8.2. Objectives

Given the limited understanding of the mapped geology of Site A, existing geotechnical and remote-sensing data were collected. As described previously, the BGS 1:50,000 map sheet recorded the site as an area of undifferentiated alluvium; however, the lidar data revealed some topographic variability, which suggested subsurface geomorphological variations (Figure 8.2). The existing geotechnical borehole data indicated that the contact between the Holocene alluvium and underlying Pleistocene sands and gravels might vary across Site A. In addition, the Essex Historic Environment Record (HER) indicated the presence of archaeological remains, including a possible Romano-British well, which was recorded in 1967 (SMR 5188, Point 9, Figure 8.2). The geotechnical data was considered to be of variable quality for the purposes of archaeological assessment and was unevenly distributed; therefore, it was decided to undertake purposive geoarchaeological fieldwork to inform the construction of a deposit model.

The objectives for the Site A deposit model were to:

- Provide an understanding of the interface between the Pleistocene and Holocene sediments;
- Identify any variations in sediment composition that could be related to areas of high palaeoenvironmental, ecofactual and archaeological potential;
- Produce a geomorphological map that zoned the site in relation to its archaeological potential;
- Use the deposit model to inform evaluation strategies for trial trenching and other mitigation options.

If, as described by the BGS, Site A comprised a deep alluvial sequence, a watching brief would be the most cost-effective mitigation strategy. In such circumstances, it could be predicted that the archaeological potential within the top 1m of the sediment stack (the proposed depth of the surface reduction) would be low. Moreover, even if archaeological remains did survive within this zone, the difficulty of predicting their location with any degree of confidence would favour a continuous watching brief during ground disturbance. In contrast, if areas of elevated subsurface topography were identified beneath the alluvium, such as gravel islands or terrace remnants, these would have a higher archaeological potential, reflecting previously drier areas more suitable for habitation/exploitation at the intertidal edge and would require more extensive evaluation. Consequently, an understanding of sediment stratigraphy at Site A was

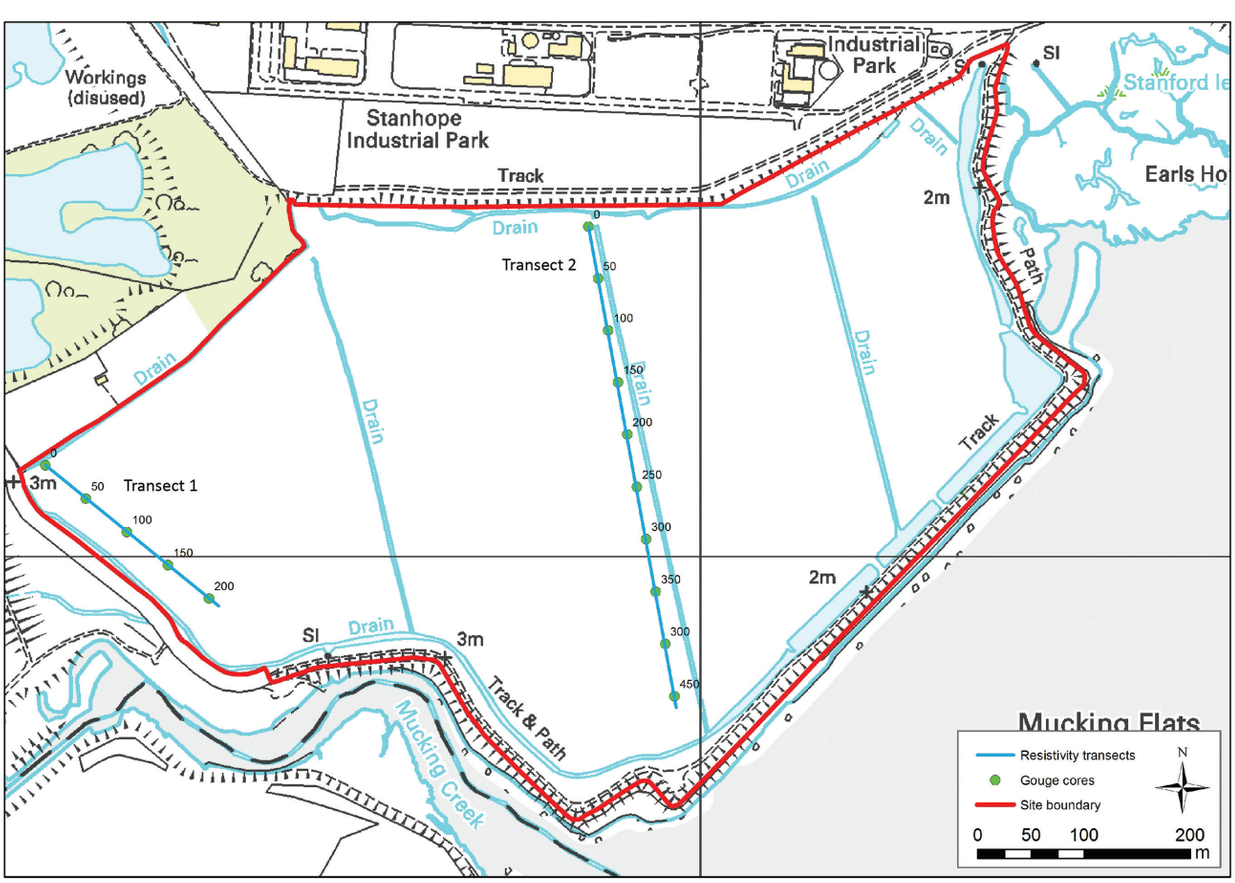


Figure 8.3: Resistivity transect and gouge auger locations

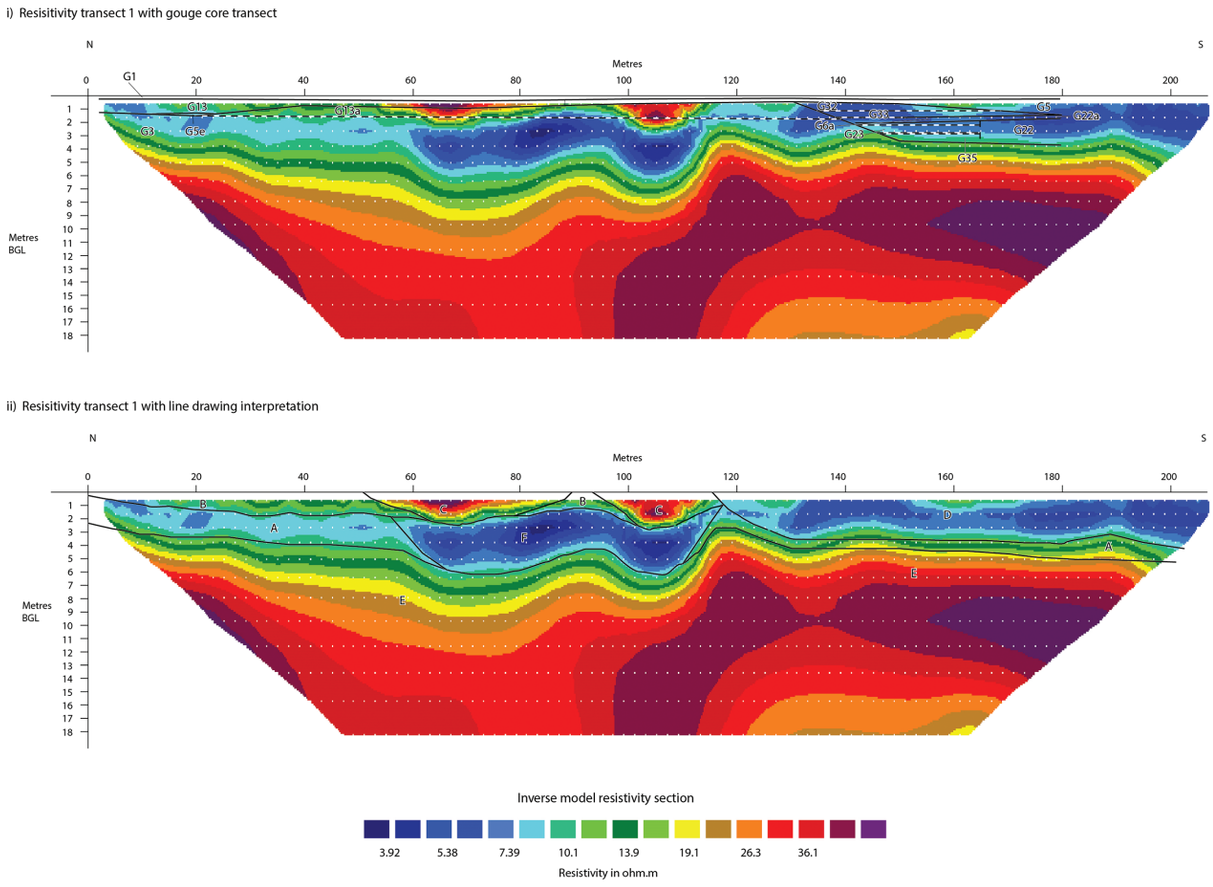


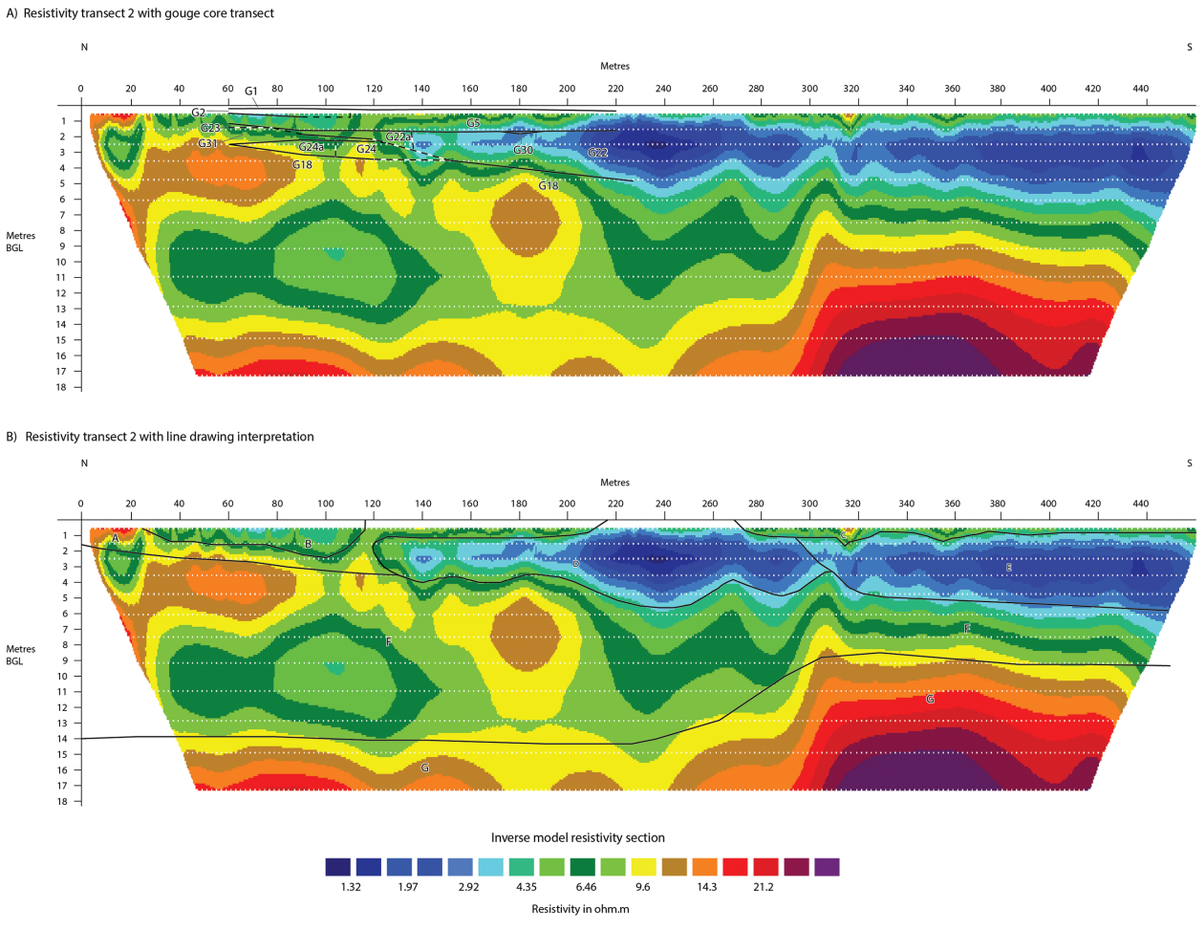
Figure 8.4: Electrical resistivity Transect 1 results, with gouge core data and interpretation. A clear difference is visible between the north and south ends of the transect. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

deemed to be essential for defining intra-site variations in archaeological potential.

8.3. Methodology

The purposive fieldwork that was undertaken to inform the construction of the deposit model involved the capture of data along two electrical resistivity transects, orientated broadly north-west to south-east. The presence of higher ground to the north of the site and of intertidal deposits to the south, within the general framework of the Thames terrace sequence (Bridgland 1994), meant that the key trends in the interface between Pleistocene and Holocene sediments would be identified from a broadly north-south transect. Transect 1 extended for 210m and Transect 2 extended for 460m (Figure 8.3). Hand gouge augering was undertaken at 50m intervals along the resistivity transects, both to investigate the nature of the Holocene sediment stack and to aid interpretation of the electrical resistivity data.

The electrical resistivity data was captured using an Iris Syscal pro 72 system with an internal switching unit using the Wenner-Schlumberger collection array. A 2m electrode spacing was used, allowing a depth penetration of *c* 15m. The IRIS Syscal was programmed using Electre II, with data downloaded into PROSYS II before being imported into Res2Dinv for processing, using a Robust Inversion method. The sediment stratigraphy from the gouge cores was recorded in the field using standard geological terminology (for example, Jones *et al* 1999).



Sediment units:

G1	Brown silty clay Ap
G2	Stiff brown grey silty clay
G23	Light grey clayey silt, Fe mottling and organics
G31	Dark grey clayey silt, with ltd organics
G5	Mottled blue, grey orange stiff clay, trace of silt and sand
G18	Undifferentiated head (brown silty clay, with small clasts)
G22a	Mid blue grey soft silty organic rich clay
G24a	Stiff brown grey silty clay, abundant organics
G29	Light grey silty clay with organics
G24	Mid brown grey silty clay
G22	Dark greyish blue soft organic rich silty clay
G30	Mixed light grey dark grey silty clay

Interpretation:

A	Higher resistance Holocene alluvium
B	Lower resistance Holocene alluvium
C	Higher resistance Holocene alluvium
D	Palaeochannel
E	Inter tidal deposits
F	Undifferentiated Head deposit
G	Bedrock

Figure 8.5: Electrical resistivity Transect 2 results, with gouge core data and interpretation. As with Figure 8.4, there is a clear difference visible between the north and south ends of the transect. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

The sediment data was hand drawn into sections and was integrated with the processed electrical resistivity transects in Adobe Illustrator.

Due to a proposed approximate 1m depth of ground disturbance, an archaeological gradiometer survey was used to identify any shallow archaeological features. As well as being able to identify archaeological remains, the gradiometer data could also be used to define variations in sediment composition and to aid the definition of geomorphological zones across the site. The gradiometer survey was undertaken using a Bartington Grad 601-2 gradiometer; all data was downloaded and processed in 'Archaeosurveyeur'. All subsequent data integration was conducted within ArcGIS, allowing integration of multiple data sources. These combined datasets were interpreted to produce a geomorphological zonation map that highlighted the variable archaeological potential of the site.

The proposed groundworks at Site A identified quickly the need for a deposit model to aid the definition of the archaeological potential. Therefore, the deposit model was created prior to any groundworks taking place. Once the deposit model had informed assessment of archaeological potential in each discrete geomorphic zone, a programme of limited evaluation trenching was instigated. This was followed by a programme of more extensive stripping, which was integrated into the construction schedule, allowing archaeological mitigation and construction groundworks to occur in tandem.

8.4. Interpretation

It became apparent from an early stage of fieldwork that the subsurface topography and depositional history of Site A varied significantly. The key trends in the resistivity transects and gouge core data are described below. The results of this work were used to construct a geomorphological zonation of Site A, which was directly linked to archaeological potential.

Resistivity transects

Transect 1 (Figure 8.4) traversed the north-west part of Site A. It revealed a very shallow alluvium (Unit G1, *c* 0.2m) at its northern end, overlying sands and gravels. Further south, between 10m and 120m from the northern end of Transect 1, deposits dominated by a mixture of sand, silt and clay were recorded (eg Units G13 and G13a: grey clay containing organic matter); these deposits overlaid sand and gravels interpreted as Pleistocene river terrace deposits (G3). Units G13 and G13a were initially interpreted as possible cultural horizons. They were defined during subsequent excavations as components of a complex sequence of archaeological deposits, some of which had been partially reworked by tidal action; the organic content in these units indicated high potential for the preservation of both ecofactual and palaeoenvironmental remains.

Within Transect 1, Unit C was interpreted as a sequence of archaeological deposits. Unit B was interpreted as alluvium, although excavation demonstrated that this zone also included complex stratified archaeological deposits. Unit D was interpreted as a palaeochannel/inter-tidal alluvium, overlying sand and gravel (Unit A) at *c* 6m BGL. From a geoarchaeological perspective, Unit F is also of interest since it was interpreted as a fine-grained deposit within the terrace sands and gravels and may correspond to a Pleistocene palaeochannel or brickearth deposit; it was noted that both of the latter had palaeoenvironmental potential, but this anomaly was not investigated further during the excavation.

Transect 2 (Figure 8.5) revealed a broadly similar pattern to that recorded in Transect 1, although the Holocene sediments in this transect rested on underlying Pleistocene Head deposits. The undifferentiated Head deposit overlay a landform that may probably be correlated with the River Terrace deposit identified in Transect 1. Above the Pleistocene Head the Holocene alluvium was observed to increase gradually in thickness

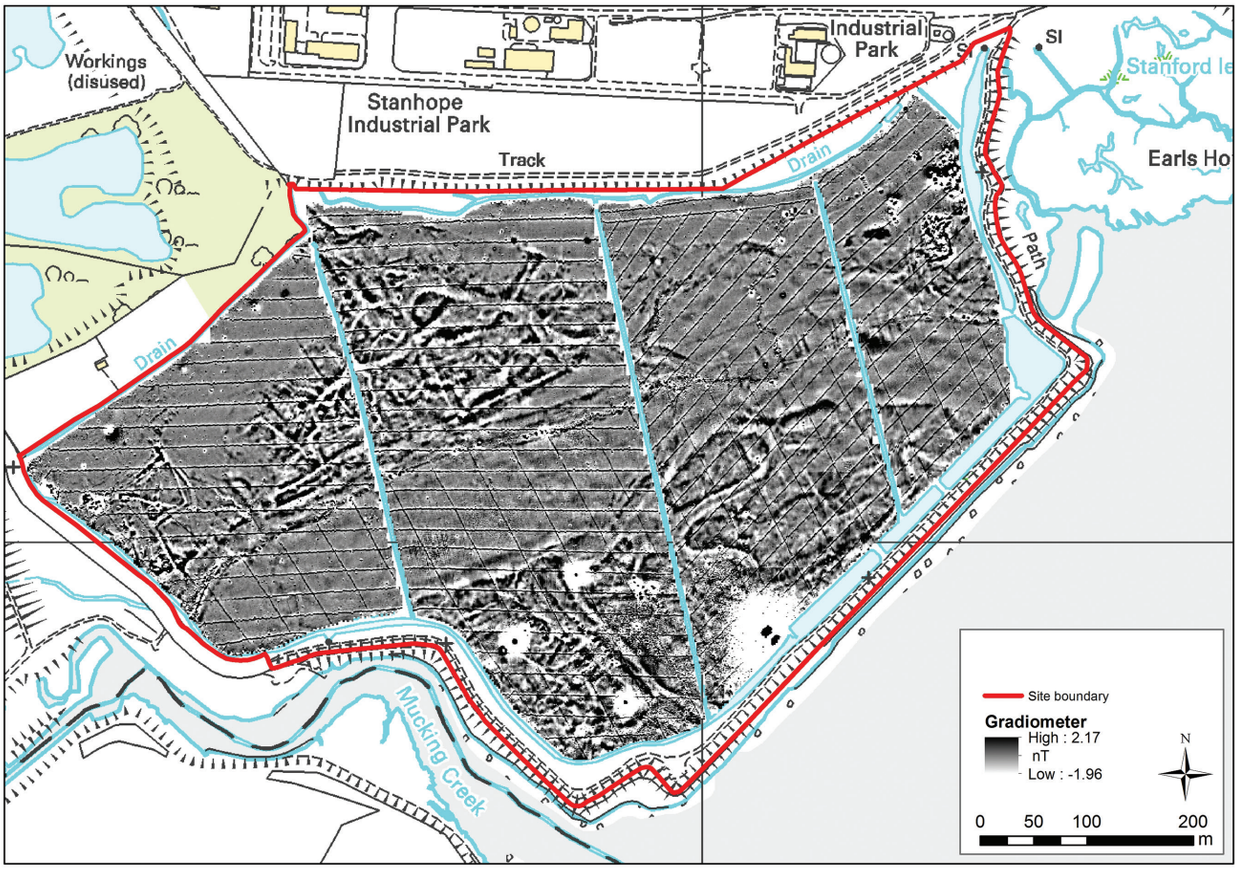


Figure 8.6: The gradiometer results, revealing a wealth of features to the north end of the site. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

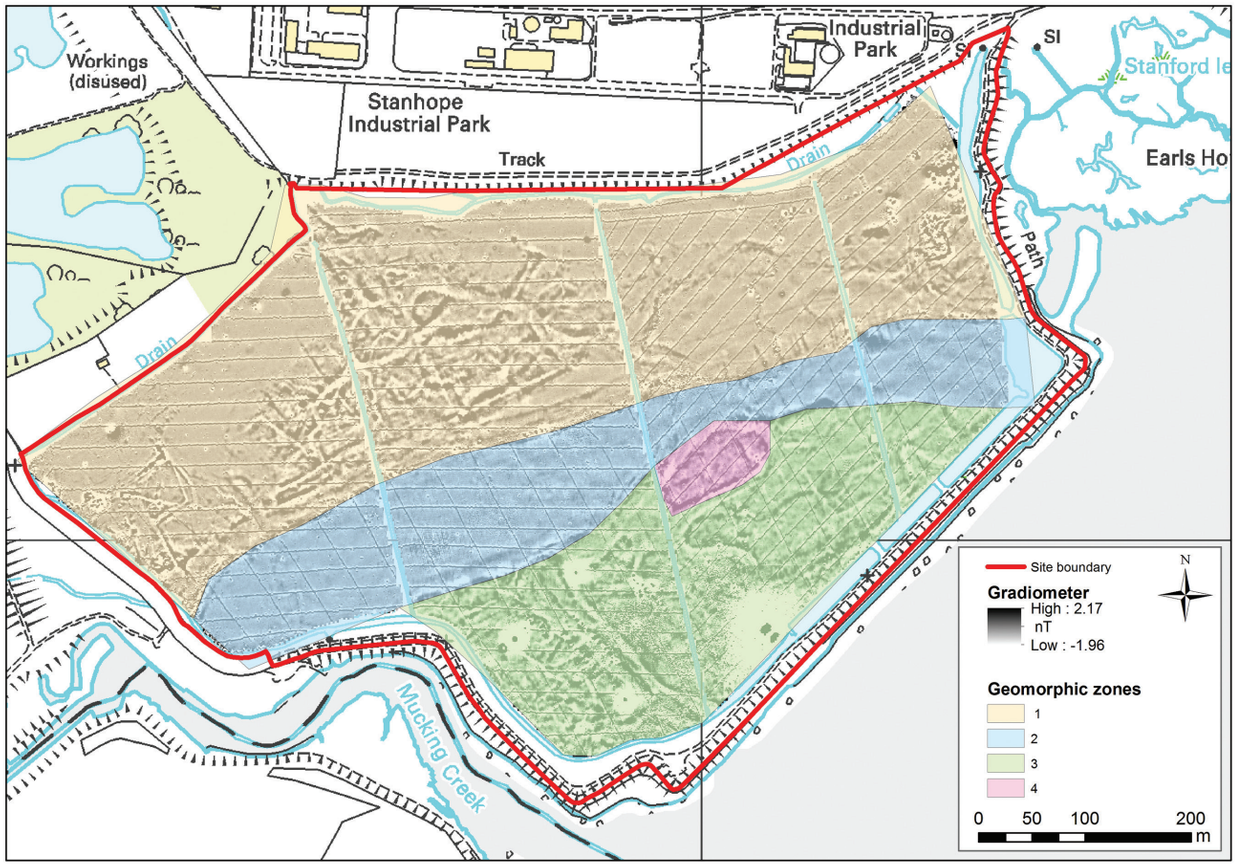


Figure 8.7: Geomorphic zonation of the site, with a description of depth of Holocene deposits and archaeological potential. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

from a depth of *c* 0.2m at the north of the transect to a depth of *c* 3.5m at 120m along the transect. The sediment sequence above this Pleistocene Head interface varied in comparison to Transect 1, with units such as G22 and G22a being recorded as blue-grey silty clays with organics and G24 and G24a as brown-grey silty clays. Across this transect the archaeological potential was more difficult to define at the northern end, but again the shallow depth of Holocene deposits above Pleistocene sediments suggested a high potential. The interpretation of sediment units from the resistivity transects defined Units A and B as Holocene alluvium until about 120m, Unit D as a central palaeochannel with a fill sequence of *c* 5m and Unit E as the intertidal alluvial deposits to the south.

