coordinates	TQ 3841 7866 51.489421224302 -0.006164268233 51 29 21 N 000 00 22 W Point

Project creators

Name of Organisation	Quaternary Scientific (QUEST)
Project brief originator	CgMs Consulting
Project design originator	D.S. Young
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"
Paper Media available	"Report"

Project bibliography 1

Publication type	Grey literature (unpublished document/manuscript)
Title	A report on the geoarchaeological borehole investigations and deposit modelling on Land at Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough Of Greenwich
Author(s)/Editor(s)	Young, D.S.
Author(s)/Editor(s)	Batchelor, C.R.
Other bibliographic details	Quaternary Scientific (QUEST) Unpublished Report September 2015; Project Number 094/14.
Date	2015
Issuer or publisher	Quaternary Scientific
Place of issue or publication	University of Reading

Project bibliography 2

Publication type	Grey literature (unpublished document/manuscript)

Title	Alcatel-Lucent Telegraph Works, Blackwall Lane, London Borough of Greenwich SE10: Environmental archaeological assessment report.
Author(s)/Editor(s)	Young, D.S.
Author(s)/Editor(s)	Batchelor, C.R.
Other bibliographic details	Quaternary Scientific (QUEST) Unpublished Report December 2015; Project Number 095/14.
Date	2015
Issuer or publisher	Quaternary Scientific
Place of issue or publication	University of Reading

Project bibliography 3

Publication type	Grey literature (unpublished document/manuscript)
Title	ALCATEL-LUCENT TELEGRAPH WORKS, LONDON BOROUGH OF GREENWICH: Geoarchaeological and Palaeoenvironmental Analysis Report
Author(s)/Editor(s)	Hill, T.
Author(s)/Editor(s)	Batchelor, C.R.
Author(s)/Editor(s)	Young, D.S.
Other bibliographic details	Quaternary Scientific (QUEST) Unpublished Report April 2017; Project Number 095/14
Date	2017
Issuer or publisher	Quaternary Scientific
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