Both transects demonstrated that the northern edge of the site was characterised by an incised river terrace deposit, consisting of both sands and gravels, together with undifferentiated Head. These terrace deposits were overlain by a shallow covering of alluvium at the northern end of the site. This alluvium slowly increased in depth southwards, in part associated with a large palaeochannel that traversed the site on a broadly east-west alignment. To the south of the palaeochannel, intertidal alluvial deposits of considerable depth (*c* 6–8m BGL) were recorded. The area of higher terrace to the north of the central palaeochannel, buried by a shallow covering of alluvium, was defined as a zone of very high archaeological potential.

Gradiometer survey

The gradiometer survey complemented the results of the deposit model and clearly defined the palaeochannel traversing the site. To the north of the site, the gradiometer also defined several significant archaeological structures, including an enclosure, multiple widespread magnetic deposits, and a variety of other features (Figure 8.6).

Geomorphic zones

On the basis of fieldwork and deposit modelling, the site was divided into four distinct geomorphic zones, each providing an understanding of sediment architecture, sequence stratigraphy and archaeological and palaeoenvironmental potential (Figure 8.7). This was displayed within a 2-dimensional plan based format, although knowledge of the depth and architecture of the underlying sequence from the resistivity and gouge coring effectively created a 3-dimensional deposit model. The key zones were:

- Zone 1: elevated fluvial terrace covered by inorganic, minerogenic alluvium, with significant potential for the preservation of archaeological features beneath alluvium. The interface between Holocene alluvial and Pleistocene terrace deposits was observed to lie within the 1m impact depth of the proposed ground disturbance; there was a strong likelihood, therefore, that archaeological features would be impacted by development;
- Zone 2: palaeochannel incised into terrace, with an interface between Holocene alluvium and Pleistocene deposits at *c* 6m BGL. The archaeological potential was difficult to define, but the palaeochannel deposits below impact depth had the potential to include significant palaeoenvironmental and ecofactual remains. The margins of the channel may also have corresponded to an area of preferential human activity at the wetland-dryland interface;
- Zone 3: Holocene estuarine intertidal sediments, overlying Pleistocene deposits at *c* 7m+ BGL. These had low archaeological potential within the 1m impact depth of the proposed ground disturbance.
- Zone 4: a slightly elevated area, interpreted as possibly a gravel island with potential for the presence of archaeological features. The depth of the interface between Holocene and Pleistocene deposits was unknown at the point of deposit modelling; it was covered by an unknown depth of alluvium, as it was located outside of the resistivity transects and was only defined through the gradiometer survey. On the basis of knowledge from the deposit model, the archaeological potential within the 1m impact depth of the proposed ground disturbance was judged as moderate, and was established by later evaluation trenching.

8.5. Investigations following development of the deposit model

Based upon the high level of understanding derived from the deposit model, a targeted evaluation trenching programme was implemented (Figure 8.8). Trenches were located with the aims of investigating discrete features to assess their archaeological potential and of testing the predictions of the deposit model regarding the depth and character of the sedimentary sequences and the presence of associated archaeological horizons. Such a focused approach confers a number of advantages. First, areas of high archaeological potential can be targeted, giving

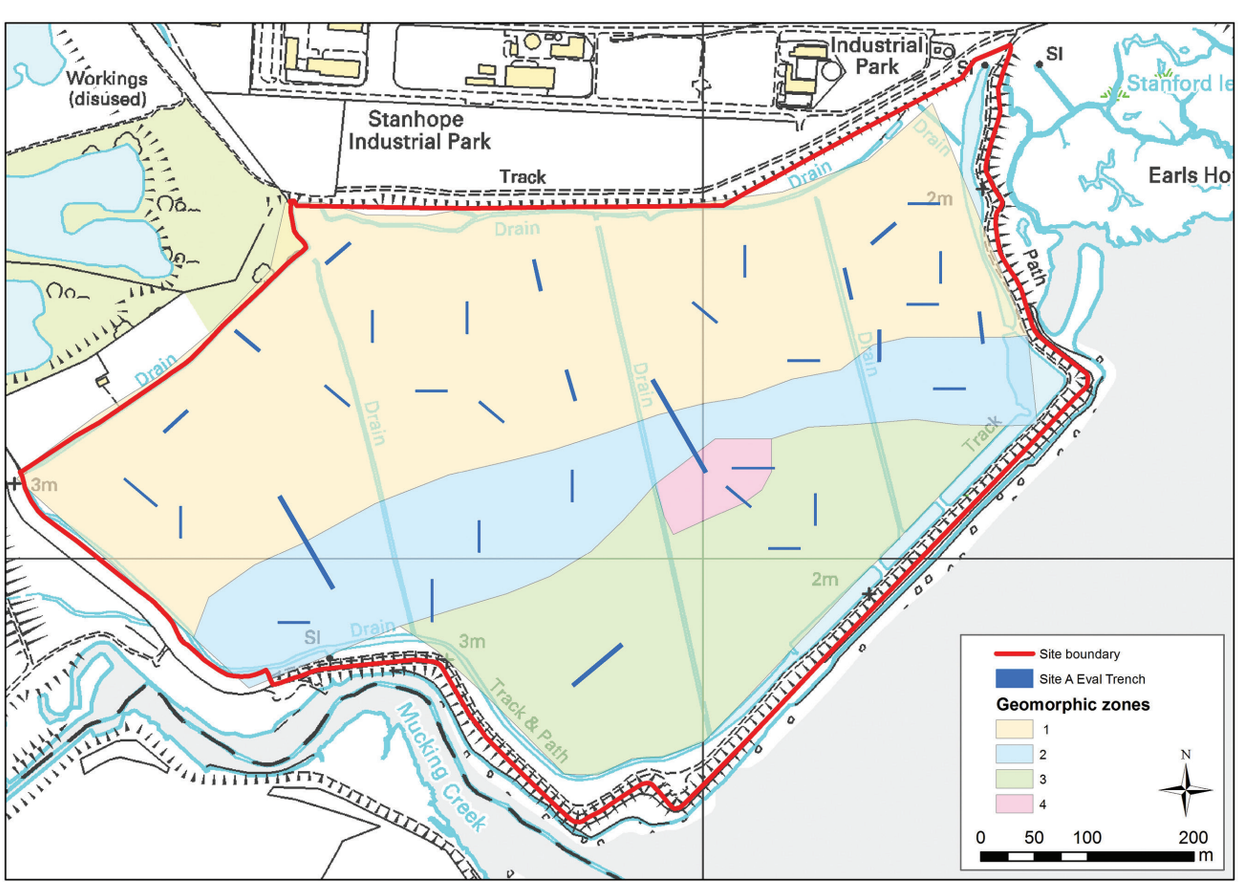


Figure 8.8: The targeted evaluation trenching programme design, using 34 evaluation trenches to evaluate the 44Ha site. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

a truer representation of the archaeology present and the resources required for any subsequent mitigation phases. Secondly, some trenches can test the areas of lower predicted archaeological potential: a task that can be undertaken with confidence at a lower trenching density. Thirdly, the approach can reduce a lengthy and at times costly evaluation programme using blanket sampling strategies (eg 5% evaluation trenching). By using a targeted evaluation programme, the trenching can focus more effectively upon the nature and potential of the archaeological remains, and less upon presence or absence.

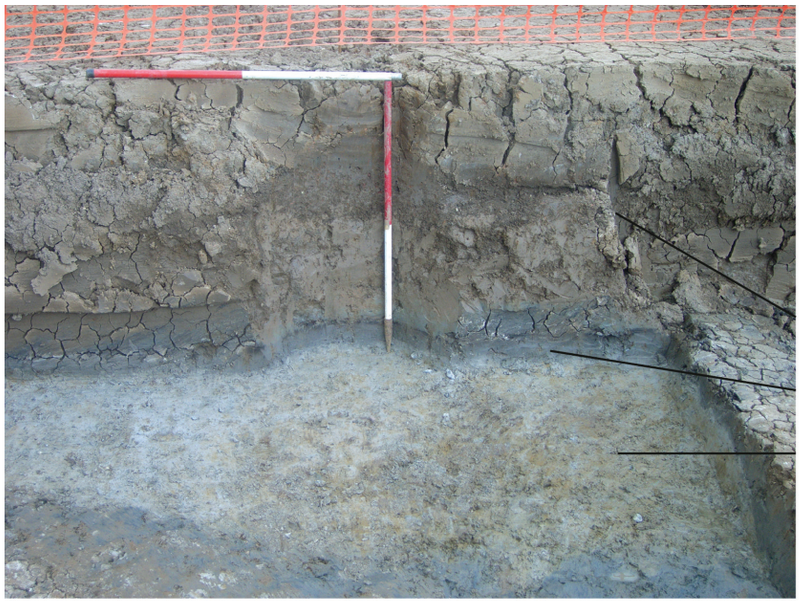
The results of this deposit model, combined with the evaluation trenching results, provided a clear picture of complex archaeological and sediment sequences within some areas of the development site. The results demonstrated an increasing depth of sediment across Zone 1, together with an increasing depth and complexity of archaeological deposits. The evaluation trenching also identified a spatially extensive sequence of Holocene units across Zone 1, which were assigned a series of geoarchaeological codes prefixed by the letter G. These G codes denoted sediment units in the excavation area that were diachronous in their formation. Numbering these sediment units as conventional archaeological contexts could cause conflicts in a Harris Matrix, as many of these units formed over protracted time periods. For example, G4 represented an early Holocene palaeosol in Zone 1 that was associated with Bronze Age and earlier activity; this was stratified above G3, a late Pleistocene/early Holocene sand-dominated sediment. Likewise, G5 corresponds to a blue-grey silty clay alluvium, which was first recorded in the southern end of Zone. With rising sea levels in the mid-Holocene, however, G5 encroached northwards; the timing of its formation thus varied significantly across the site. The application of 'G' prefixes to context codes represents an attempt to overcome the problem of age relationships by attributing unique alpha-numeric codes to Holocene sediment units extending widely across the site, while at the same time applying unique context numbers to occurrences of these sediment units in individual evaluation trenches.

Following evaluation trenching, a full archaeological surface strip was integrated into the construction schedule. Zone 1 revealed an extremely well-preserved land surface above river terrace deposits, including extensive, locally complex archaeological remains. Zones, 2, 3 and 4 were stripped under archaeological watching brief conditions and in contrast revealed no significant archaeological remains.

The deposit sequence of Zone 1, overlying the late Pleistocene and early Holocene land-surface, included an extensive and well-preserved Bronze Age palaeosol and, deeply stratified sequences of cultural deposits relating to Iron Age and Roman activity; these later deposits were often interspersed by marine incursions denoted by estuarine alluvium. Anthrosols created from extensive 'redhill' deposits (red, burnt material generated during salt production) and interleaved with further stratified archaeological remains, developed during the Romano-British periods. All of the archaeological deposits that were recorded at Site A were covered by the thin deposit of alluvium that crept over the higher, northern edge of the site in the late Roman or early Post-Roman period, sealing and preserving a rich archive of activity up to the 5th century AD (Figure 8.9).

The Iron Age and Romano-British activities at the site were investigated during the mitigation excavation. They revealed a Late Romano-British saltern with hearth (AD 200–AD 410); a later Romano-British enclosure incorporating a roundhouse defined by bedding trenches preserving wooden stakes (AD 200–AD 410); extensive redhill deposits and associated infrastructure for salt production; and evidence for Late Roman fish paste production (sample <1160>) (Biddulph *et al* 2012). Due to the extensive and locally complex nature of the Romano-British and Iron Age remains, these phases were heavily represented in the site archive. Earlier archaeological remains, however, such as those relating to Bronze Age settlement could only be investigated through window–sampling as they were located beneath later phases of activity. All of these excavations followed the principle of attributing alpha-numeric G codes to the major lithostratigraphic units, as described above, attempting thereby to harmonise sediment descriptions across this complex landscape zone.

The method of excavation provided an opportunity for detailed and extensive geoarchaeological sampling using monolith tins and bulk samples. Multiple samples were obtained for post-excavation analysis, with the focus upon understanding the cultural deposits, anthrosols and palaeosols by a combination of soil micromorphology and the study of diatoms, pollen, charred plant remains, waterlogged plant remains and foraminifera. By combining these analyses, a rich narrative was generated for the occupation and exploitation of this site at the wetland-dryland interface. In the post-excavation process, the deposit model was updated with data obtained by excavation. The deposit model provided the framework for the contextualisation of the archaeological remains discovered and for the detailed post-excavation analysis of artefacts and samples. The post-excavation strategy was devised with the aim of facilitating site-wide palaeoenvironmental and sediment investigations by the analysis of localised archaeological sequences and features. In all cases the deposit model was central for understanding the depositional environment of the samples and their archaeological position within the overall narrative of site evolution. As the deposit model was firmly embedded into the archaeological process, the end product can be considered to have created a holistic understanding of the sediment and archaeological sequences. In this sense the deposit model was central



Part of the sequence on the western side of Zone 1, showing:

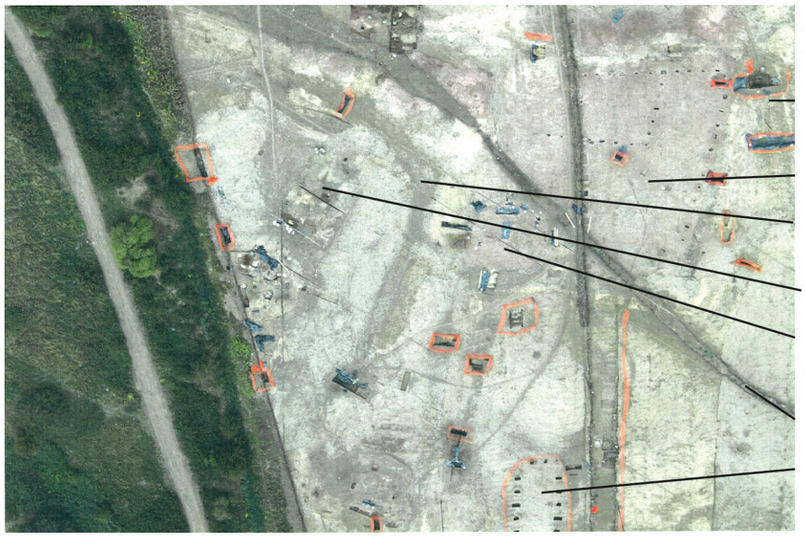
Burial by alluvium, in this sequence Bronze Age saline incursion

Bronze Age palaeosol

The Early Holocene terrace surface



Western part of zone 1 showing two anthrosol formations interspersed by inter-tidal alluvial deposits



Aerial view of the western part of Zone 1 showing multiple features:

Enclosure ditch cutting the redhill spread

Romano-British enclosure built on top of redhill deposit

Ditches, possibly for small river craft

Two storey Roman building

Romano-British roundhouse with in-situ evidence of salt production

Post Medieval ditch

Possible Roman boat house at the edge of Zone 2 (palaeochannel)

Figure 8.9: Some of the archaeological sequences and remains revealed on the western side of zone 1, showing (top plate) palaeosol and land surface, (middle plate) one of many locally variable complex deposit sequences and (bottom plate) aerial shot of the mitigation excavation in progress. Reproduced with permission of Oxford Archaeology (© Oxford Archaeology)

to the archaeological process from inception through to publication.

8.6. Conclusions

The DP World London Gateway deposit model generated multiple benefits for the client and enhanced significantly our understanding of the archaeological remains at Site A. It highlights the benefits for archaeologists in using such methodological approaches to identify areas of both high and low archaeological potential within deeply stratified (>1m) and complex geomorphological and sedimentary environments. The deposit model also allowed resources to be efficiently targeted and enabled the archaeological programme to be firmly embedded within the construction schedule. The evaluation trenching demonstrated that in such environments, following the application of a deposit model, a blanket evaluation trenching strategy (for example of 5%) is not suitable. The subsequent excavation provided a rich archive of samples for detailed archaeological, palaeoenvironmental and geoarchaeological analysis.

The deposit model is archived within a GIS environment and the shapefiles and raster files are accessible for future researchers to use. Oxford Archaeology produced very promptly a monograph exploring the results of deposit modelling and other site investigations (Biddulph *et al* 2012), creating thereby a lasting legacy. A further important outcome was the use of deposit modelling as a training and education vehicle for project staff. Not all of the staff who were involved with the project were used to working within such mitigation frameworks or in such sedimentary environments. The application of 'G' codes represented an attempt to integrate geoarchaeological investigations of the major lithostratigraphic units with traditional context recording systems. Since the application of new recording systems and new methodological approaches to site investigation can take a while to be understood before they become normal best practice, it is essential for the geoarchaeologist undertaking deposit modelling to be embedded within the project team and to provide a geomorphological context for the mitigation process. It is vital to explain the value of deposit modelling in the process of site investigation and how the results need to be firmly embedded in the site archive. It might seem obvious, but it is important to communicate why samples are required from the excavation and how the full integration of geoarchaeological and archaeological data will provide a richer and more comprehensive site narrative.

In more general terms, although deposit modelling can increase the capacity of archaeologists to uncover complex and often exceptionally well-preserved archaeological remains, the surviving remains, once disturbed, will often degrade through increased oxidation and the lowering of water-tables. This presents a major challenge to the historic environment sector, as there is clearly a need to maximise data recovery once such sites are uncovered. In an era of tightening budgets, this issue needs to be considered not only during the design of archaeological programmes but also during communications with developers, ensuring thereby the design of cost-effective investigation strategies that can maximise understanding of the archaeological and environmental resource.

Acknowledgements

Oxford Archaeology is thanked for allowing the publication of some of the figures from the original site investigation. DP World London Gateway is also thanked for allowing publication of this data and funding of the original project. Special thanks to Martin Bates, Liz Stafford and Gill Andrews for their help and support throughout the lifetime of the project and the publication of this chapter.

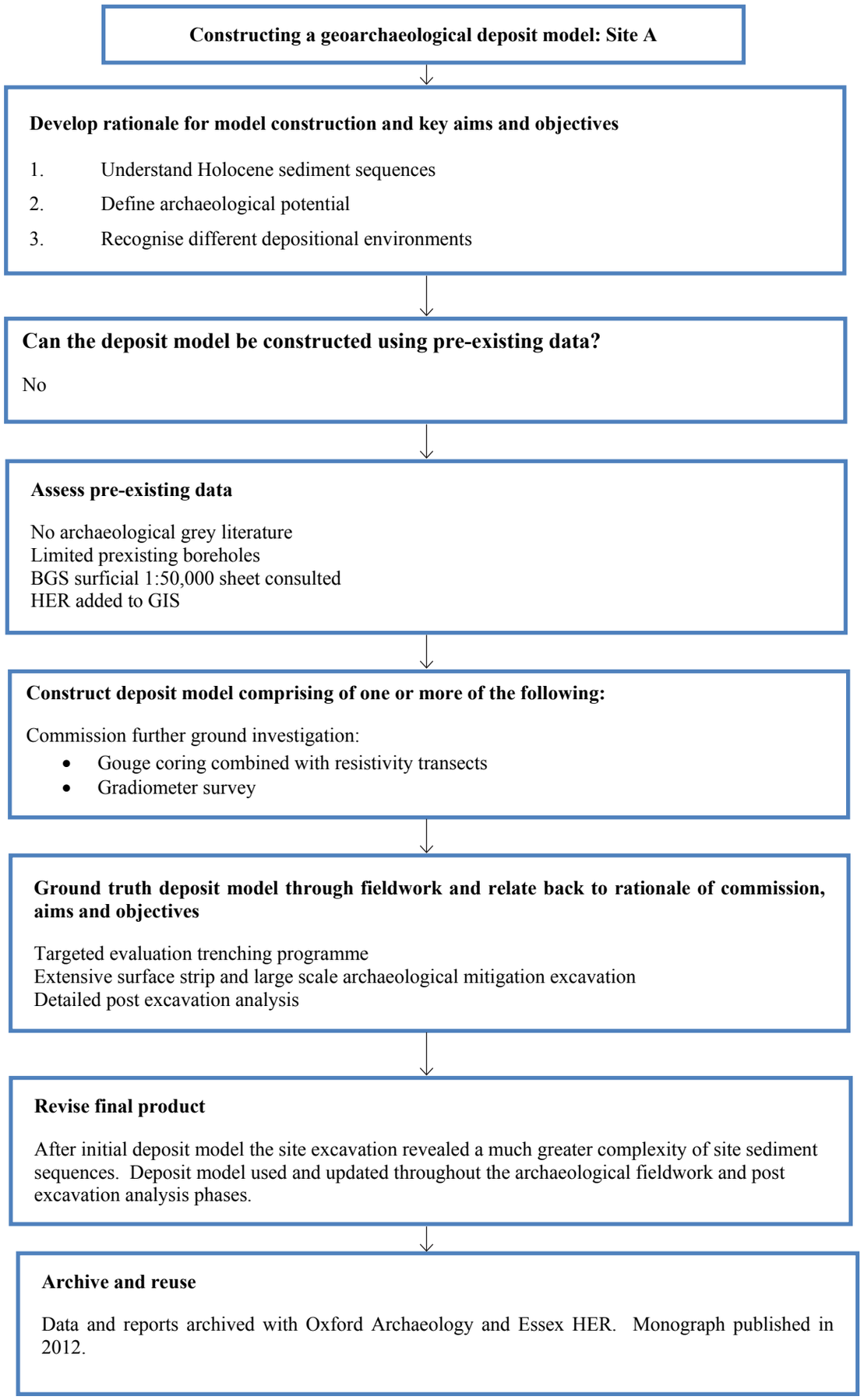
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Constructing a geoarchaeological deposit model: Site A
Develop rationale for model construction and key aims and objectives
1. Understand Holocene sediment sequences
2. Define archaeological potential
3. Recognise different depositional environments
Can the deposit model be constructed using pre-existing data?
No
Assess pre-existing data
No archaeological grey literature
Limited prexisting boreholes
BGS surficial 1:50,000 sheet consulted
HER added to GIS
Construct deposit model comprising of one or more of the following:
Commission further ground investigation:
• Gouge coring combined with resistivity transects
• Gradiometer survey
Ground truth deposit model through fieldwork and relate back to rationale of commission, aims and objectives
Targeted evaluation trenching programme
Extensive surface strip and large scale archaeological mitigation excavation
Detailed post excavation analysis
Revise final product
After initial deposit model the site excavation revealed a much greater complexity of site sediment sequences. Deposit model used and updated throughout the archaeological fieldwork and post excavation analysis phases.
Archive and reuse
Data and reports archived with Oxford Archaeology and Essex HER. Monograph published in 2012.

9. Post-Medieval marsh and reclamation activity at Sadds Wharf, Maldon, Essex

Martin Brook and Dan McConnell

Britannia Archaeology Ltd, Unit 2, The Old Wool Warehouse, St Andrews Street South, Bury St Edmunds, IP33 3PH

Abstract

An evaluation and borehole survey was undertaken ahead of development at Sadds Wharf, Station Road, Maldon, Essex. The development site lay adjacent to the river Chelmer and close to its confluence with the river Blackwater, where they join to form the Blackwater estuary. British Geological Survey (BGS) mapping indicated that the site was situated upon Pleistocene river terrace sands and gravels and silt and clay alluvium, the latter formed in an intertidal, salt marsh environment. Ground investigations included a borehole survey aimed at assessing the deeper fine-grained alluvial sediments and associated organic remains, with the data also used to construct a deposit model. The borehole records revealed varying levels of episodic reclamation across the site. Pollen samples obtained from the alluvial silts indicated an absence of pollen, strongly suggesting that the deposits were degraded through prolonged exposure to oxygen. This affirms the documentary and cartographic data for the Post-Medieval environment, which remained marshland until the 19th century. The borehole survey also revealed an absence of alluvial silts in some areas of the site and confirmed the known level of the rising gravel deposits. This supports the BGS mapping of the area and suggests that gravel islands were present in the intertidal zone and a prominent feature of the earlier landscape. The subsequent trial trench evaluation successfully identified and characterised a Post-Medieval timber causeway running between the gravel islands, across an area of alluvium. The study also confirmed that the marsh was formerly higher, wetter and more difficult to navigate than at the present day.

Comparative data table of this deposit model	
Deposit model location	Maldon, UK (NGR: 585460 207310)
Depositional environment	Intertidal zone of the rivers Chelmer and Blackwater
Size of deposit model	The deposit model covered the area of development *c* 1.80Ha
Data collection strategies	Cable percussive boreholes, followed by trial trench evaluation
Position in the archaeological process	Initial ground investigation prior to trial trenching
Reason for deposit model construction	To model, assess and analyse the deeper alluvial sediments and any associated organic deposits, and to map the extent of the known reclamation activity at the site
Archaeological question	Define the extent of the Post-Medieval reclamation and consolidation activity at the site
Software and modelling process	The data was sorted in Excel, and mapped to a stratigraphic sediment model in AutoCad. Subsequent drawings were also produced using AutoCad
Outputs from the deposit model	A series of representative cross-sections and location plans

9.1. Introduction

An archaeological evaluation and geoarchaeological investigation was undertaken at Sadds Wharf, Station Road, Maldon, Essex (NGR: 585460 207310), in advance of the proposed development of the site (Figure 9.1). The development was located adjacent to the river Chelmer and close to its confluence with the river Blackwater. British Geological Survey (BGS) mapping indicated that the site was situated upon Pleistocene river terrace sands and gravels and silt and clay alluvium, the latter formed in an intertidal, salt marsh environment. The underlying bedrock geology comprised London Clay. A deposit model was requested by the Local Planning Authority (LPA) to map the full extent of the intertidal alluvial deposits and to assess their relationship to any archaeological assets that might survive within the proposed development area.

Given the logistical issues surrounding the development, which included a large remediation project, it was agreed that a borehole survey would be undertaken prior to archaeological trial trenching. The deposits were to be sampled in transects using a cable percussion borehole rig with sediment retained for later palaeoenvironmental assessment. Analysis of a number of proxy indicators would enable reconstruction of the local palaeoenvironments. The borehole transects would be used, therefore to elucidate site formation processes and to understand changes in the geomorphology and hydrology of the site. The deposit modelling was undertaken by Britannia Archaeology Ltd in consultation with Dr Steve Boreham (University of Cambridge) and Maria Medlycott (Essex County Council).

9.2. Aims and objectives

Deposit modelling was undertaken to provide an assessment of the geoarchaeological potential of the site and, if possible, to correlate visible topographic features with the buried sedimentary sequence. In addition to recording the general stratigraphy, a specific aim of the borehole survey was to target and sample organic-rich, fossiliferous sediments and to characterise associated minerogenic interfaces. The subsequent archaeological

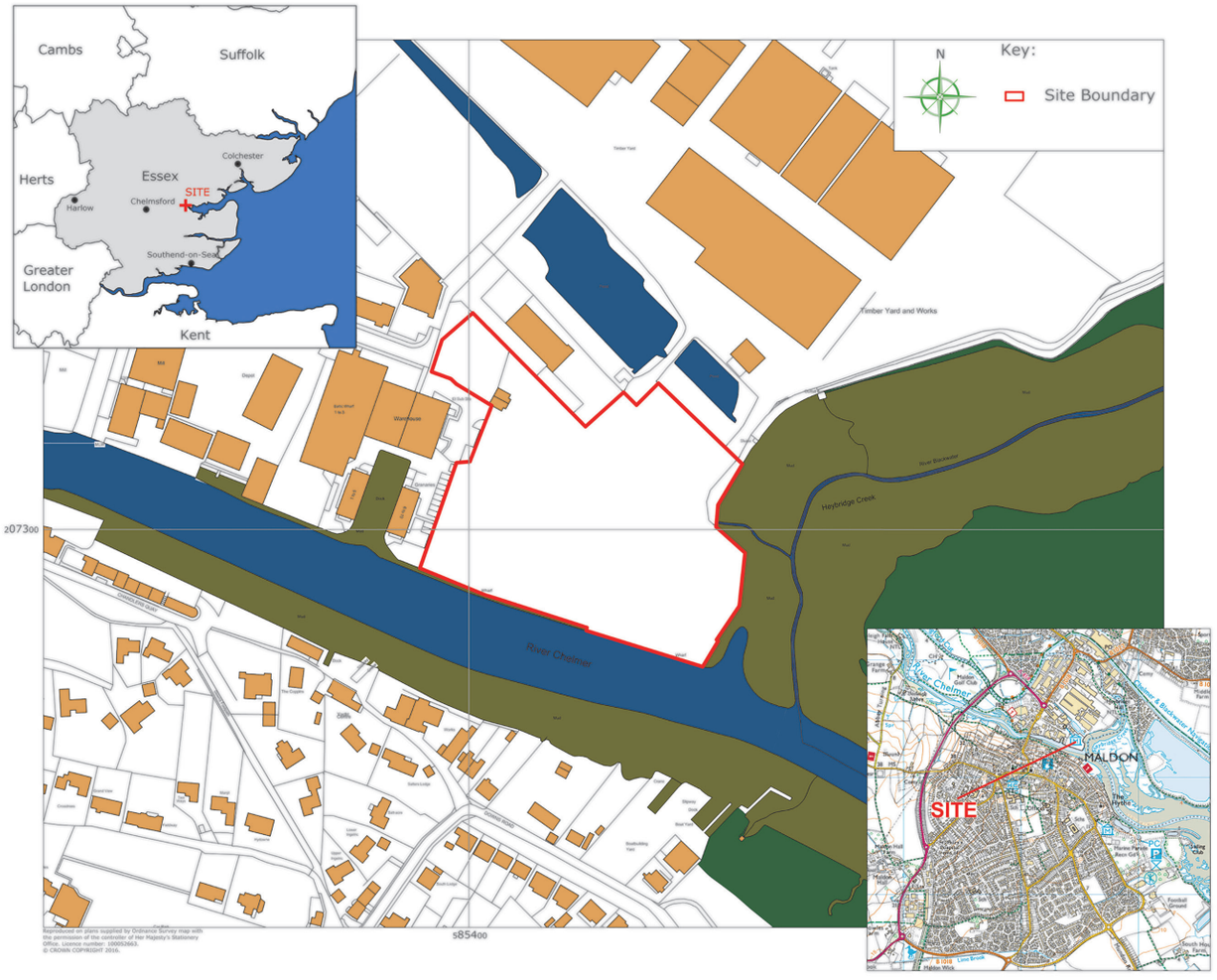


Figure 9.1: Location plan of the development site immediately adjacent to the river Chelmer and within the wider Essex landscape

evaluation sought to determine the location, character and level of preservation of surviving cultural remains, in particular, those associated with the now demolished Sadds Steam Saw Mill in the northern part of the site. Whilst the geoarchaeological investigations were restricted to the depth of impact of the proposed development, the scheme included the construction of basement parking and hence the proposed depth of investigation was significant.

9.3. Methodology

The deposit model was completed in two phases (Brook 2014). Phase 1 involved two cable percussion borehole transects across the site (Figure 9.2) aimed at assessing the thickness and character of the deposits. The transects (A and B) were aligned north to south and east to west. In total, eight boreholes were drilled along these lines, with a ninth borehole situated on the higher ground to the northern edge of the site, located in order to test deposit depth away from the alluvial zone. Each borehole location was surveyed using a differential global positioning system, (DGPS). The cores from the boreholes were extracted on-site using U100 tubes in Perspex sheaths (100mm in diameter and 450mm in length), allowing undisturbed samples to be retained, described and sub-sampled in the laboratory for further palaeoenvironmental analysis and radiocarbon dating. All natural and cultural strata that were observed in the cores were described on *pro forma* recording sheets.

Phase 2 involved the creation of a deposit stratigraphic model based on the borehole logs and, where appropriate, informed by the palaeoenvironmental analyses and radiocarbon dating of selected core sub-samples. Particular attention was paid to the presence or absence of pollen and mollusca within the alluvial layers, adding a layer of palaeoenvironmental data to augment the sedimentary descriptions.

Subsequent to the borehole survey, trial trenches were cut by a mechanical excavator under the supervision of a qualified professional archaeologist. The modern overburden was removed to the first archaeological horizon (Figure 9.3), and thereafter, all excavation work was undertaken by hand. Archaeological remains were preserved by record using *pro forma* sheets, plans, section

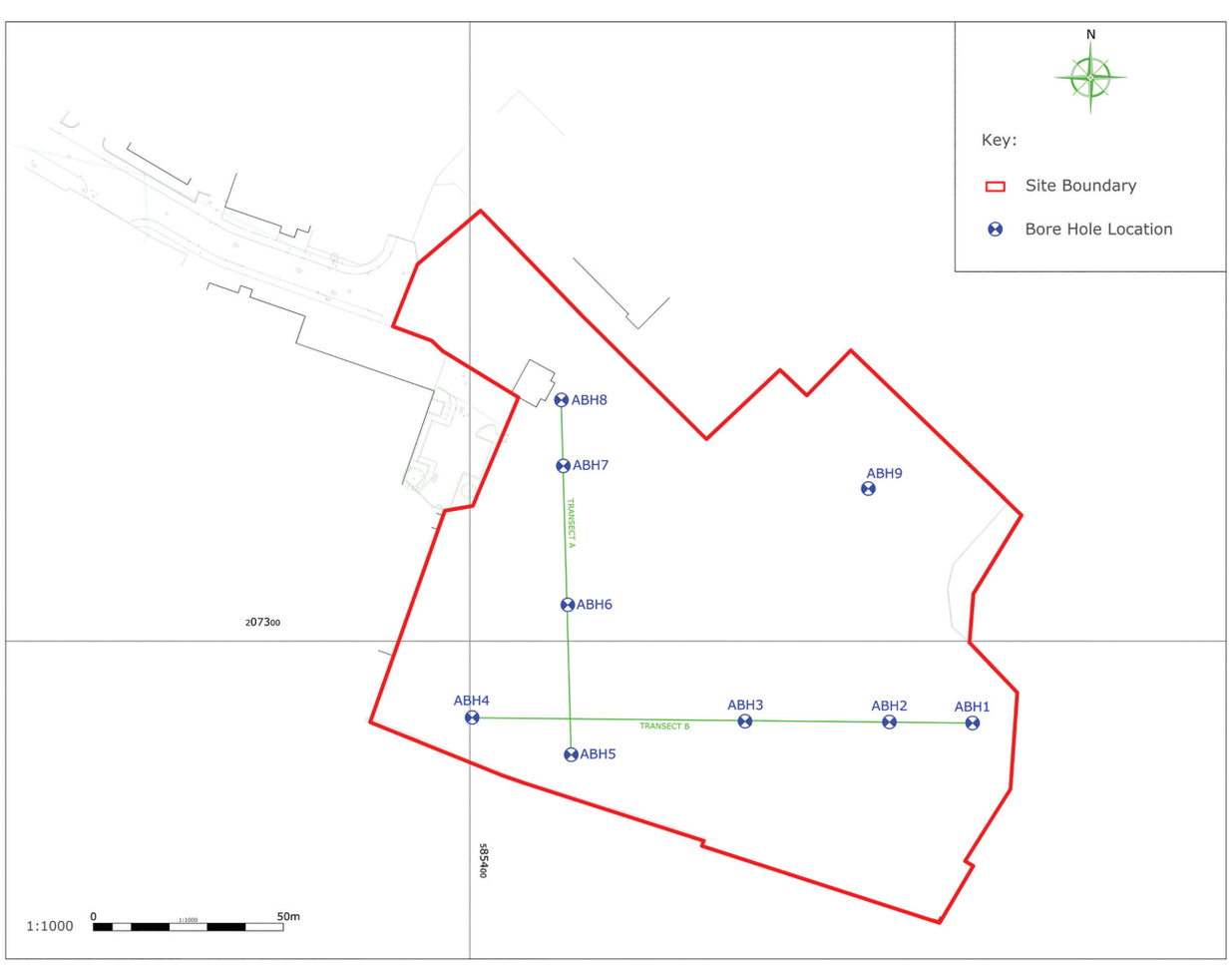


Figure 9.2: Position of boreholes within the immediate site area. Boreholes were drilled using a cable percussion rig with samples taken in U100 tubes for further analysis

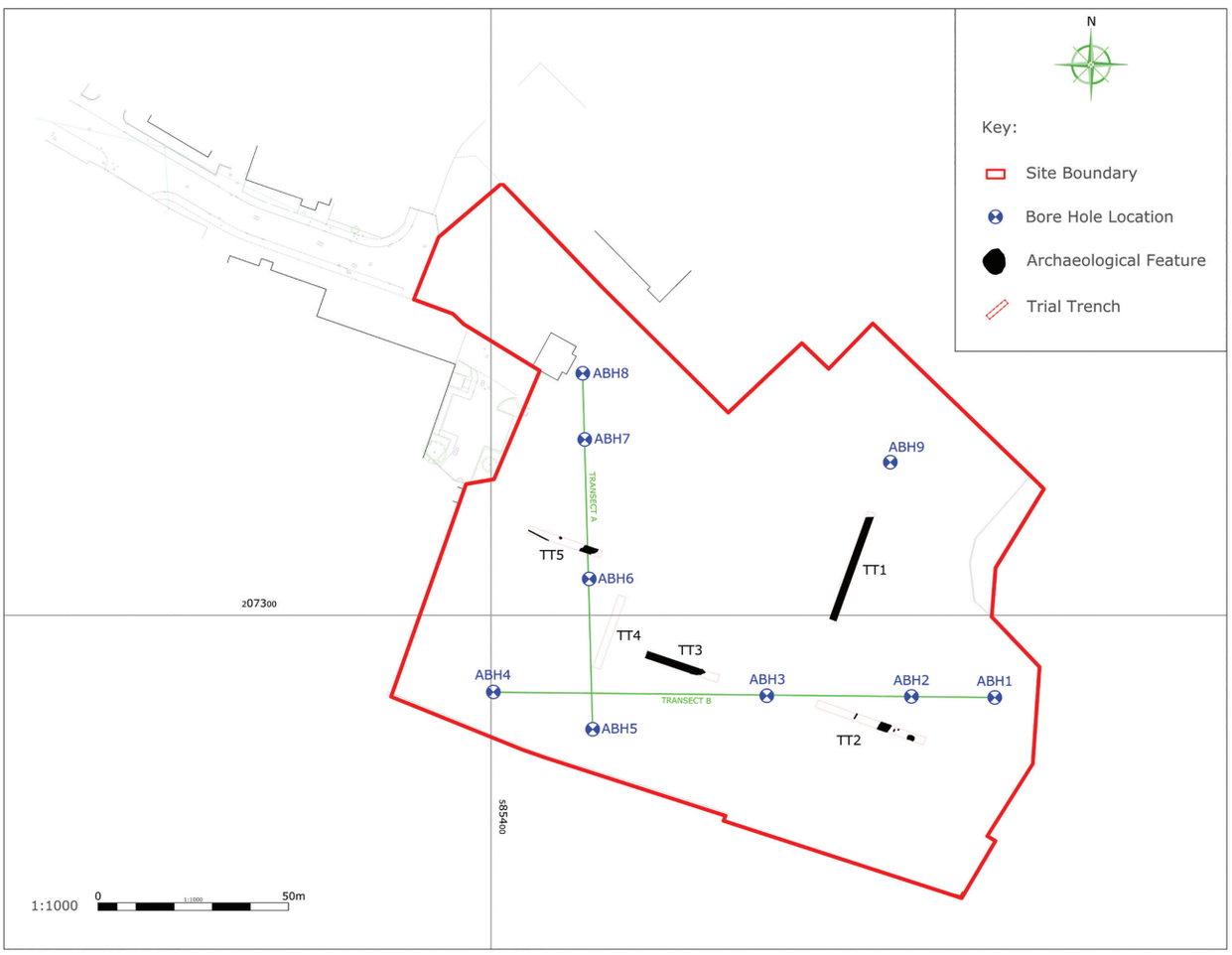


Figure 9.3: Trail trench positions in relation to borehole transects. The location of archaeological features recorded in trial trenches is also shown

drawings and photography. All layers were given unique context numbers, assigned during recording on-site. The sediments observed within these trial trenches were correlated with the stratigraphy recorded in the borehole survey to provide an overall stratigraphic model (Brook 2014).

9.4. Interpretation

The stratigraphic sequence recorded across the site was largely uniform despite the significant degree of ground disturbance caused by multiple phases of demolition and subsequent redistribution of material over the site to level the ground. From the information obtained through the borehole transects, a deposit model was constructed (Figure 9.4).

The top of the stratigraphic sequence consisted of a modern, made ground layer, which varied in thickness to a maximum depth of 1.30m. A spatially restricted demolition layer, associated with the former buildings of the John Sadd Timber Yard, was recorded below the made ground layer. This layer comprised an ash deposit that could relate to *in situ* burning associated with demolition of the buildings at the end of the 20th century or with a major fire that is recorded in 1907.

Four key stratigraphic units were recorded in the borehole survey beneath the modern made ground deposits. These units comprised an upper sandy gravel interpreted as a reclamation layer, above estuarine clays and gravels, river gravels and silts, and London Clay bedrock; they are each described in turn below.

Reclamation layer (1002)

This layer comprised light yellow-orange, loose sandy gravel with frequent large, rounded flint clasts. This unit is interpreted as the result of anthropogenic deposition of sediment across the eastern part of the site; it was spread across the area to raise, consolidate and reclaim an area of saltmarsh and to allow expansion of the Sadds Timber Yard. This episode of reclamation gives the site its current outline and topographic form. The line of the former sea defences was revealed during ground investigations in Trench 2 and is shown on the 1873 Ordnance Survey map (Figures 9.5 and 9.6), marking the eastern limit of this

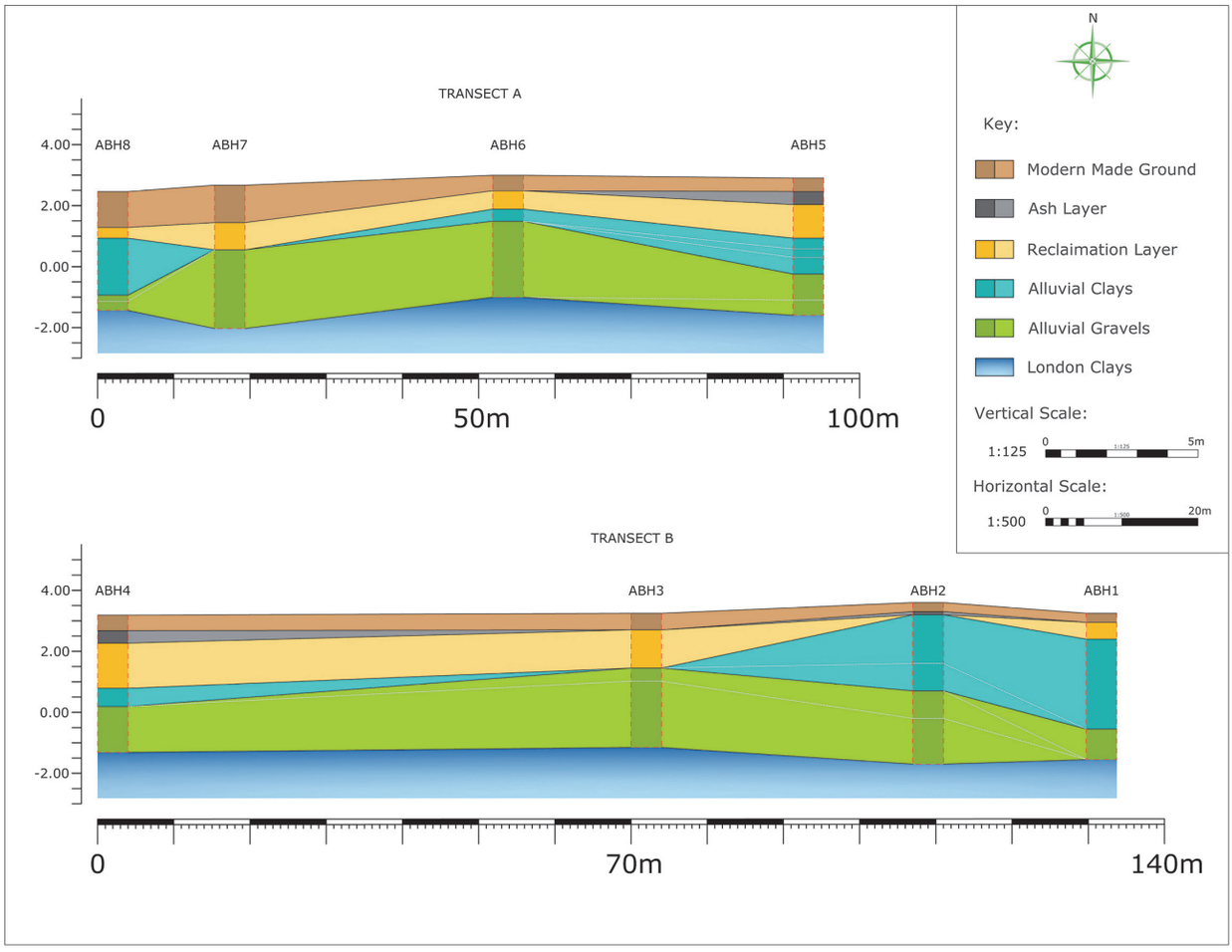


Figure 9.4: Archaeological deposit models constructed along Transects A and B

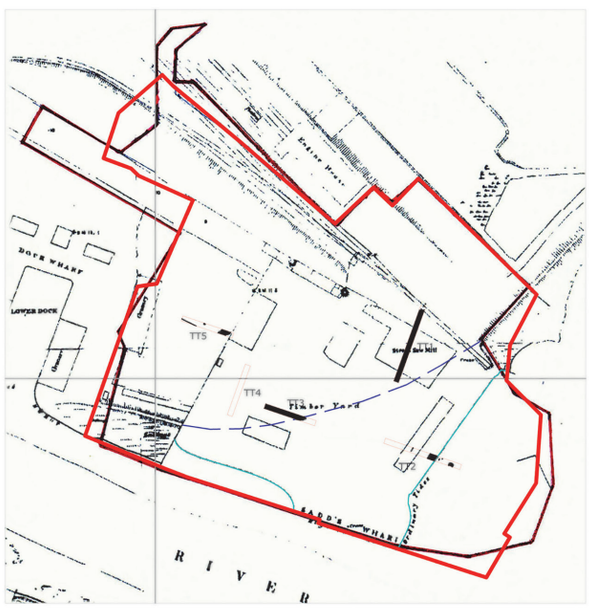
stage of reclamation. Trench 2 was located in the former intertidal zone, and this area of the site presumably required more material for consolidation than the remainder of it. This observation is demonstrable in Trench 5 where this reclamation layer is only recorded at the eastern end of the trench and is only 0.42m thick; the layer is absent at the western end of the trench reflecting an area of dryer, higher ground, which was already in use at the time of the consolidation of the eastern portion of the site.

Estuarine clay layer (1003)
This layer comprised dark blue-black, compact silty clay with infrequent small, sub-rounded flint clasts. This unit is interpreted as estuarine sediments deposited in a saltmarsh environment prior to the consolidation and reclamation of the site represented by Layer 1002. A wooden structure was located in Trench 3 on top of the silty clay (Figure 9.6) and is interpreted as a probable timber causeway constructed to facilitate access across the wetland.

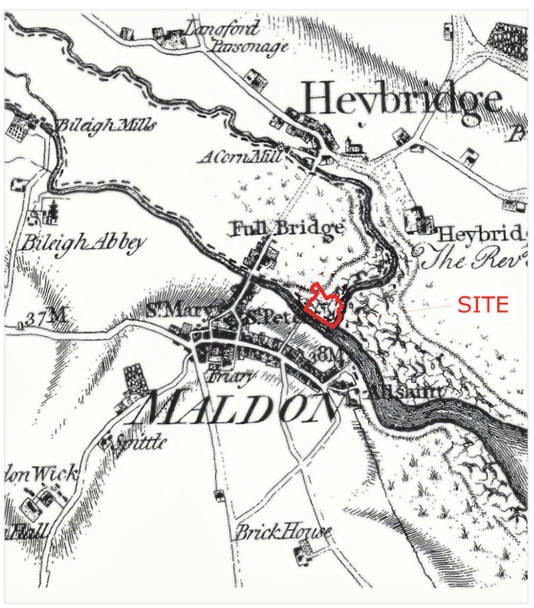
Estuarine clay and gravel layer (1004)
This layer was recorded below the blue-black silty clay and comprised a light blue-brown, firm, mottled silty clay with small sub-angular gravel clasts. The layer is interpreted as an estuarine deposit aggraded in the intertidal zone close to the confluence of the rivers Chelmer and Blackwater.

Basal river gravels and silts layers (1006, 1007)
Underlying the estuarine deposits, a sequence of mid yellow-brown, loose gravel with frequent sub-rounded flint clasts was recorded. These sediments are interpreted as representing the sands and gravels of late Pleistocene and early Holocene date that infill the lower parts of the palaeovalleys of the Chelmer and Blackwater prior to sea level rise at the end of the last glacial stage. As well as being buried beneath later, finer-grained alluvial deposits, these sediments also crop out as higher gravel islands in the valley floors.

London Clay layer (bedrock, 1008)
Boreholes encountered the London Clay (bedrock) at an average depth of 5.3m across the site.



Ordnance Survey 6 Inch Series, 1873.



Andre & Chapmans Map of Essex, 1777.

Figure 9.5: Map regression illustrating the physiography of the site at key points in time. The position of the archaeological trenches is shown on the map of AD 1873



DP8: Sea Defences - View West.



DP10: Timber Causeway - View West.

Figure 9.6: The timber causeway and sea defences exposed during trial trenching at the site

The stratigraphy observed across the site demonstrates topographic variability within the natural saltmarsh surface; this would have required, therefore, varying levels of remediation and reclamation in order to create drier areas for human activity. In addition to the dumping of sediments to raise ground levels, recorded archaeological structures, including sea defences and a causeway, reflect other ways in which local communities overcame the physical environment to utilise the area. The discovery of the causeway across the estuarine clay confirms the presence of buried archaeological remains and reinforces the approach taken to 3-dimensional modelling of the site. The estuarine clays were thickest in the east, representing the area that had most recently formed part of the intertidal zone. Unfortunately, no peat deposits, which would have provided material for dating were recorded, however associated pottery recovered from the causeway dates from the late 17th century. The assessment for pollen of clay sub-samples from borehole ABH 5 revealed an absence of pollen (from the Estuarine Clay layer), strongly suggesting protracted sub-aerial exposure – thus supporting the documentary evidence for a saltmarsh environment in the Post-Medieval period. The absence of estuarine clays in borehole ABH 6 and the elevated position of the first layer of gravel deposits (1006 and 1007) are of particular interest, suggesting that the intertidal zone incorporated a series of gravel islands raised above lower areas infilled with finer-grained alluvial sediments.

9.5. Further field investigation

The archaeological evaluation which followed borehole modelling revealed four phases of site development. The earliest sedimentation phase was represented by gravel deposition by the local rivers in channels at the interface of the terrestrial and intertidal zones (Layers 1006, 1007). The local environment comprised marshland and bog separating higher gravel islands. No archaeological phases correlating with discrete anthropogenic sediments believed to be earlier than the Post-Medieval period were recorded. Cartographic evidence illustrates that the site was located in marshland until at least the middle of the 19th century. Andre and Chapman's AD 1777 Map of Essex (Figure 9.5), for example, shows little or no development of the area, marked as marshland and records the causeway crossing the site. This is in contrast to the AD 1873 6 Inch Series Ordnance Survey map (Figure 9.5), which shows significant development of the site that is clearly marked 'Timber Yard'.

The evaluation revealed the presence of a probable timber causeway (Figure 9.6). Nationally, there is very little evidence of Post-Medieval timber causeways and thus information on their construction, including preferred materials and techniques, is limited. Timbers sent for further analysis show that the causeway was probably built from off-cuts of timber processing (Bale and Nayling 2014). This can be seen in the presence of bark edges on the timber that would have been of little use commercially but would have been suitable for use as a stabilising surface on wet ground. The cartographic evidence indicates a timber industry in the vicinity of this site from at least AD 1777, when the first evidence of the causeway appears in the historic record. Unfortunately the analysis of the timbers by Dr Roderick Bale has not helped to provide an absolute date, and none of the timbers that proved to be oak were considered suitable for dendrochronological dating.

It should be noted that the probable timber causeway was not present in Trench 4, which ran perpendicular to Trench 3 and only 10m west of the trench. The reclamation layer (1002) is particularly deep in Trench 4, and it is possible that either the causeway did not extend this far or (more likely) that some timbers were removed or destroyed when the reconsolidation of the site commenced. Another possibility is that the causeway was discontinuous, comprising several discrete lengths connecting drier areas of the marsh. This was demonstrated in boreholes ABH 3 and ABH 6, where no estuarine clays were encountered. In both cases, however, the basal river gravels (1006) were recorded at a shallower depth, again suggesting small, elevated gravel islands within the wider floodplain.

9.6. Conclusions

The deposit model was created to provide an assessment of the geoarchaeological potential of the site and to correlate visible topographic features with the subsurface topography and geology. In the absence of a deposit model, a full interpretation of the natural evolution of the site and its development in relation to key archaeological features (the probable timber causeway and tidal defence structures) and the former intertidal environment would have not been possible.

It is interesting to note that the timber causeway runs on an alignment towards the location of borehole ABH 6, suggesting that the causeway may have comprised several lengths linking higher gravel islands and overlying estuarine clays. The causeway created a barrier in some areas, thereby enhancing sedimentation and making the marshland higher, wetter and difficult to navigate.

Further excavations are planned at the site and will provide an opportunity for the full extent of the timber causeway to be mapped and defined within the sites boundary. The deposit model constructed during this initial phase of investigation may be expected at that stage to contribute significantly to the interpretation of the archaeological record.

Acknowledgements

Britannia Archaeology Ltd would like to thank Mr Jeffrey Ciffer (The Baltic Consortium) for commissioning and funding the project, Maria Medlycott at Essex County

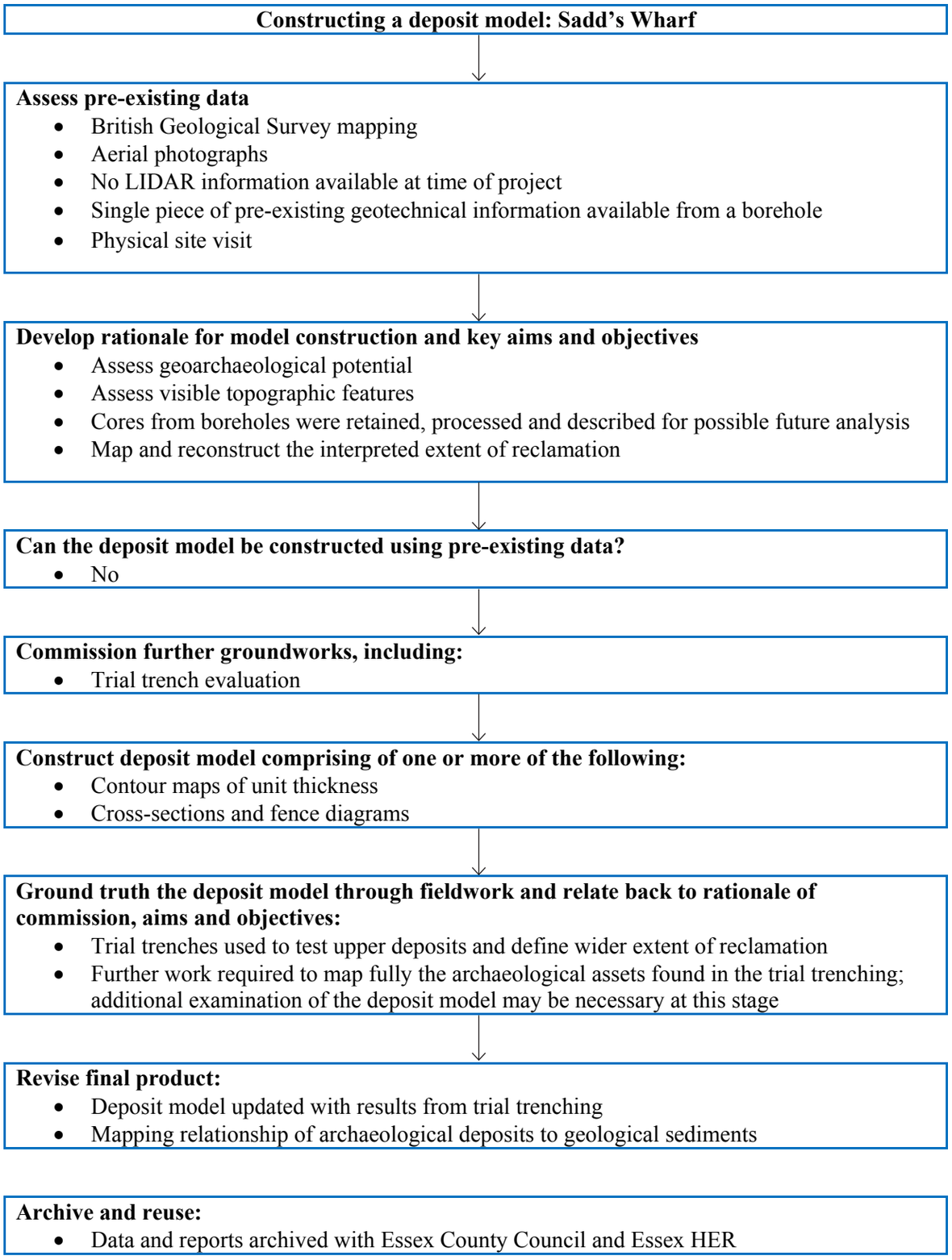
Council for all her advice and assistance throughout the project, Dr Steve Boreham (Cambridge University Department of Geography) for his advice and analysis of the soil samples and to Dr Roderick Bale (University of Wales Lampeter Archaeological Services) for his help and advice regarding the recording and analysis of the timbers.

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14681 - Deposit Modelling and Archaeology.indb 116 22/03/2018 15:10:08


Constructing a deposit model: Sadd's Wharf
Assess pre-existing data
British Geological Survey mapping
Aerial photographs
No LIDAR information available at time of project
Single piece of pre-existing geotechnical information available from a borehole
Physical site visit
Develop rationale for model construction and key aims and objectives
Assess geoarchaeological potential
Assess visible topographic features
Cores from boreholes were retained, processed and described for possible future analysis
Map and reconstruct the interpreted extent of reclamation
Can the deposit model be constructed using pre-existing data?
No
Commission further groundworks, including:
Trial trench evaluation
Construct deposit model comprising of one or more of the following:
Contour maps of unit thickness
Cross-sections and fence diagrams
Ground truth the deposit model through fieldwork and relate back to rationale of commission, aims and objectives:
Trial trenches used to test upper deposits and define wider extent of reclamation
Further work required to map fully the archaeological assets found in the trial trenching; additional examination of the deposit model may be necessary at this stage
Revise final product:
Deposit model updated with results from trial trenching
Mapping relationship of archaeological deposits to geological sediments
Archive and reuse:
Data and reports archived with Essex County Council and Essex HER

SECTION 5

Modelling beyond a single site

14681 - Deposit Modelling and Archaeology.indb 119 22/03/2018 15:10:08

10. Deposit modelling in the Lower Thames Valley (East London): correlating the sedimentary sequence with archaeological and palaeoenvironmental evidence of prehistoric human activity

Dan Young, Rob Batchelor and Chris Green

Quaternary Scientific (QUEST), School of Archaeology, Geography and Environmental Science, University of Reading, Whiteknights Campus, Reading, RG6 6AB

Abstract

Several years of geoarchaeological investigation in the London Boroughs of Newham and Greenwich, arising from archaeological mitigation of construction impacts, have resulted in a database of over 2000 stratigraphic records on the floodplain of the lower Thames Valley. This data has been used to develop a high-resolution spatial and temporal model of the floodplain landscape during the Late Devensian/Holocene, providing an opportunity to assess the potential of such a model as a predictive tool for identifying evidence of human activity and for locating thick sequences of palaeoenvironmental potential. The models have revealed a number of topographic features of interest in both Boroughs, including gravel highs and possible late Devensian/early Holocene channels. The models demonstrate that in general, greater thicknesses of alluvium are recorded in areas of lower gravel topography as might be expected, but that peat thickness shows a less predictable relationship with the underlying gravel topography. The distribution of the known prehistoric archaeology suggests that such sites have thus far only been recorded in areas of gravel 'highs' (generally above -1m OD), and that many of the sites are recorded where the peat is either relatively thin (<1m) or absent. The model highlights the importance of larger-scale deposit models in areas subject to intensive redevelopment and demonstrates that such models can be a useful tool in identifying areas of palaeoenvironmental and archaeological potential.

10.1. Introduction

The deposit model presented here forms the basis of a forthcoming publication, created in order to examine the potential of such a model to establish the archaeological and palaeoenvironmental significance of the floodplain in two areas of east London: the Borough of Newham, north of the River Thames, and the Royal Borough of Greenwich, south of the river. Such an exercise was facilitated by several years of geoarchaeological investigations in these Boroughs, undertaken by QUEST in collaboration with a number of archaeological units and heritage consultants; these resulted in a large body of sedimentary, palaeoenvironmental and archaeological evidence that also draws on existing geotechnical and archaeological databases (for example, the British Geological Survey [BGS] and Greater London Historic Environment Record [GLHER] archives) and site-specific geotechnical, geoarchaeological and archaeological investigations. The deposit model was initially presented as a poster at the Conference on the *Environmental Archaeology of European Cities* (27th-29th May 2015) in Brussels. The sedimentary data was therefore compiled, interrogated and interpreted over several years by QUEST geoarchaeologists, with a more thorough interrogation of the data undertaken more recently by the authors using deposit modelling software (RockWorks 16). Since the deposit modelling exercise was not directly funded by commercial work, funding was sought from a variety of sources, including an initial phase of data compilation conducted as part of the Undergraduate Research Opportunities Placement (UROP) scheme (funded by the

Comparative data table of this deposit model	
Deposit model location	London Borough of Newham and the Royal Borough of Greenwich, east London(NGR centred on: 540220 180130)
Depositional environment	Floodplain in the lower Thames Valley
Size of deposit model	Approximately 1,100Ha
Data collection strategies	Combination of British Geological Survey archive boreholes, site-specific geotechnical (borehole and test pit) data, and site-specific geoarchaeological boreholes
Position in the archaeological process	Prepared for publication, collating various site-specific geoarchaeological site investigations
Reason for deposit model construction	To produce a model of the sub-surface stratigraphy across the two Boroughs, including the surface of the late Devensian gravel, and the surface and thickness of the subsequent Holocene alluvial deposits
Archaeological question	To predict where evidence of human activity might be preserved, to place that evidence in its environmental context, and to establish how human activity influences, and is influenced by, environmental change
Software and modelling process	Data sorted in Excel and then imported to RockWorks 16. Models generated using an Inverse Distance Weighting algorithm. Output grid files modelled as raster files in ArcGIS
Outputs from the deposit model	A series of topographic surface plots, thickness models and selected representative cross-sections; assessment of archaeological and palaeoenvironmental potential

University of Reading). The time spent on the deposit modelling was ultimately funded by the University of Reading, who recognise the publication output of QUEST as a contribution to academic research.

10.2. Objectives

The overall objective of the study was to construct a high-resolution deposit model of the floodplain landscape, and to examine the interactions between topography, hydrology, vegetation and human activity in this part of east London. Ultimately, it was hoped that the model would help to: (1) predict where evidence of human activity might be preserved, and to place that evidence in its environmental context; (2) establish areas of greater palaeoenvironmental potential; and (3) establish how human activity influences, and was influenced by, environmental change. The sediment sequence beneath the floodplain in this area of the lower Thames Valley is well-documented, consisting of Pleistocene river gravel (the Shepperton Gravel) overlain by finer-grained Holocene alluvial deposits, often including peat, and masked by Made Ground (derived from waste material, demolition debris and redeposited alluvium).

The boundary surfaces between these sediment types are of interest since they represent evidence of local and regional environmental change. The most significant surface is that of the underlying Pleistocene gravel which, influenced by relative sea-level change and changing river behaviour, has largely determined the pattern of Holocene sedimentation in this area of the Lower Thames Valley.

Landforms, such as palaeochannels and gravel islands (eyots), have been identified in the surface of the Pleistocene gravels and their topographic form (altitudinal expression) have implications for soil formation, the location of archaeology and the potential for peat formation. The construction of a deposit model should enable the researcher to identify areas with higher archaeological potential. For example, areas of raised gravel topography may have increased archaeological significance, as demonstrated by analogous areas such as the Horselydown Eyot (Leary *et al* 2011), the Bermondsey Eyot and beneath the Royal Docks Community School (Holder 1998), all of which have all yielded evidence of utilisation and/or occupation by prehistoric people. In addition, peat forming in palaeochannels and other depressions on the margins of gravel highs and other dryland areas probably has a higher potential of containing prehistoric structures, as is demonstrated by a number of Neolithic and Bronze Age trackways, platforms and causeways at sites such as Golfers Driving Range, Beckton (Carew *et al* 2009). Finally, modelling allows the identification of areas where thick sequences of peat and alluvium are likely to be located; these have the potential to preserve high-

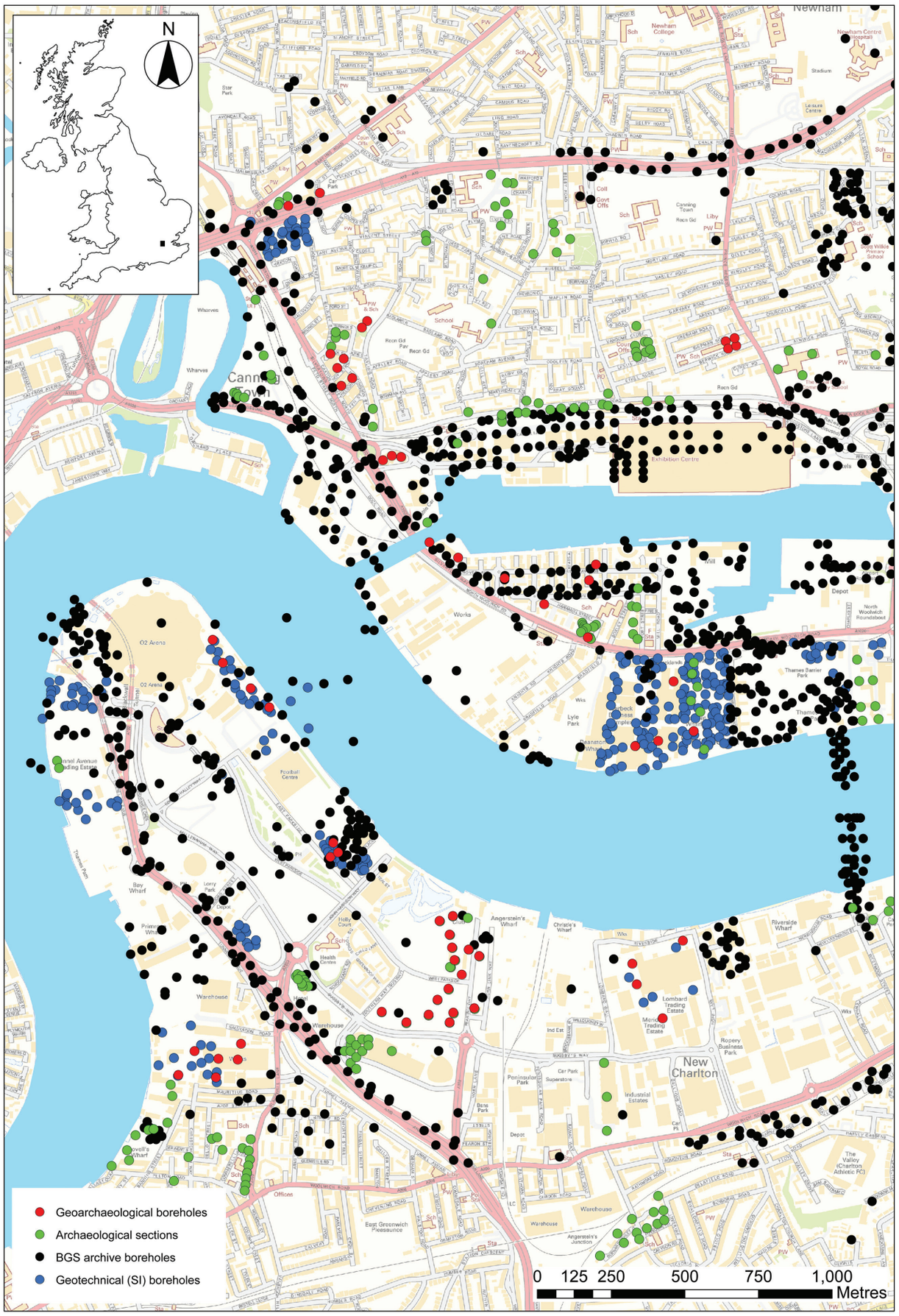


Figure 10.1: Records used in the deposit model for the London Boroughs of Newham and Greenwich: geoarchaeological boreholes, archaeological sections, BGS archive boreholes and site-specific geotechnical interventions. Contains Ordnance Survey data © Crown copyright and database right [2016]



Figure 10.2: Location of selected geoarchaeological and archaeological sites in the area of the deposit model. Contains Ordnance Survey data © Crown copyright and database right [2016]

resolution proxy palaeoenvironmental records of climate change, vegetation history, past hydrological regimes and human activity.

10.3. Methodology

The deposit model incorporated over 2000 records from a number of site-specific geoarchaeological, archaeological and geotechnical investigations, with the addition of borehole scans from the British Geological Survey (BGS) geoindex (http://mapapps2.bgs.ac.uk/geoindex/home.html) (see Figures 10.1 and 10.2). The data were compiled, interrogated and entered into the deposit modelling software during previous site investigations in the two Boroughs over a period of several years. It became apparent during this exercise that many of the geotechnical records from both site-specific investigations and the BGS geoindex were lacking sufficiently accurate spatial information (location and elevation), with geoarchaeological and archaeological records tending to be more reliable. With this in mind, only those records that included these data were included in the models. In addition, it was important to recognise at this stage that multiple sets of boreholes were represented; these were drilled at different times and recorded using different descriptive terms, and were subject to differing technical constraints in terms of recorded detail (including the exact levels of stratigraphic boundaries). An additional complication was presented by those records from the area of Royal Victoria Dock (Borough of Newham) where substantial excavation and subsequent infilling of the western inlet from the Thames created challenges for stratigraphic interpretation.

The initial phase of work involved the inspection of geotechnical logs from site-specific investigations and the BGS geoindex; those that were considered reliable were divided into their relevant sedimentary units, with the depth of the upper surface of each unit recorded in an Excel spreadsheet. The same data from geoarchaeological boreholes, including those drilled during site-specific investigations by QUEST and those recorded in unpublished (for example, http://archaeologydataservice.ac.uk/archives/view/greylit/query.cfm) or published accounts relating to other sites, were also inputted to Excel. Finally, relevant stratigraphic data from archaeological sections recorded in published and unpublished sources was also compiled. The spatial and stratigraphic data were then imported to RockWorks 16, using the 'Import from spreadsheet' function.

Topographic surface plots and thickness models were generated for each of the main stratigraphic units, using an Inverse Distance Weighting algorithm to optimise the smoothness of the interpolated outputs. Despite the number of available records for the two Boroughs, the boreholes are not uniformly distributed and a number of notable 'gaps' in the model may be observed. The reliability of the models is therefore variable. As a consequence of this the modelling procedure was manually adjusted so that only those areas for which sufficient stratigraphic data are present are modelled; in order to achieve this, a 'maximum distance cut-off filter' equivalent to a 100m radius around each record was applied to all deposit models.

The output from these models (in the form of RockWorks 16 grid files) was exported to ASCII format and then converted to Raster files within ArcMap. The Raster files were subsequently overlain on Ordnance Survey Street View mapping (open-source data) for the creation of the final models. Stratigraphic transects were generated using RockWorks 16 and were edited in Adobe Illustrator. Prehistoric archaeological data was compiled from the Greater London Historic Environment Record (GLHER). Figures 10.3, 10.4 and 10.5 illustrate the modelling of key units and surfaces, whilst Figures 10.7, 10.8 and 10.9 illustrate selected stratigraphic cross-sections (see Figure 10.6 for their locations).

10.4. Interpretation

10.4.1. Floodplain landscape evolution

Overlying the London Clay bedrock, a total of five main stratigraphic units were identified in the modelled area. These are described below, commencing with the modern ground surface:

- *Made Ground*: widely present and derived from waste material, demolition debris and redeposited alluvium;
- *Upper alluvium*: widely present across both Boroughs, usually clay-rich and largely inorganic. The sediments of the Upper Alluvium are considered to be indicative of deposition within low energy fluvial and/or estuarine floodplain environments associated with rising sea level during the Middle and Late Holocene. The high mineral content of the sediments probably reflects increased sediment loads resulting from intensification of agricultural land use from the later prehistoric period onward;
- *Peat*: frequently recorded across the floodplain but of variable thickness and recorded at differing depths; the peat often separates the deposits of the Upper and Lower Alluvium, but occasionally rests directly on the Pleistocene Shepperton Gravel. The peat is indicative of a transition towards semi-terrestrial (marshy) conditions, supporting the growth of sedge fen/reed swamp and/or woodland communities across the floodplain areas of both Boroughs;
- *Lower alluvium*: locally present, typically sandy/silty and frequently containing wood or macroscopic plant remains. The sediments of the Lower Alluvium are considered to be indicative of deposition by actively meandering channels during the Early to Middle Holocene, by which time the main course

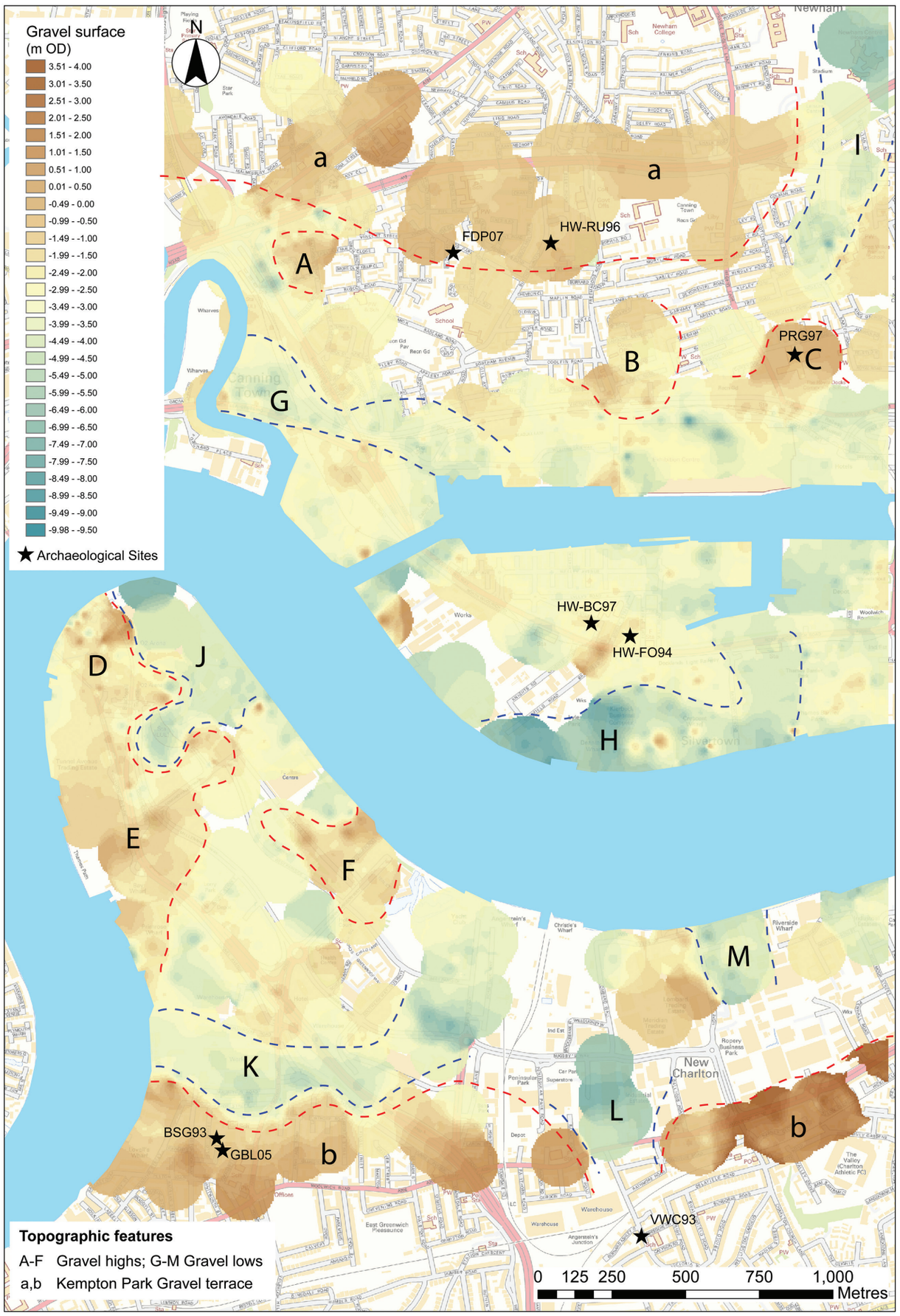


Figure 10.3: Modelled surface of the Pleistocene Shepperton Gravel (modelled using an Inverse Distance Weighting algorithm, with a maximum distance cut-off filter of 100m), showing the location of prehistoric archaeological sites and features described in the text. Contains Ordnance Survey data © Crown copyright and database right [2016]

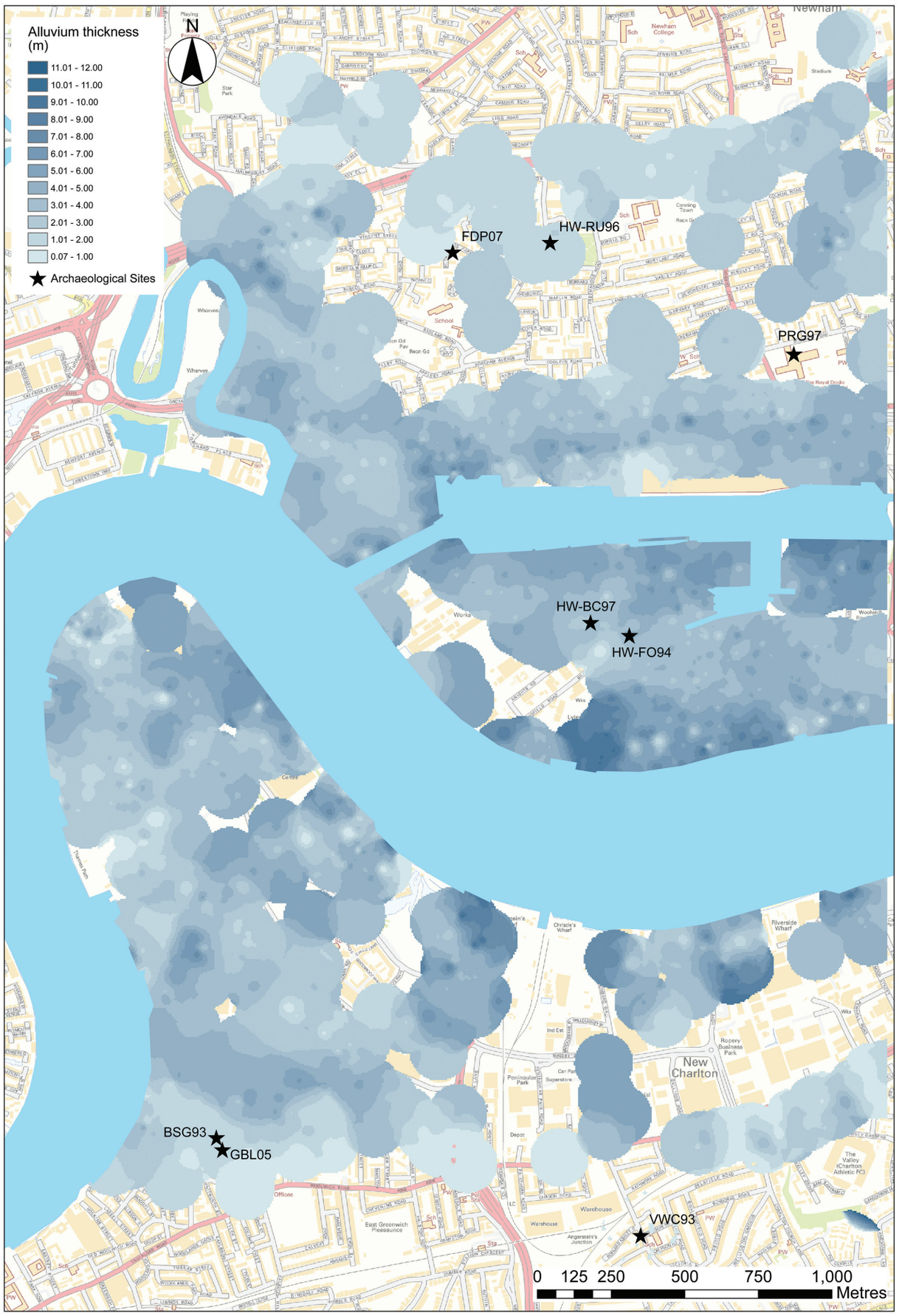


Figure 10.4: Modelled thickness of the Holocene alluvium (modelled using an Inverse Distance Weighting algorithm, with a maximum distance cut-off filter of 100m), showing the location of prehistoric archaeological sites (see text). Contains Ordnance Survey data © Crown copyright and database right [2016]

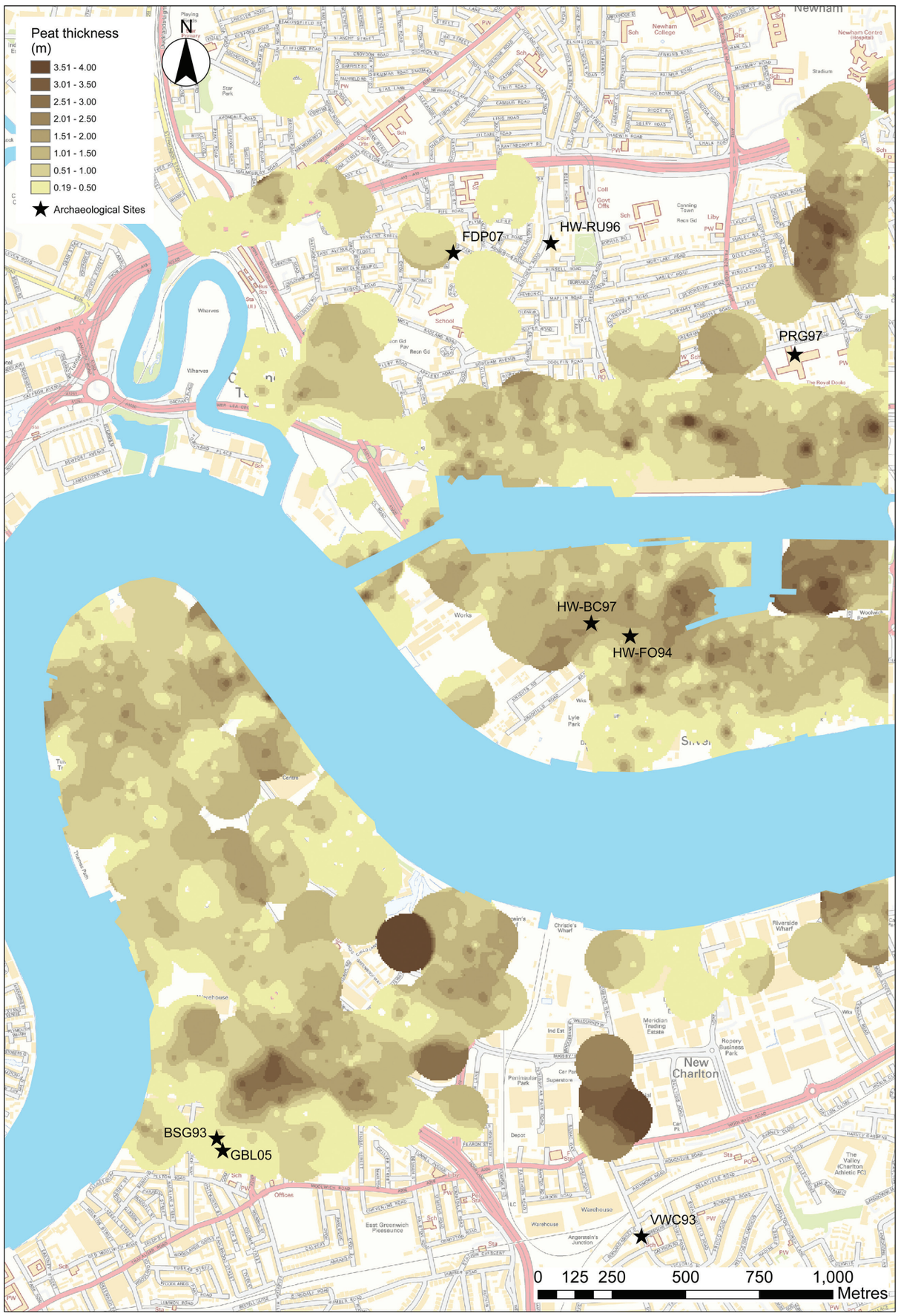


Figure 10.5: Modelled peat thickness (modelled using an Inverse Distance Weighting algorithm, with a maximum distance cut-off filter of 100m), showing the location of prehistoric archaeological sites (see text). Contains Ordnance Survey data © Crown copyright and database right [2016]

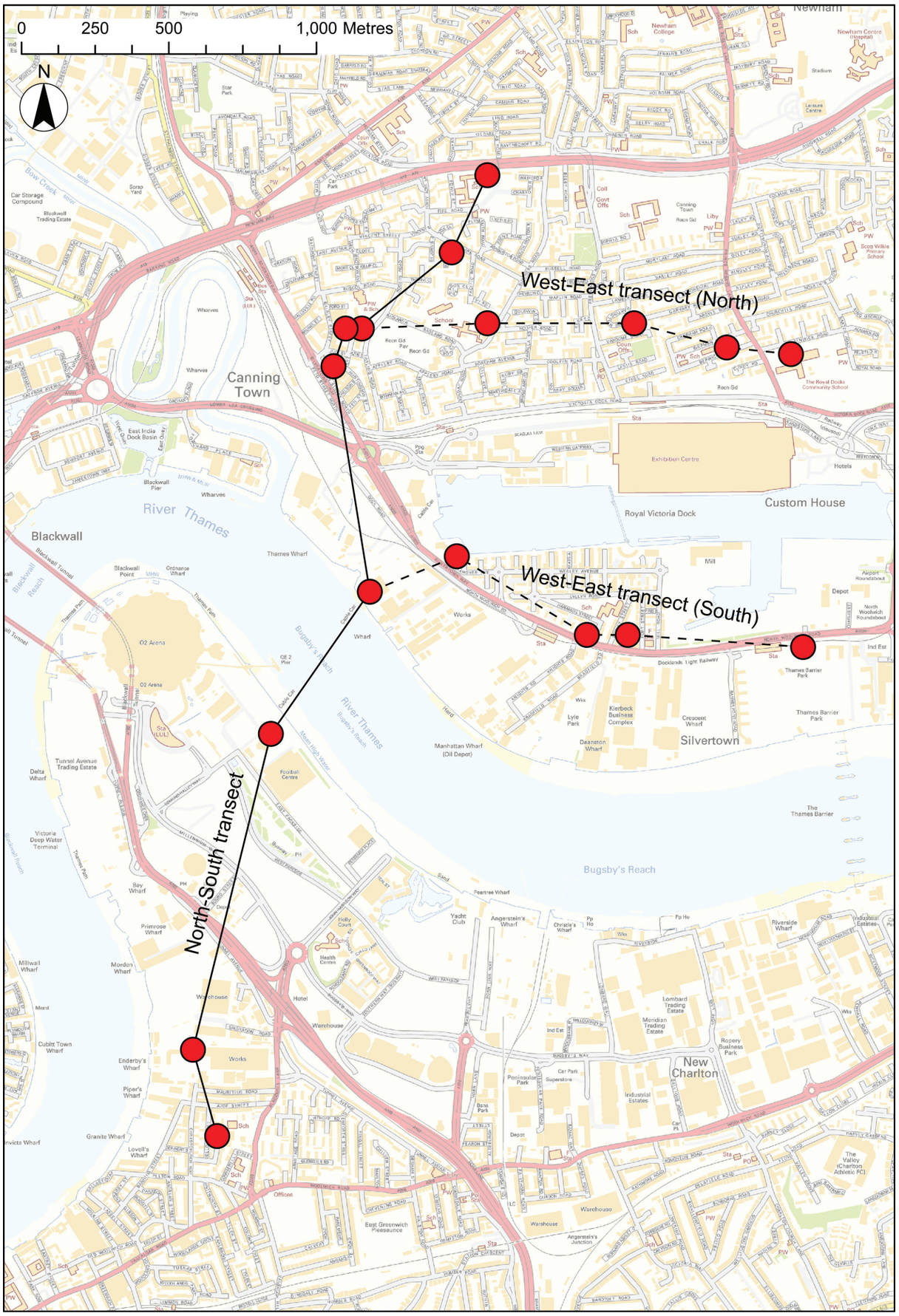


Figure 10.6: Map showing the location of the North-South and West-East transects. Contains Ordnance Survey data © Crown copyright and database right [2016]

of the Thames was probably established as a single channel close to its present alignment (although subsidiary, actively meandering channels appear to have survived elsewhere on the floodplain). During this period, the surface of the Shepperton Gravel was locally buried beneath sandy and silty channel and floodplain deposits. The distribution of the Lower Alluvium tends to confirm that this was a period during which the valley floor was occupied by a number of actively shifting channels, with a drainage planform pattern that was still determined to some extent by the underlying relief of the upper surface of the Shepperton Gravel;

- *Pleistocene sand and gravel*: sand and gravel is widely present across the modelled area, overlying the London Clay bedrock. Across much of the floodplain, and where it lies below *c* 0m OD, this unit is considered to represent the Shepperton Gravel, deposited during the Late-glacial period (15-10,000 years before present [BP]). Possible remnants of earlier Kempton Park Gravel (Middle Devensian; *c* 80-30,000 years BP) are recorded, in particular towards the southern and northern edges of the floodplain (see below); these perhaps form part of a 'low terrace', generally lying above *c* 0m OD. Both mappable lithostratigraphic units comprise sands and gravels deposited in a high-energy, braided river system; the latter, while it was active, would have been characterised by longitudinal gravel bars and by intervening low-water channels in which finer-grained sediments might have accumulated. Such a pattern of floodplain relief and this sedimentation regime would have been present on the valley floor at the beginning of the Holocene, although this was a time of transition to a lower-energy fluvial regime.

The position of the former Holocene floodplain of the Thames can be defined within the deposit models, with rising gravel surfaces (0-1m OD; see Figures 10.3, 10.5, 10.7, 10.8 and 10.9) and successively thinner alluvial sequences towards the northern and southern boundaries of the floodplain (where possible remnants of the Pleistocene Kempton Park Gravel terrace are recorded as features 'a' and 'b' on Figure 10.3). The model of the Shepperton Gravel has also revealed a number of topographic features of interest in both Boroughs (see Figure 10.3) including:

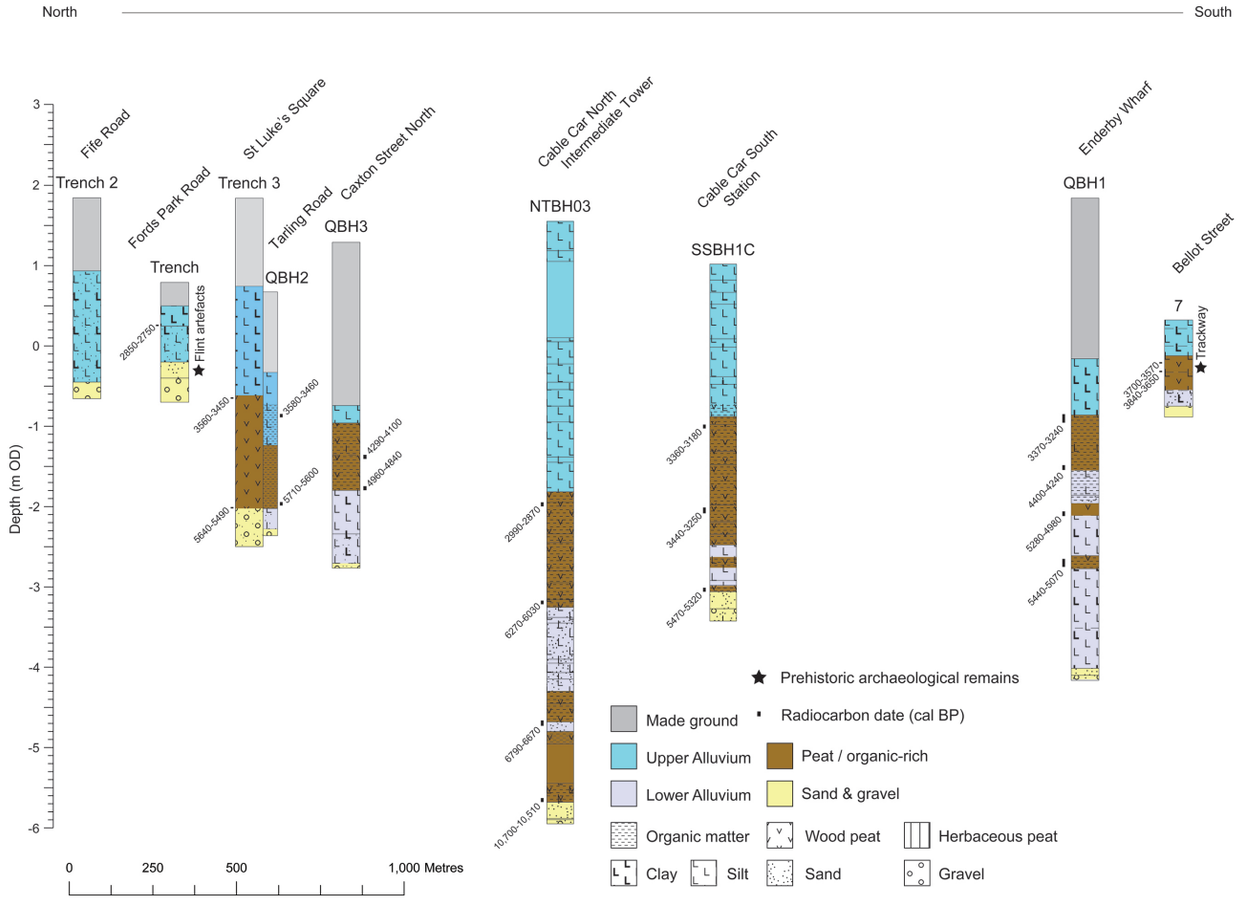


Figure 10.7: Selected lithostratigraphic sequences along a North-South transect across the modelled area (see text)

- Gravel highs, where gravel surfaces are recorded at between -2m and 0m OD (features A-F). These may represent either 'eyots', composed of Shepperton Gravel, or remnants of the higher Kempton Park Gravel terrace;

- Low gravel topography (-4m to -8m OD) indicative of former late Devensian/early Holocene palaeochannels (features G-L). Features G (Newham) and K (Greenwich) are of particular interest; the former represents a possible relict meander of the River Lea and the latter a large, perhaps late Devensian channel that may pre-date the modern course of the Thames. Features I and L meanwhile appear to dissect the Kempton Park Gravel terrace in the northern and southern areas of the floodplain respectively, forming deep, subsidiary or tributary channels of the River Thames and/or River Lea.

The deposit models for the subsequent Holocene alluvial deposits demonstrate that, as might be expected, greater thicknesses of alluvium (5m-8m) are generally recorded in areas of lower gravel topography (for example, infilling palaeochannels; Figure 10.4). However, the thickness of the peat (Figure 10.5) shows a less predictable relationship with the underlying gravel topography. Although some of the channel features identified above are infilled by 2-4m of peat (for example, features K, L and I), some

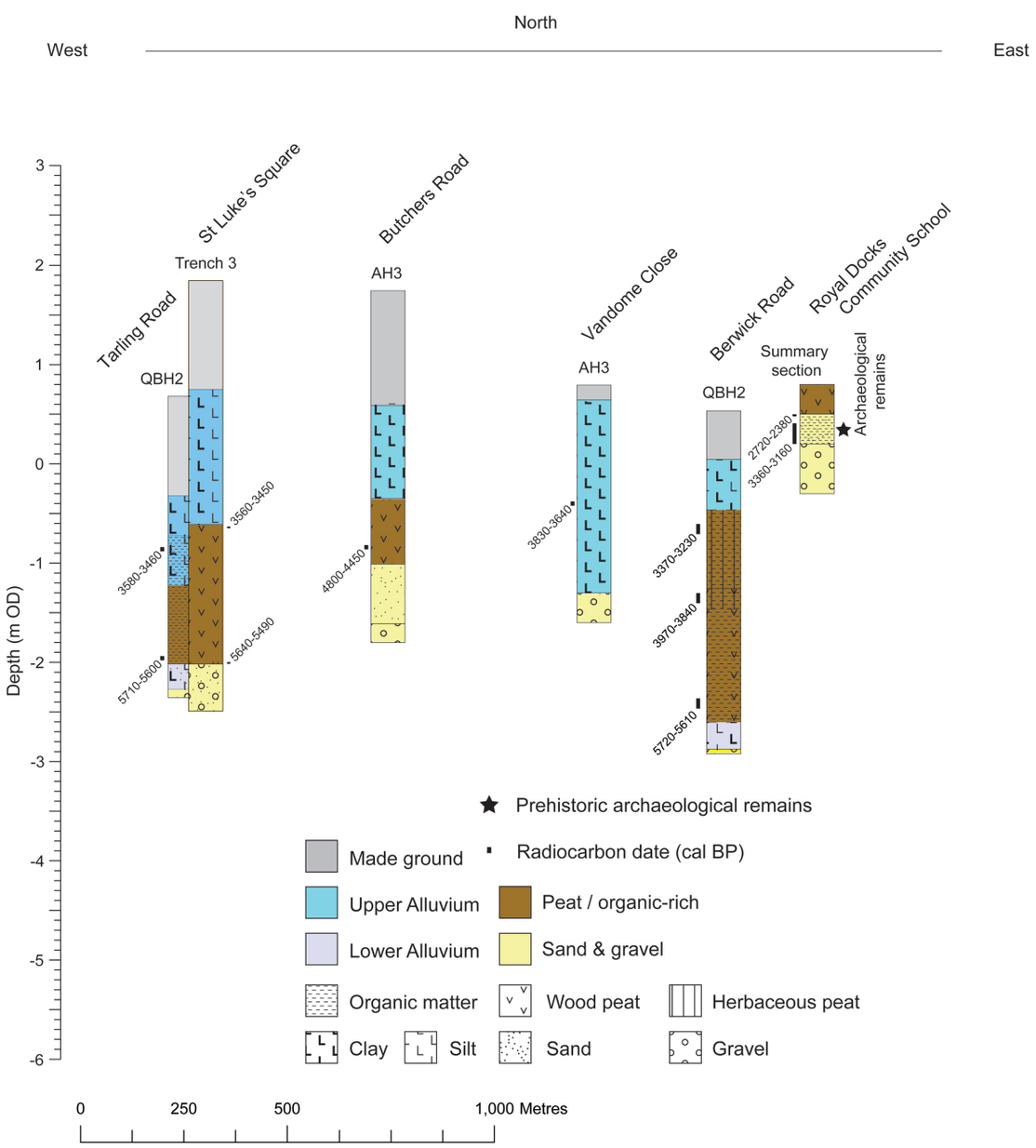


Figure 10.8: Selected lithostratigraphic sequences along a West-East transect (North) (see text)

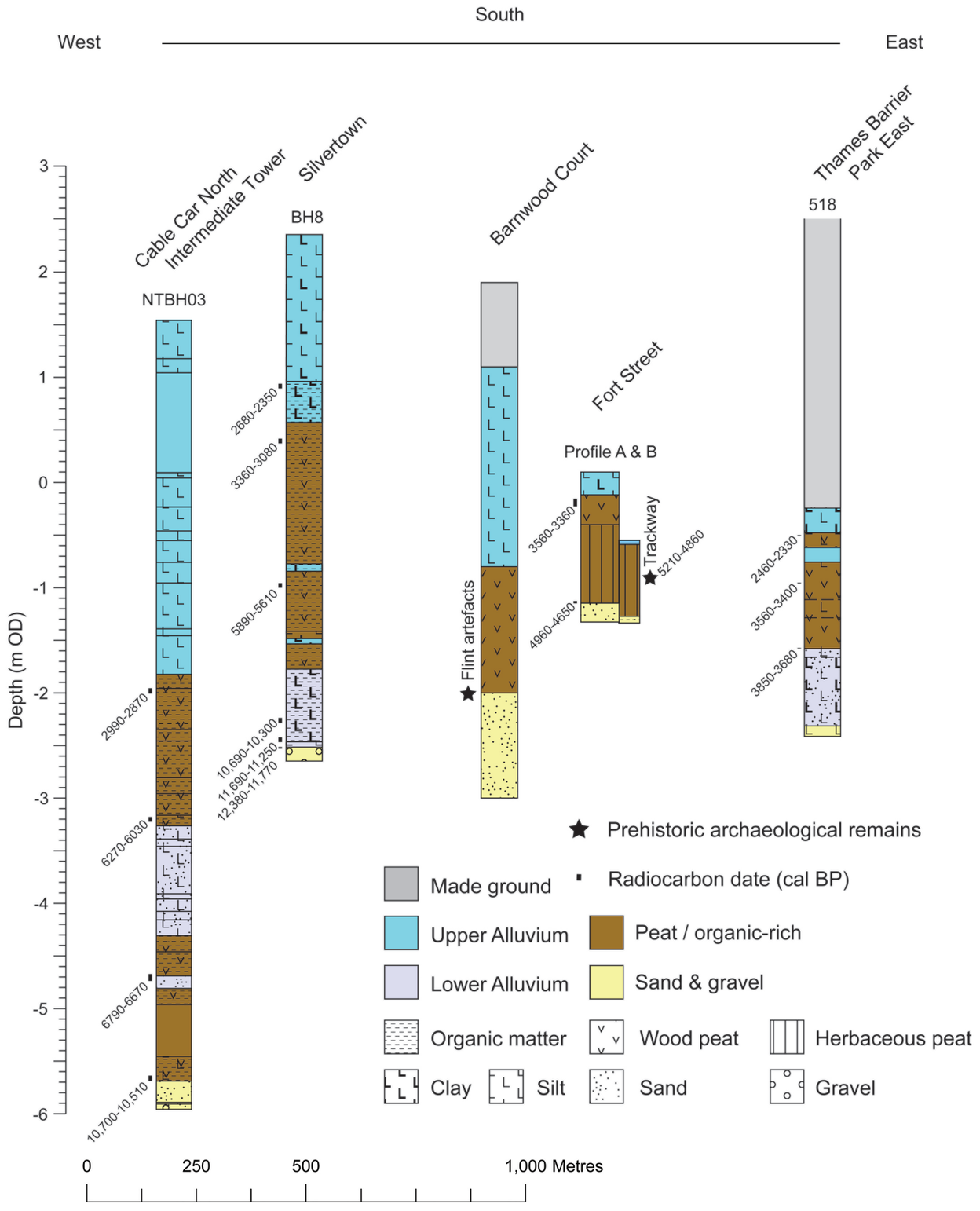


Figure 10.9: Selected lithostratigraphic sequences along a West-East transect (South) (see text)

Table 10.1: Prehistoric archaeological sites in the floodplain area of the London Borough's of Greenwich and Newham

Site name	Site code	Description of prehistoric archaeological remains	Easting	Northing	Reference
Royal Docks Community School, Newham	PRG97	>1300 fragments of Bronze Age and Neolithic flint tools and pottery recorded with a few Mesolithic flint tools, over a sand and gravel land surface.	541305	181105	Holder 1998
Victoria Way, Greenwich	VWC93	Various flints/burnt flints. Possibly not *in situ*	540785	178115	Bowsher 2003
Garage site, Bellot Street, Greenwich	GBL05	Bronze Age wooden structure (3840-3650 to 3700-3570 cal. BP) orientated north-west to south-east; recorded within the peat (-0.22m OD), above an elevated gravel surface (-0.70m OD)	539365	178405	Hawkins 2005
Barnwood Court, Newham	HW-BC97	6 fragments of burnt flint and 1 struck flint recovered from sand at *c* -1.81m OD; sealed by peat	540615	180195	Farid 1997
72-82 Bellot Street, Greenwich	BSG93	Bronze Age wooden structure (3550-3260 cal. BP) orientated north-south; recorded within the peat (-0.60m OD), above an elevated gravel surface (-0.58m to -0.79m OD)	539345	178447	Philp 1993
Butchers Road, Newham	HW-RU96	Small quantities of burnt and worked flint and a sherd of pottery (late Bronze Age?); recorded within peat	540478	181484	Wessex Archaeology 1996
Fort Street, Newham	HW-FO94	Short length of early Neolithic trackway of *Alnus* sp. (5210-4860 cal. BP); recorded within peat (-0.99m to -1.28m OD), above an elevated sand surface	540747	180151	Crockett *et al* 2002
20 Fords Park Road, Newham	FDP07	2367 struck flints, >2000 burnt flints and 44 pottery sherds recorded on a sandy eyot. The flint is largely later Mesolithic, with a few Neolithic/Bronze Age pieces	540148	181451	Nicholls *et al* 2013

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areas of lower gravel topography coincide with relatively thin (<1m) horizons (G, H and M); in addition, thick peat horizons (2-3m) are recorded in the area of selected gravel highs (D, B). At least part of the variation in the thickness of the peat may be a result of erosion associated with later fluvial activity.

10.4.2. Archaeological and palaeoenvironmental potential

Both the palaeochannels and gravel highs identified above would have represented significant features in the prehistoric landscape in this part of the Lower Thames Valley floodplain. The distribution of known prehistoric archaeology in relation to the underlying gravel topography (Figures 10.3, 10.5, 10.7, 10.8 and 10.9) suggests that such archaeology has so far been recorded only in areas of gravel 'highs' (generally above -1m OD). Five of the eight known prehistoric sites (Table 10.1) are associated with high gravel features identified above, whilst the other two (HW-8C97 and HW-FO94) are recorded in an area of moderately high gravel (-1m to -2m OD). Regarding the relationship between prehistoric archaeological remains and peat deposits, many sites of this period are recorded where the peat is either relatively thin (<1m; GBL05, BSG93, HW-BC97, HW-FO94) or absent (for example, FDP07, HW-RU96, PRG97, VWC93). Perhaps notably, with the exception of those sites towards the northern edge of the floodplain, the remainder of the sites are located on gravel highs that lie close to or on the margins of deeper channel features (for example, features K and H). Such relationships thus indicate that in this area of the floodplain, around Newham and Greenwich, archaeological potential may be greater in areas of higher gravel topography, in particular those areas that lie close to or on the margins of palaeochannel features. However, it is important to note that more deeply stratified archaeology may be difficult to locate, and the rate of sea-level rise (and areas of inundation) may have been a significant factor in determining the location of earlier to later prehistoric activity.

The areas of thicker peat (3-4m in places) indicate locations which might provide long, continuous records of environmental change and human activity through the preservation of biological remains, which are of particular relevance in areas close to known prehistoric activity. A good example of this is channel feature K at Bellot Street (Greenwich), where up to 4m of peat is recorded within *c* 150m of a Bronze Age trackway (Philp 1993). The deposit models presented may therefore be used as a guide for future archaeological and palaeoenvironmental investigations in advance of development of these areas.

10.5. Further developments to the deposit model

Notable gaps have been identified in the deposit models, some of which are located in key areas, which might provide further information to aid our understanding of landscape evolution and archaeological potential in this part of the floodplain. These include the area to the south-east of Greenwich Peninsula, where the relationship between channel features K, L and M is poorly understood, the northern area of the floodplain around channel feature I and gravel highs A, B and C. Prior to future publication of the model, any newly available data from geotechnical, geoarchaeological or archaeological site investigations will be sought in order to refine it. At the time of writing, geoarchaeological investigations are underway in both Greenwich and Newham; data from these interventions will be incorporated into the existing models.

10.6. Conclusions

The London Boroughs of Greenwich and Newham are both the subject of significant programmes of redevelopment, which may be expected to provide valuable opportunities for further archaeological and geoarchaeological investigations. By highlighting archaeological and palaeoenvironmental potential in this highly dynamic floodplain landscape, the models presented here provide valuable tools for use by heritage managers, archaeological practitioners, consultants and their clients. This study emphasises the potential of larger-scale deposit models to enhance understanding and to inform evaluation and mitigation strategies in areas subject to intensive redevelopment, and demonstrates that such models can assist the development of more integrated approaches to archaeological and geoarchaeological investigation. None of these models, however, should be viewed as definitive, and it is intended that they be updated and revised over the coming years to integrate data from future archaeological, geoarchaeological and geotechnical site investigations.

Acknowledgements

We are grateful to the following organisations for commissioning Quest to carry out geoarchaeological investigations within the area detailed above: CgMs Consulting, RPS Planning & Environment, AOC Archaeology and Pre-Construct Archaeology.

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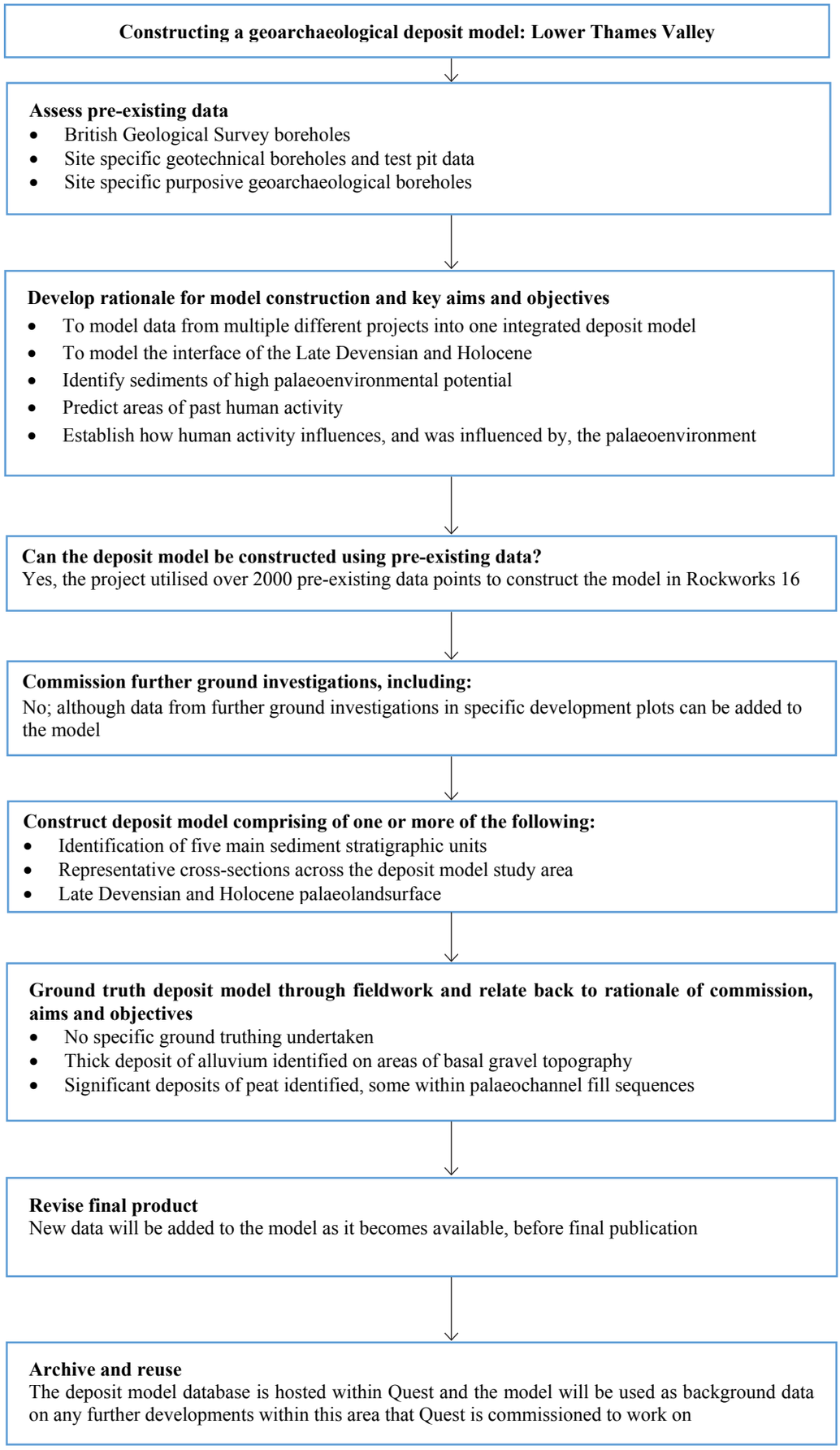
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Constructing a geoarchaeological deposit model: Lower Thames Valley
Assess pre-existing data
British Geological Survey boreholes
Site specific geotechnical boreholes and test pit data
Site specific purposive geoarchaeological boreholes
Develop rationale for model construction and key aims and objectives
To model data from multiple different projects into one integrated deposit model
To model the interface of the Late Devensian and Holocene
Identify sediments of high palaeoenvironmental potential
Predict areas of past human activity
Establish how human activity influences, and was influenced by, the palaeoenvironment
Can the deposit model be constructed using pre-existing data?
Yes, the project utilised over 2000 pre-existing data points to construct the model in Rockworks 16
Commission further ground investigations, including:
No; although data from further ground investigations in specific development plots can be added to the model
Construct deposit model comprising of one or more of the following:
Identification of five main sediment stratigraphic units
Representative cross-sections across the deposit model study area
Late Devensian and Holocene palaeolandsurface
Ground truth deposit model through fieldwork and relate back to rationale of commission, aims and objectives
No specific ground truthing undertaken
Thick deposit of alluvium identified on areas of basal gravel topography
Significant deposits of peat identified, some within palaeochannel fill sequences
Revise final product
New data will be added to the model as it becomes available, before final publication
Archive and reuse
The deposit model database is hosted within Quest and the model will be used as background data on any further developments within this area that Quest is commissioned to work on

11. The Battersea Channel Project: geoarchaeological deposit modelling as a unifying and dynamic resource for historic environment mitigation and dissemination

Virgil Yendell

MOLA (Museum of London Archaeology), Mortimer Wheeler House, 46 Eagle Wharf Road, London, N1 7ED

Abstract

Multiple small and large-scale developments in the Nine Elms area of south-west London motivated Historic England to form the Battersea Channel Project (BCP). The Battersea Channel, now absent from the modern landscape, once formed part of the Late-glacial to early Holocene multi-channel braided network of the Thames. It was separated from the main channel by the Battersea Eyot, a relic island feature also not obvious in the modern topography. The intensive development around Nine Elms encompassed the entire eastern part of the area, which had previously received little attention, but was deemed to have the potential to preserve significant archaeological and palaeoenvironmental resources. A significant portion of the ongoing work, supported by the major partners (Historic England, MOLA, Quest and Wessex Archaeology), has focused on the construction of large-scale deposit models. As a result of this initiative, these major archaeological units, practitioners and curators have used the results of deposit modelling to target more effectively archaeological significant layers and to consider issues of preservation and geoprospection during planning and evaluation phases of construction. As the project progresses, partner and stakeholder involvement has been shown to significantly improve deposit modelling methodologies, data interpretation and presentation. The future benefits for the BCP in use, interpretation and dissemination of deposit modelling data are described and discussed, and a future for deposit modelling and landscape visualisation as a dynamic canvas for the integration and dissemination of archaeological knowledge is proposed.

11.1. Introduction

Over the last few years, the Nine Elms area of south-west London has become the focus of intense and widespread redevelopment, with up to 20 new construction/regeneration projects either finished or in the process of completion; many of these projects have either been attracted by, or are associated with, iconic sites such as the former Battersea Power Station and New Covent Garden Market, or new developments such as the relocation of the United States Embassy and Northern Line Extension. The Nine Elms area includes a landform feature known as the Battersea Channel, which once formed part of the Late-glacial to early Holocene multi-channel braided network of the Thames and is separated from the modern course of the river by the Battersea Eyot (Figure 11.1). In contrast to the modern foreshore of the river, where considerable Mesolithic to Iron Age evidence has been recorded, only sparse archaeological records existed for the wider Battersea Channel area prior to redevelopment of the Nine Elms area. Therefore, these multiple construction projects, particularly in the eastern part of the area, provided a significant opportunity to investigate the archaeological and palaeoenvironmental resource of the Thames floodplain and to record evidence of human occupation in the area (see also Payne *et al* Chapter 7 this volume for discussion of the New Covent Garden Market site).

As the geoarchaeological projects accompanying these construction schemes were being undertaken by a number of archaeological units and practitioners with input from a variety of curatorial officers, Historic England created an umbrella forum known as the Battersea Channel Project (BCP). The aim of this grouping was to bring together

Comparative data table of this deposit model	
Deposit model location	London, UK (NGR: 529900 177400)
Depositional environment	Floodplain sequence of the Battersea Channel: a Late-glacial and early Holocene landform of the River Thames
Size of deposit model	The deposit model covered a study area of c 200Ha
Data collection strategies	A mixture of geotechnical and purposive test pits, window samples and CPT boreholes, augmented by ongoing archaeological watching briefs and evaluation trenching providing additional sedimentological descriptions
Position in the archaeological process	The Battersea Channel Project provides an umbrella structure for multiple projects at various stages from pre-planning through to post-excavation analysis and publication
Reason for deposit model construction	1. To model the interface of the Pleistocene sediments (gravels) and the overlying Holocene sequence and to identify the major stratigraphic units in order to investigate the character and define the position of the Battersea Channel 2. To use the model to assess archaeological potential and to place discoveries within a secure landscape context
Archaeological question	To bring together archaeological and palaeoenvironmental information from multiple development sites in order to investigate the archaeological record of the Battersea Channel
Software and modelling process	The data was collated and sorted in Rockworks 15, with surfaces of key stratigraphic units modelled in ArcGIS 10.2 and 10.3. Representative stratigraphic transects were compiled in Rockworks 15 and were illustrated using Corel Draw and Illustrator
Outputs from the deposit model	Ongoing work as part of this study includes a series of topographically modelled surfaces, peat density maps and representative cross-sections. However, it is hoped that the raw data will form part of a limited but dynamic resource for use by curators, archaeologists, clients and the public

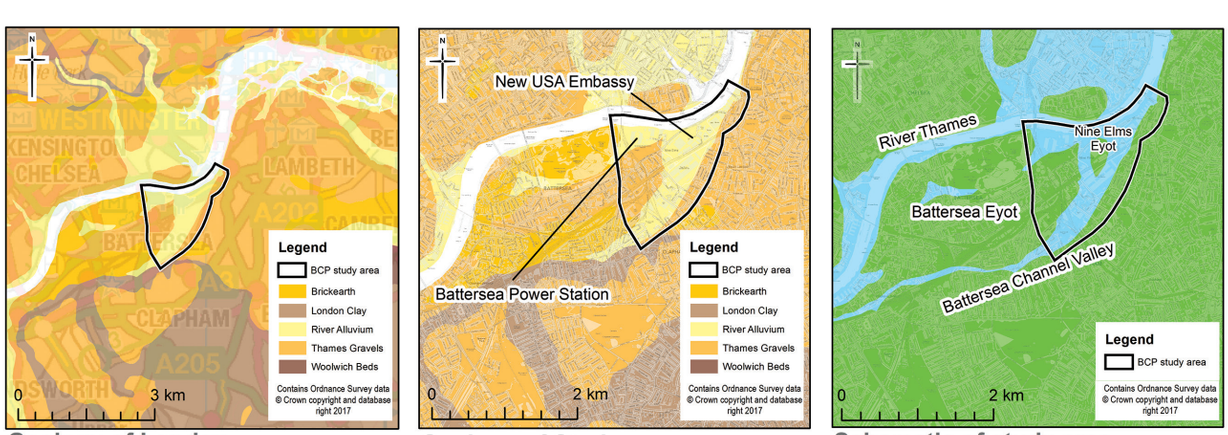


Figure 11.1: Location of Battersea Channel, wider Nine Elm's study area and surficial geology

representatives of Historic England, MOLA, Quest and Wessex Archaeology to share knowledge of ongoing and unpublished projects in order to target more effectively archaeological investigations and to aid the interpretation of findings with respect to the threatened heritage resource in the area.

11.2. Aims and objectives

Deposit modelling played a key role in the advancement of several of the project's specific research aims. Digital Elevation Models (DEM) interpolating the upper surface of the Pleistocene deposits (primarily gravels) provided a landscape template for study of the early Holocene palaeotopography, and enabled investigation of the location, orientation, size and depth of the channels that may have developed within the Battersea Channel landform.

The early Holocene topography DEM (in conjunction with cross-sections showing the character of the overlying deposits) was used to investigate how the Battersea Channel and its internal smaller landforms (subsidiary channels, islands etc) shaped the prehistoric landscape and how the natural environment responded to changes in relative sea-level and associated tidal processes. Palaeoenvironmental evidence provided by botanical and faunal remains recovered from secure stratigraphic contexts afforded an opportunity to consider the scale and complexity of both natural environmental change and the impacts of human activity. With past landscapes reconstructed, the topographic and environmental models provided a framework to consider how contemporary human populations would have experienced, reacted to and shaped environmental change. Finally, beyond the specific aims and objectives relating to individual projects, an overarching aim of the BCP was to encourage close co-operation between different archaeological units, practitioners, and curators. This required the dovetailing and harmonisation of methodologies, philosophies and systems in order that knowledge and data could be usefully and rapidly shared. In this way, deposit modelling assumed a pivotal role in the sharing of data and discussion of the results of field investigations.

11.3. Methodology

Prior to inception of the BCP, MOLA's portion of the geoarchaeological dataset held for the Nine Elms area formed part of the MOLA Borehole Database, comprising over 11,000 separate entries compiled during work undertaken as an element of major MOLA initiatives such as the Lea Valley Mapping Project, investigations of the 2012 Olympic site and extensive work in the City of London, Westminster and Southwark (Figure 11.2). The entire BCP database consists of over 1,100 separate entries (590 provided by MOLA, 429 provided by Wessex Archaeology and 288 by Quest) relating to both historic and modern geotechnical and archaeological records.

Whilst the database may appear large for a relatively small area, it is important to be aware of both the key advantages and disadvantages of the different data sources and methodologies used (Table 11.1).

Since the deposit models constructed from the datasets described in Table 11.1 are part of ongoing geoarchaeological work, some areas investigated under the auspices of the BCP are only represented by a

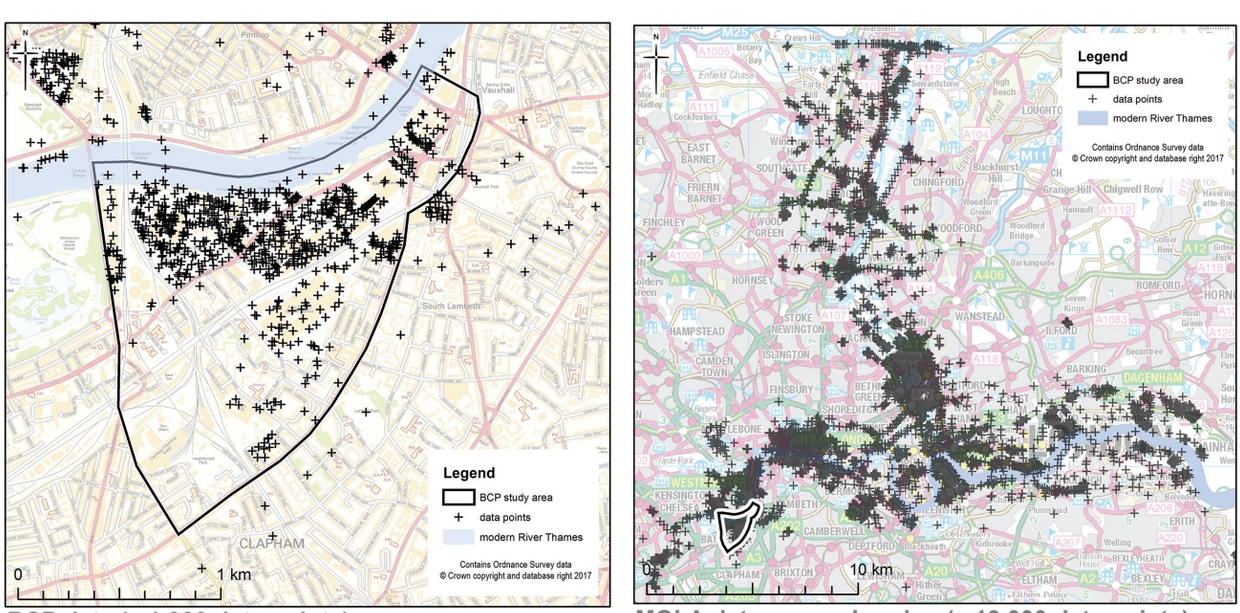


Figure 11.2: Data points within the wider MOLA Borehole Database and within the Battersea Channel Project area

Table 11.1: Summary of advantages and disadvantages of key source data

Source or method (proportion of the BCP database)	**Advantage**	**Disadvantage**
Historic British Geological Survey (BGS) and other geotechnical data (20% of MOLA BCP)	Large number of records available at no cost	Holocene deposit descriptions can be superficial and may not be sufficiently detailed to answer geoarchaeological questions
Geoarchaeological logs interpreted from monitored geotechnical interventions (boreholes and trial pits; estimated 60% of MOLA BCP)	Log descriptions are sufficiently detailed for geoarchaeological investigations	Interventions are not always continued to full depth (ie to bedrock/natural), may be disturbed or incomplete, or may not coincide with the most desirable sample location due to geotechnical drilling priorities
Geoarchaeological logs from purposive geoarchaeological interventions (boreholes and trial pits; estimated 15% of MOLA BCP)	Log descriptions are compiled specifically for geoarchaeological investigations and use tailored drilling methodologies aimed at applying the most effective sampling strategy and obtaining bespoke stratigraphic descriptions.	Can be prohibitively expensive for some developments
Archaeological trench sections (estimated 5% of MOLA BCP)	Associated with archaeologically significant layers such as old ground surfaces. More extensive exposures provide significant information on stratigraphy and sediment architecture	Stratigraphic records compiled during earlier investigations may not provide sufficiently detailed or comprehensive descriptions to answer geoarchaeological questions

sparse selection of database entries relating to historic geotechnical records; in contrast, other areas benefit from higher frequency and well-distributed geoarchaeological data, together with detailed archaeological records acquired through fieldwork campaigns. The ongoing approach, with regular updates and data-sharing between BCP partners, should allow investigation strategies for the various developments to adapt and target areas where data entries are sparse or inconclusive. It may benefit future statements of confidence in a deposit model if a standardised method for describing the distribution of both known and potential remains of archaeological significance is included; at present in MOLA, we are investigating whether the application of K function (Dixon 2006), spatial autocorrelation (Chatfield 2006) or hot spot analysis (Patil 2013) can provide an objective and appropriate way to quantifying the risk and validity of the model.

Rockworks 15 is being used for digital storage of geotechnical and geoarchaeological sediment log records and to create the basic profiles and transects for interpretation. In addition, illustrations for reports and publications are finessed with the aid of programs such as Adobe Illustrator and Corel Draw. The Spatial Analyst module, and in particular the Inverse Distance Weighted (IDW) tool of ArcGIS 10.3.1, is being used to create DEMs, while ArcScene 10.3.1 is being used to visualise these in 3-dimensions (see Jamieson in Corcoran *et al* 2011 for an extended discussion of the GIS tools used). MOLA is also developing the BCP's use of ArcGIS Online in order to share more freely data and deposit models with project partners.

A standard geoarchaeological approach was adapted for both research and commercial requirements, employing the following methodology:

- For all MOLA modelling projects, deposit description logs are inputted to the MOLA database. Discrete stratigraphic units are identified using pre-defined lithologies; these are generally defined by a capitalised primary component and a secondary lower case component (eg SAND, silty);
- The only pre-defined stratigraphy is a zero thickness unit denoting the early Holocene surface. MOLA GIS Toolbox was used in the construction of an early Holocene palaeotopographic DEM and thickness plots;

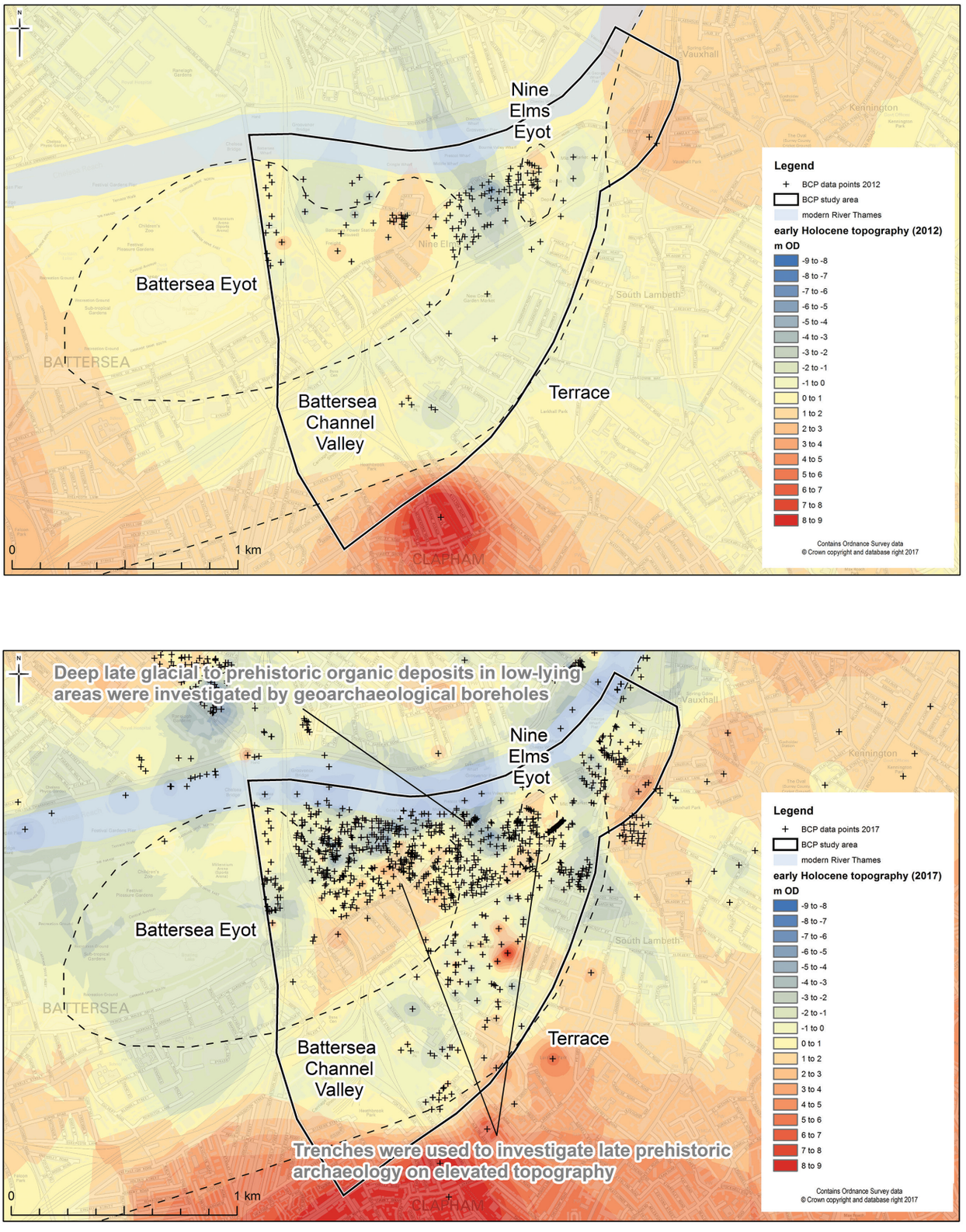


Figure 11.3: Comparison of (a) preliminary 2012 modelled early Holocene topography and (b) ongoing modelled early Holocene topography, from 2017, after initial targeted archaeological works



Figure 11.4: Photographs of archaeological evidence found within the study area (a) burning horizon found on the surface of the Nine Elms Eyot, on the new US Embassy site, representing prehistoric hearths, with micromorphological evidence of multiple phases of burning and associated Brown Bear remains; and (b) a Mesolithic timber piles on the Thames foreshore within the study area, radiocarbon dated between 4790 and 4540 BC (Thames Discovery Program)

- Transects were constructed and landscape zones identified, aiding thereby integration into the model of other sources of information (eg palaeoenvironmental, dating and archaeological evidence). The entire dataset provided a platform for data synthesis, geoprospection and interpretation.

It was foreseen that database terminology could become a significant issue as the BCP progressed. Lithological classifications and descriptions were broadly consistent across project partners, but stratigraphy varied significantly between sites in response to the complexity of taphonomic processes. Many of the inter-site differences could be accommodated automatically in Rockworks or resolved during the collation of Excel spreadsheets. However, the biggest methodological challenge of the BCP was the creation of systems capable of generating outputs which aided productive synthesis and debate between partners. The problem was compounded by the fact that participants needed to consider ongoing work on adjacent sites that were separately funded, employed different archaeological units and were at different stages of the archaeological planning process.

11.4. Preliminary interpretation and use of the deposit model

Precursors to the BCP model and the model itself have been used at various stages in the planning process to aid archaeological understanding of several different developments. The Battersea Channel was highlighted as a feature of archaeological and palaeoenvironmental interest by deposit modelling undertaken by MOLA at Stewart's Road back in 2009 (Morley 2009). However, by focusing initially on its use at the pre-fieldwork or pre-evaluation stage, the early models lacked detail. These earlier models (based on historic data or monitored geotechnical works; MOLA 2012) were used to highlight areas of archaeological or geoarchaeological potential based on different fieldwork approaches (Figure 11.3). The areas of higher ground were targeted mainly for evaluation trenching and watching briefs. On the Nine Elms Eyot, for example, within the new United States Embassy development, a watching brief successfully recorded burnt horizons, which were interpreted as the remains of prehistoric hearths; these were associated with faunal remains of Brown Bear (Figure 11.4) and were found close to the degraded remains of a small wooden structure (MOLA 2015). Large palaeochannels, in the low-lying parts of the floodplain were targeted for palaeoenvironmental investigation using less invasive window sample surveys; these yielded organic deposits radiocarbon-dated to important periods of climatic transition over the Late-glacial (Windermere Interstadial) and early Mesolithic periods (MOLA 2015). In addition, aligned timber stakes (as yet undated) and Iron Age pottery have been identified on the buried Thames foreshore of the Battersea Eyot at Battersea Power Station (Richard Meager, CgMS: pers. comm.), at the same location as previous finds of timber structures (Figure 11.4; Elliot Wragg, Thames Discovery Programme: pers. comm.).

Grey literature reports, predominantly geoarchaeological in focus, describe these preliminary findings for the separate developments of the BCP and present 2-dimensional updates of the early Holocene topography (DEM formats) and associated stratigraphy (cross-section or DEM formats). Regular BCP meetings inform all the partners of significant archaeological finds and the raw subsurface data, and deposit models are shared digitally and combined into the full BCP database. This ongoing process allows pre-fieldwork, evaluation and assessment findings to feed back into the deposit model, thus allowing strategies to be revised more dynamically. Deposit models are well suited as the front ends of databases integrating specialist chronostratigraphic, palaeoenvironmental, geological and archaeological information, and provide excellent tools for communicating widely the changing interactions of human communities with their environment. This approach should permit continual refinement of strategies and priorities and contribute to the creation of a final publication and other dissemination products that are closely integrated and widely accessible.

11.5. Conclusions

All MOLA geoarchaeological work that has been undertaken over the last decade has become part of an evolving MOLA borehole database, providing thereby a wider context for landscape reconstructions. However, the use of this resource is predominantly restricted to MOLA personnel, as it is generally regarded as a commercial asset containing confidential data for active projects. These issues notwithstanding, MOLA is now sharing more data than ever before, and it is hoped that the BCP database will become more widely accessible in the future. Despite inherent problems within archaeological practice, especially in urban environments where experience has demonstrated that data may be incomplete or highly dispersed, deposit modelling remains an important investigative and explanatory tool. The distribution and reliability of data and the derived models must, however, be fully discussed, and in this respect the discussions and reflections about issues of accuracy and methodological rigor that have been encouraged by the BCP represent significant achievements. Hopefully, such an integrated and overarching approach will minimise shortfalls and improve methods, although even the BCP lacks a truly centralised dynamic resource; data integration is therefore slower and more difficult than it could be, which has significant implications for ongoing data capture and data dissemination between partners. As part of the ongoing BCP, MOLA is working towards the use of ArcGIS Online to share raw data, DEMs and models in something

approaching a dynamic resource, but this may only be fully realised at the final stages of the BCP.

For curators and project designers, the construction of simple and accessible overarching deposit models like that described here means that appropriate strategies can be developed to assess and mitigate the threats to archaeological remains. If these deposit models are digitally integrated with the wider archaeological knowledge base, then curators will be better informed about the potential resource and opportunities to address both regional and national research priorities. All archaeological units involved in work in the BCP study area become part of the project and benefit from access to the project's shared knowledge and the interaction between project partners; this in turn can forge stronger links between participating organisations that will reap wider benefits.

Many archaeological practitioners have emphasised to clients the benefits of deposit modelling as a cost-effective means of mitigating the threats to the preserved archaeological and palaeoenvironmental resource. By ensuring that the financial and programming advantages of focusing investigations upon key areas of sites impacted by construction work are widely understood, many London developers now understand the benefits of commissioning approaches that include deposit modelling.

Basic deposit modelling is relatively cheap, with clear planning benefits to all, and it is hoped that the BCP will show that GIS modelling has a greater potential to integrate and convey archaeological findings under broader research and engagement themes than it presently does. The behind-the-scenes nature of this type of work, in contrast to the more visible benefits of archaeological excavation, puts the onus on the practitioners of deposit modelling to show what impact such work can truly have. Engaging the wider public with environmental and landscape histories can be more difficult, but the Museum of London's 'Street Museum' app has shown that using digital datasets in an innovative way can prove popular; this phone app allows users to view historic images of London streets using geospatial information, including real-time GPS data. More complex integrated systems, with landscape as the framework, can be migrated easily to simplified online resources where landscape represents the visual pivot around which modern communities can experience and learn the heritage story of where they live and work. Whilst major infrastructure projects such as Crossrail and the regeneration of parts of east London for the 2012 Olympics have investigated large areas and many different types and periods of archaeological interest, it can be difficult to collate coherently such a broad corpus of information for publication. Such large-scale projects could benefit significantly from the heritage integration and narrative capabilities of landscape-based systems such as ESRI's Story Maps (https://storymaps.arcgis.com/en/). Story maps have the potential to demonstrate to the local community and wider public the benefits of clients' development as well as updating heritage colleagues on the results of specific site investigations. With appropriate investment, individuals might even be able to access a Story Map about a new development on their phones or, in the future, see a virtual past landscape using low-cost equipment such as Google Cardboard (https://vr.google.com/cardboard/).

There is a bright future for deposit modelling if innovation continues, but without more centralised and dynamic resource coordination the current *status quo* may continue. In such a scenario, commercially advantageous resources (collected by single organisations or through one-off multi-partner collaborations) cease to be dynamic or even accessible beyond the financial limits of a project. It is hoped that the BCP will be a decisive first-step towards a better future for deposit modelling.

Acknowledgements

The author would like to extend particular thanks to Mark Stevenson of Historic England for spearheading the Battersea Channel Project and to Stewart Hoad for project management of BCP activities within MOLA. In addition, BCP deposit modelling would not have been possible without the significant input and partnership of Rob Batchelor (Quest) and David Norcott (Wessex Archaeology), as well as the other BCP partners.

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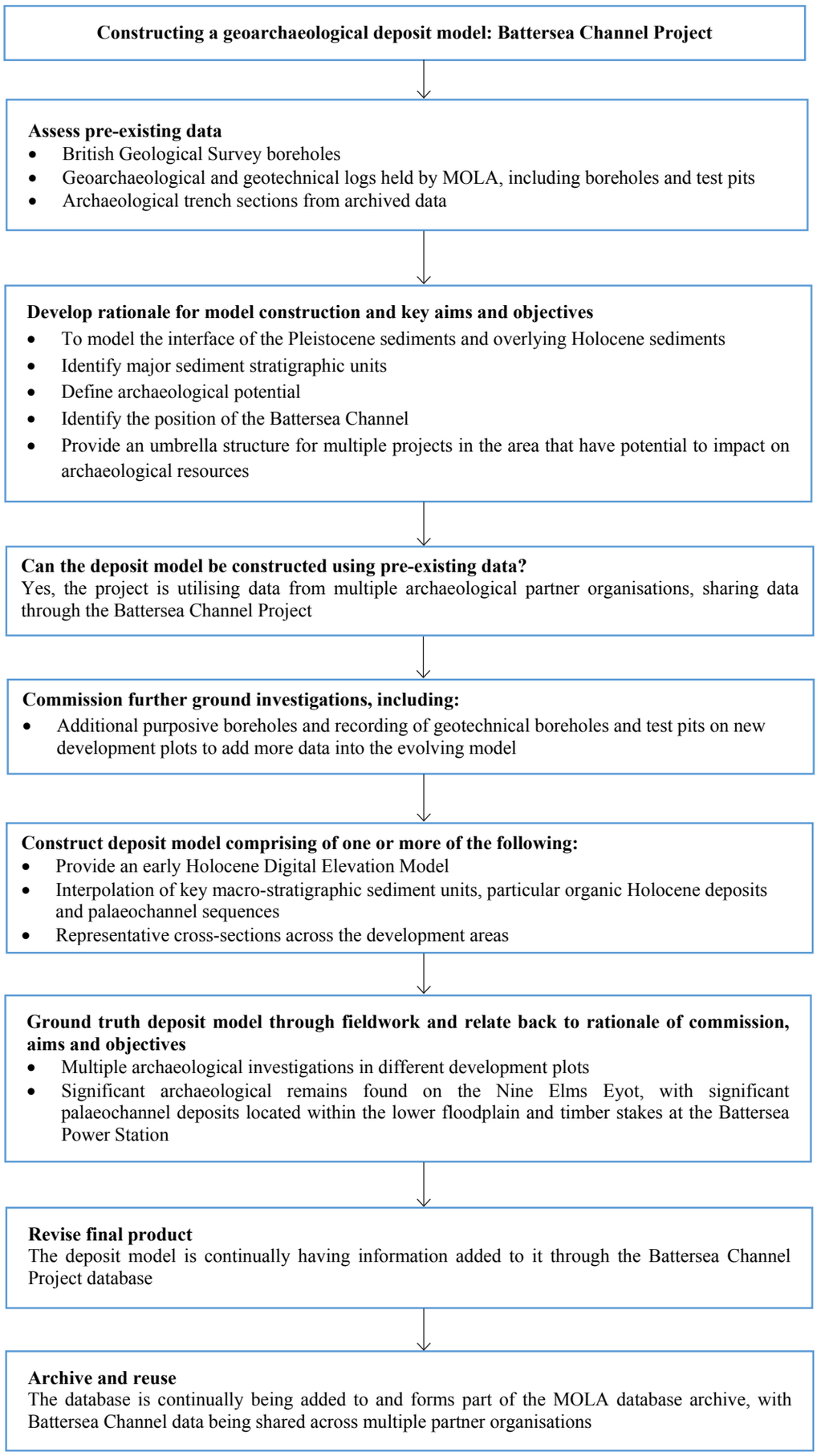
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SECTION 6

Modelling as an aid to post-excavation analysis

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12. Medmerry Managed Realignment Scheme, West Sussex: a Holocene deposit model of a coastal environment

Kristina Krawiec

Archaeology South-East, 2 Chapel Place, Portslade, Brighton BN41 1DR

Abstract

An Environment Agency funded managed coastline realignment scheme was completed at Medmerry, West Sussex in 2013. The construction of a perimeter bund necessitated the extraction of material from within the scheme and afforded an opportunity to investigate both the archaeological and palaeoenvironmental remains and the landscape evolution of the area. The site is located to the west of Selsey Bill on the Manhood Peninsula and has long been known to preserve important Quaternary sedimentary archives. There has, however, been little targeted work prior to this project to investigate these deposits, particularly with reference to the Holocene record.

In order to characterise the landscape evolution of the site, a programme of hand auger survey and palaeoenvironmental analysis was carried out. During the post-excavation phase of the project, the deposits recorded at the site were modelled using both ArcGIS and Rockworks to aid in the visualisation of the sequences investigated. This modelling demonstrated the presence of a deeply buried Late Mesolithic-Early Neolithic peat deposit indicative of a former freshwater wetland. This was replaced by a large protected lagoon during the Late Neolithic-Middle Bronze Age. The models facilitated interpretations of the archaeological and environmental data gathered during the project and were also used as part of the outreach programme and ongoing monitoring of the site by local volunteer Heritage groups.

12.1. Introduction

The site of Medmerry is located on the Manhood Peninsula to the west of Selsey Bill at the tip of the West Sussex Coastal Plain, a low-lying area which stretches for 16km from the foot of the South Downs (Figure 12.1). The Peninsula has long been recognised as having the potential to preserve important Quaternary sedimentary sequences and associated archaeological remains of both Pleistocene and Holocene age (Bates *et al* 2009; Bone 1996; Bone and Tracey 1996).

In recent years the area has suffered from increasing storm frequency and magnitude, which have had a detrimental effect on the livelihood of the local residents. In 2008, the Bunn Leisure Caravan Park and surrounding agricultural land were inundated by floodwaters, causing widespread damage. Consequently, between 2009 and 2013 the Environment Agency undertook a managed realignment scheme. This was a soft-engineered scheme which involved the construction of a 7km long perimeter flood bank designed to store floodwaters and absorb better the impact of future storm events. As a result of the construction works, the scheme created a wetland nature reserve to meet Environment Agency requirements for compensatory habitat under the Habitat and Species Regulations 2010 (http://www.legislation.gov.uk/uksi/2010/490/contents/made); the reserve is now under the management of the Royal Society for the Protection of Birds (RSPB). The scheme covered 300ha and, as part of the works, a programme of archaeological investigation was undertaken. In parallel, geoarchaeological investigations were also carried out. Since the area had received little previous attention and lacked pre-existing geotechnical information, the work included targeted hand auger survey, palaeoenvironmental sampling and analysis. The resulting data was incorporated into a deposit model during the post-excavation process, using both ArcGIS and Rockworks.

12.2. Aims and objectives

Deposit modelling was utilised as a post-excavation visualisation tool. The lack of any previous data from the

Comparative data table of this deposit model	
Deposit model location	Medmerry, West Sussex, UK (NGR: 483469 095339)
Depositional environment	Holocene freshwater wetland and brackish lagoon
Size of deposit model	Development area of *c* 300Ha; 182Ha of intertidal habitat created
Data collection strategies	Hand auger survey in an area with no existing borehole data for investigating sediments with archaeological and palaeoenvironmental potential
Position in the archaeological process	Model was undertaken after fieldwork was completed as part of the post-excavation analysis
Reason for deposit model construction	To understand the subsurface topography and distribution of sediments in order to characterise better the Holocene palaeogeography of the Manhood Peninsula
Archaeological question	How to reconcile the palaeoenvironmental data with the historical understanding of the development of the Manhood Peninsula
Software and modelling process	The sediments were entered into a Rockworks database to create 2-dimensional and 3-dimensional models of the subsurface topography. Surfaces were also created in ArcGIS
Outputs from the deposit model	A series of images to aid visualisation were exported as jpegs for inclusion in the final publication. In addition, a Rockworks database was created which will be included as part of the site archive

area relating to Holocene coastal development highlighted the importance of representing the sediments in an easily accessible and interpretable format. Therefore, the principle objectives of the deposit modelling were to:

- Record the stratigraphic sequence of deposits to allow the creation of a visual representation of the subsurface sediment architecture;
- Enhance understanding of the sequence of deposits in relation to the modern coastal configuration;
- Integrate within the model the results of palaeoenvironmental analysis.

The modelling and analysis of deposits at the site was intended to demonstrate its research potential and to identify historic environment themes for further study. It was also conducted with the aim of enhancing the corpus of research focused on low cost, low impact methodological approaches to the recovery of geoarchaeological information from complex and deeply buried sedimentary sequences.

12.3. Methodology

The lack of existing geotechnical data for the site and of previous targeted investigations prevented modelling prior to the commencement of fieldwork. The site was divided into areas of historic environment impact, which comprised three large borrow pits for the extraction of bund material (BP8, 10 and 11). The underlying superficial Quaternary geology of the site, as mapped by the British Geological Survey (BGS), comprised Raised Marine Deposits, River Terrace Deposits, Raised Beach Deposits, Head, and Beach Tidal Flat Deposits. The solid geology is characterised by the Selsey Sand Formation and Marsh Farm Formation of the (Eocene) Bracklesham Group.

The significant size of the managed realignment scheme at Medmerry was such that the survey was confined either to areas that were accessible during the archaeological excavations (BP8 and BP11) or to areas that had already been stripped by machine (eg BI1, where highly oxidised silts overlay peat deposits; Figure 12.2). A rapid hand auger survey was carried out first with the aim of focusing more effectively the collection of data; this led to the selection of BP8, BP11 and BI1 as the main areas for further investigation and survey of the subsurface stratigraphy. The deposits were investigated using an Eijelkamp gouge auger with a 1m long open chamber, and were sampled at a 5m spacing. The core locations were recorded with RTK GPS. The lithology was recorded using the Troels-Smith (1955) system of sediment classification, which characterises the sediments on a scale of 1-4 in terms of a number of criteria (Table 12.1):

In total, 169 cores were recorded across the three areas, with the majority focused on BP8 due to the presence of a large medieval fish weir (Figure 12.2). The

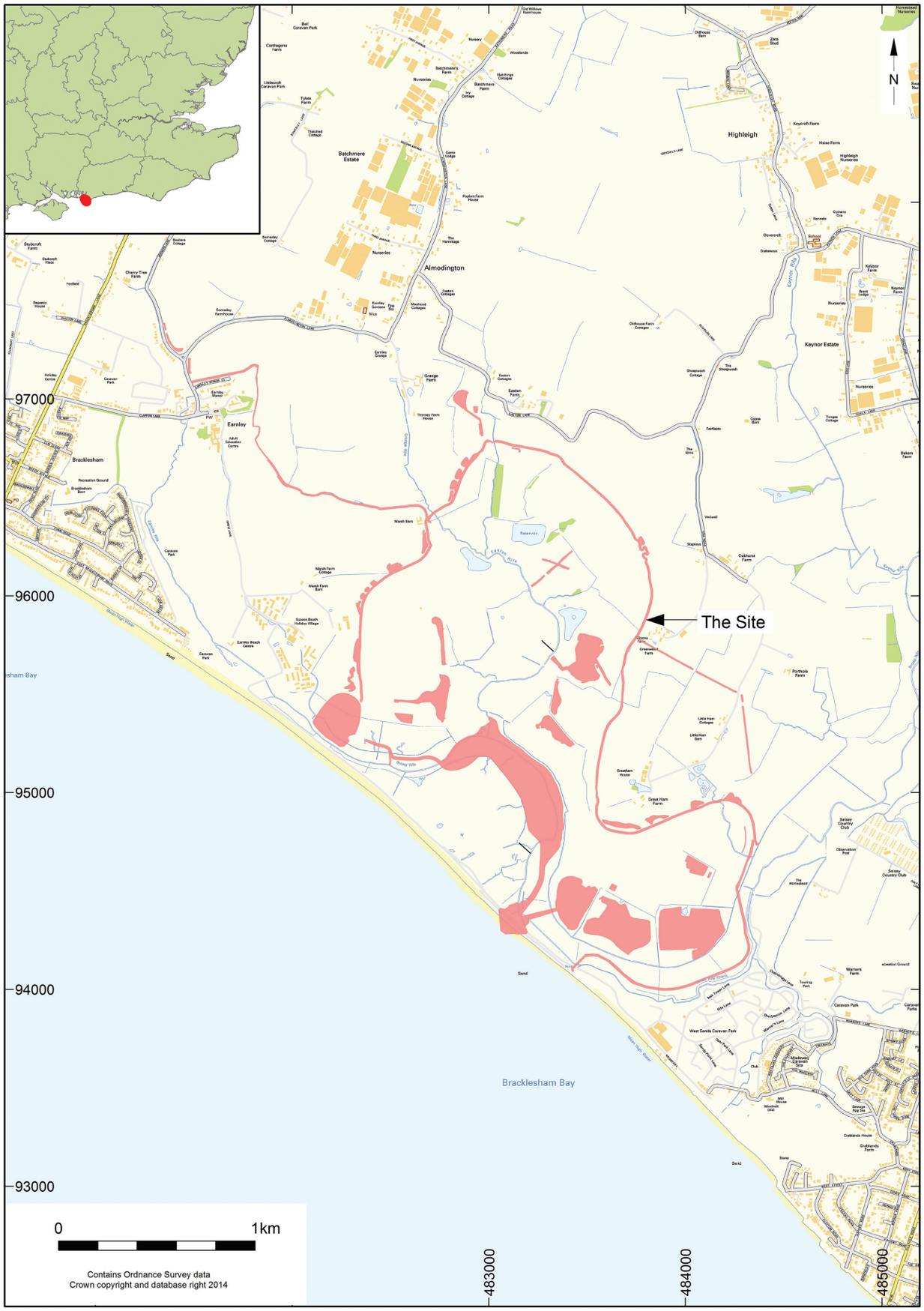


Figure 12.1: Medmerry Managed Realignment Scheme study area on the West Sussex Coastal Plain

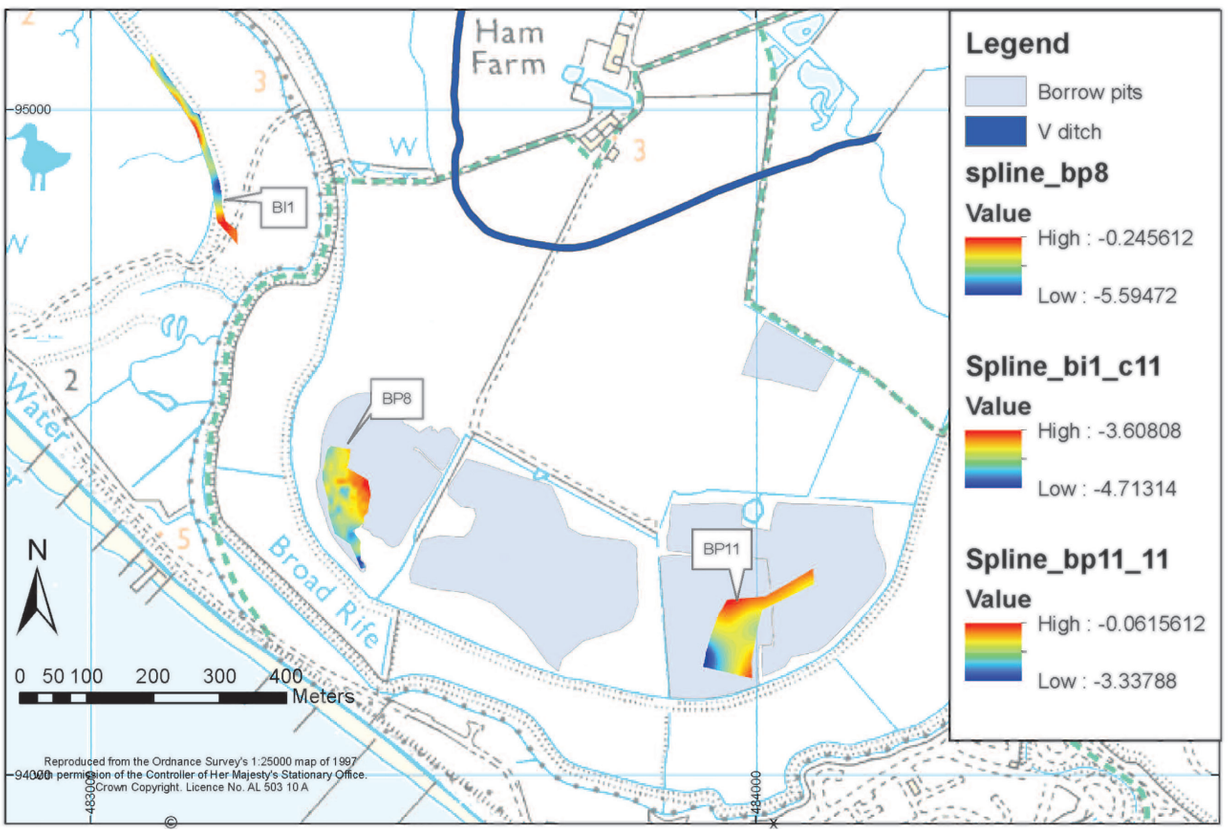


Figure 12.2: Key features of the Medmerry study area including borrow pits, perimeter V ditch and GIS surfaces in the areas of coring

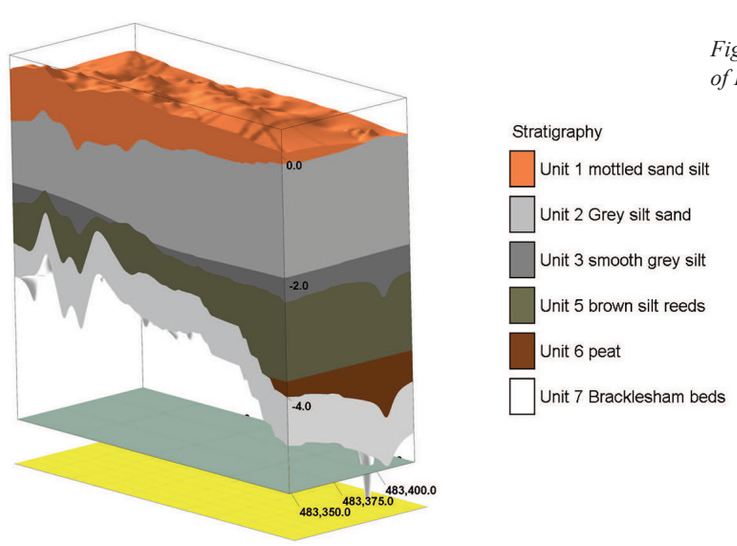


Figure 12.3: Deposit model of Borrow Pit 8

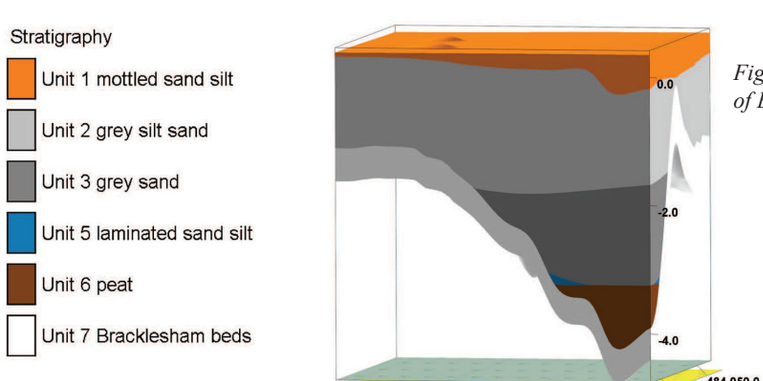


Figure 12.4: Deposit model of Borrow Pit 11

Table 12.1: Criteria of sedimentological assessment according to Troels-Smith

Degree of Darkness	
nig.4	black
nig.3	
nig.2	
nig.1	
nig.0	white

Degree of Stratification	
strf.4	well stratified
strf.3	
strf.2	
strf.1	
strf.0	no stratification

Degree of Elasticity	
elas.4	very elastic
elas.3	
elas.2	
elas.1	
elas.0	no elasticity

Degree of Dryness	
sicc.4	very dry
sicc.3	
sicc.2	
sicc.1	
sicc.0	water

	Sharpness of Upper Boundary
lim.4	< 0.5mm
lim.3	< 1.0 & > 0.5mm
lim.2	< 2.0 & > 1.0mm
lim.1	< 10.0 & > 2.0mm
lim.0	> 10.0mm

	Sh	*Substantia humosa*	Humous substance, homogeneous microscopic structure
I Turfa	*Tb*	*T. bryophytica*	Mosses +/- humous substance
	Tl	*T. lignosa*	Stumps, roots, intertwined rootlets, of ligneous plants
	Th	*T. herbacea*	Roots, intertwined rootlets, rhizomes of herbaceous plants
II Detritus	*Dl*	*D. lignosus*	Fragments of ligneous plants >2mm
	Dh	*D. herbosus*	Fragments of herbaceous plants >2mm
	Dg	*D. granosus*	Fragments of ligneous and herbaceous plants <2mm >0.1mm
III Limus	*Lf*	*L. ferrugineus*	Rust, non-hardened. Particles <0.1mm
IV Argilla	*As*	*A.steatodes*	Particles of clay
	Ag	*A. granosa*	Particles of silt
V Grana	*Ga*	*G. arenosa*	Mineral particles 0.6 to 0.2mm
	Gs	*G. saburralia*	Mineral particles 2.0 to 0.6mm
	Gg(min)	*G. glareosa minora*	Mineral particles 6.0 to 2.0mm
	Gg(maj)	*G. glareosa majora*	Mineral particles 20.0 to 6.0mm
	Ptm	*Particulae testae molloscorum*	Fragments of calcareous shells

sediments were sampled in the field using kubiena tins and by taking bulk samples from open sections; the deeper sediments were extracted using a Russian auger, which recovered sediment in 0.50m lengths. These samples were submitted for multi-proxy palaeoenvironmental study, including analyses of pollen, diatoms, ostracods, foraminifera, insects and plant macrofossils. In addition, age determinations were recovered from organic samples using radiocarbon dating; the results were refined further by using Bayesian analysis, which seeks to increase the accuracy and precision of chronologies (Bronk Ramsey 2009).

The lithological data was divided into stratigraphic units on the grounds of similarities in the sedimentary characteristics. The thickness and height (altitude) of the upper and lower bounding surfaces of key stratigraphic units were inputted initially into spreadsheets to provide data for the creation of a series of surfaces in ArcGIS 10 (Figure 12.2). These surfaces were interpolated using a tension spline, which smooths out topographic variations in the data. As post-excavation analysis progressed, the data was also modelled within Rockworks 16; this allowed solid 3-dimensional models (Figures 12.3 and 12.4), fence diagrams (Figure 12.5) and 2-dimensional cross-sections (Figure 12.6) to be produced. The data in Rockworks is stored within an Access database, which will form part of the site archive.

12.4. Interpretation

The auger survey demonstrated that across the three areas modelled a 0.2m thick peat horizon had accumulated above the solid geology (Figures 12.3 and 12.4**).** This peat layer was overlain in BP8 and BP11 by a thick unit of (reed-rich) brown silt which, in turn, was overlain by a smooth grey silt (Figure 12.5 and 12.6) grading into an upper grey silt-sand up to 2m thick. At BI1, to the north-west of the site, the lower peat was overlain by a smooth, grey silt-clay, similar to that recorded in BP8 and BP11, but this silt unit graded into a laminated silt-clay sand (Figure 12.7). In all areas, thin, discontinuous layers of shell fragments were recorded (Figure 12.8).

The subsequent palaeoenvironmental and radio-carbon analyses demonstrated that the peat deposit at the base of the sequence dated to the Late Mesolithic-Early Neolithic period (5469 ± 31 BP; 4360–4260 cal. BC; SUERC-60632). The pollen assemblage indicated that the contemporary landscape was a freshwater wetland; the thin nature of the deposit suggests that the sample site may lie at the northern extreme of this wetland and that thicker deposits may be buried and preserved farther to the south of the site. However, the upper boundary of this unit was sharp, suggesting an erosional contact associated with marine transgression, which might also have removed an unknown amount of sediment. It is only by undertaking survey further south of the sampling site that this can be established. The microfossil assemblages that were recorded in the overlying silts demonstrate that this transgression led to the formation of a large protected, brackish lagoon similar to the contemporary Fleet Lagoon behind Chesil Beach (Dorset), approximately 125km west of Medmerry. The timing of this change from freshwater to brackish water environments has proved hard to establish with confidence, but it is likely to have occurred during the Late Neolithic to Middle Bronze Age period in keeping with regional models of sea level rise. The subsequent ostracod and foraminfera analyses of the shelly horizons suggest that they represent the remains of

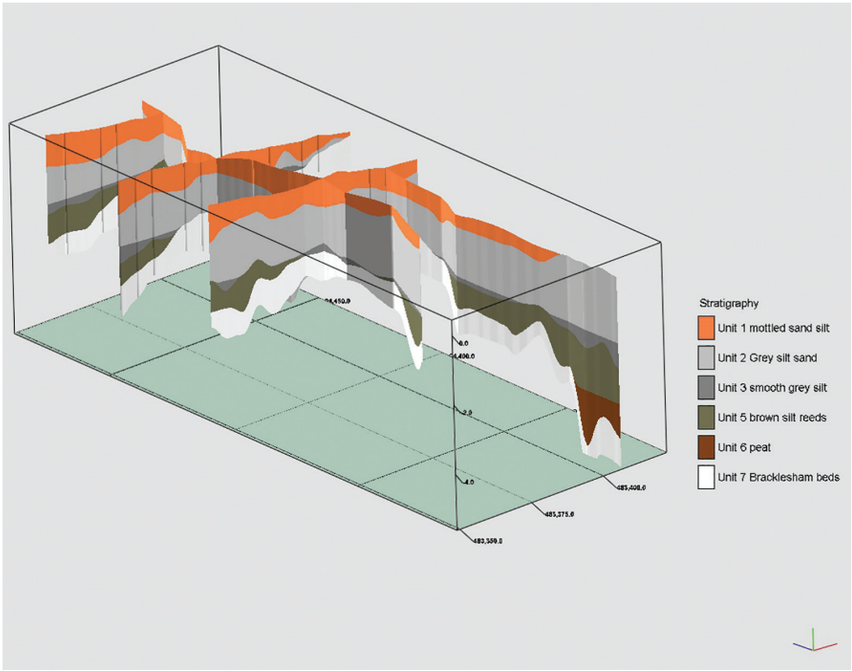


Figure 12.5: Fence diagram illustrating the 3-dimensional stratigraphy of Borrow Pit 8

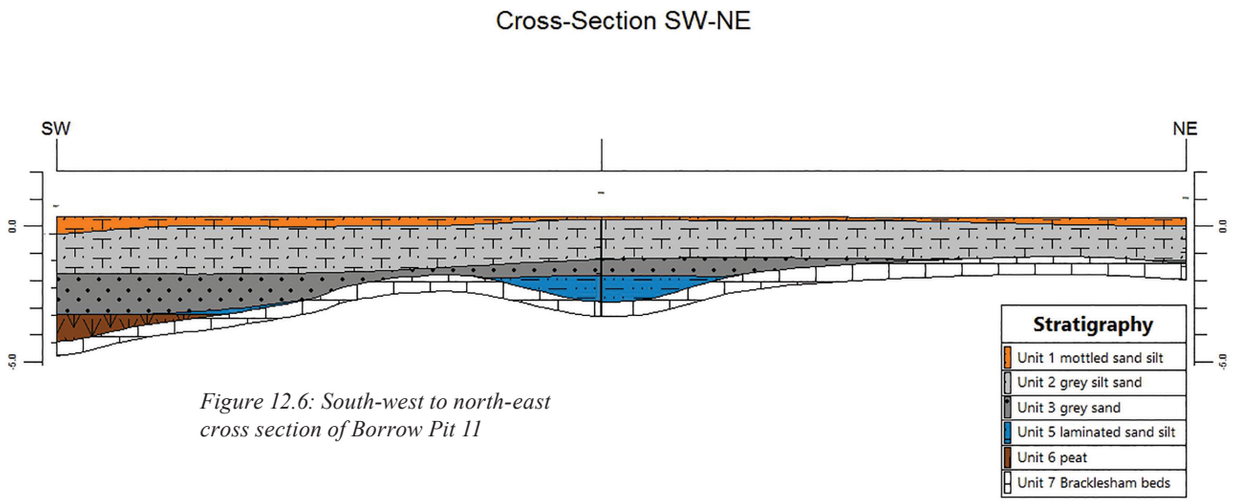


Figure 12.6: South-west to north-east cross section of Borrow Pit 11

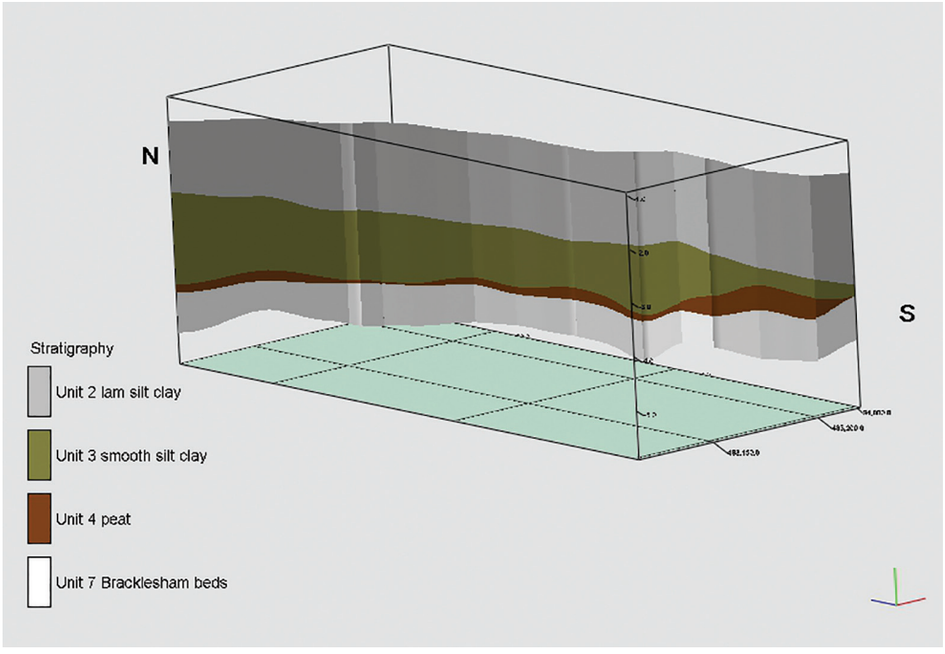


Figure 12.7: Fence diagram illustrating the 3-dimensional stratigraphy of Bird Island 1(BI1)

storm surge deposits; these are likely to have breached the shingle barriers that characterised the south coast in the Early-Middle Holocene (Long *et al* 2006).

The analysis of the deposits at Medmerry is by no means intended to create a definitive narrative for the evolution of the coastal zone, but has demonstrated that deposits survive at the site and have the potential for palaeoenvironmental reconstruction. The model has also allowed these deposits to be visualised in a way that aids interpretation and understanding of the palaeoenvironmental and archaeological data by both the archaeological community and other stakeholder groups.

12.5. Post-excavation analysis

The deposit model was used to build the narrative for the post-excavation publication (Stevenson 2014; Stevenson and Krawiec in prep). Moreover, as the data is in a digital format that can be exported as either a MS Access database or MS Excel spreadsheet, it can be utilised by other researchers. The models and analyses were intended as useful starting points for future research within the Medmerry area. In addition, it was hoped to provide baseline data that could be employed for comparison with other regional sequences and models as and when they are developed. The Medmerry data has been uploaded to the West Sussex Historic Environment Record (HER). The file sizes are relatively small, which will expedite the addition and storage of further data if this becomes available.

The model has also been used to challenge interpretations of landscape change which have become ingrained in the literature. The presence of a continuous navigable channel from Pagham to Selsey has long been suggested to have isolated Selsey Bill from the rest of the Manhood Peninsula (Wallace 1996, 205), but this is

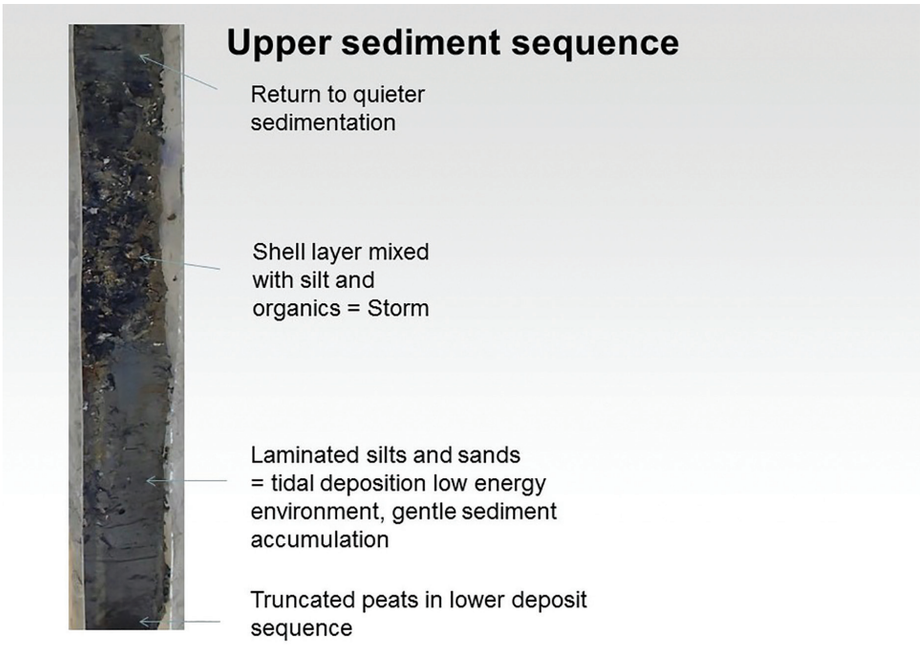


Figure 12.8: Plate illustrating thin, discontinuous shelly layers recorded during auger survey

not borne out by the evidence gathered in the field by Archaeology South-East during this project. In addition, the persistent theory of an Iron Age oppidum at the site (Cunliffe 2005, 172; Davenport 2003, 105; Wallace 1996) is unlikely in view of the lack of evidence for an inland channel and the formation of the lagoon behind a shingle barrier. The palaeoenvironmental evidence is supported in this respect by the results of archaeological investigations, which provide no evidence of high-status or dense Iron Age occupation at the site.

The deposit model has also been used to demonstrate the nature of the deposits within the Peninsula to a non-specialist audience. The continually eroding foreshore is currently being monitored by the Chichester District Archaeology Society, members of which participated in training events informed by the deposit model. The model has also been used to demonstrate the sometimes abstract concepts of landscape reconstruction and subsurface deposit modelling as part of the project's outreach programme.

12.6. Conclusions

The deposit model created for the Medmerry managed realignment scheme has demonstrated that palaeoenvironmentally significant deposits and interbedded archaeological remains survive at the site, despite past and present coastal erosion. In addition, the use of hand augering has demonstrated that the acquisition of data need not be prevented by costly field investigation.

The auger survey and archaeological investigations were carried out during the realignment works, which necessarily led to time-constraints in the field. The application of this methodology would ideally be carried out in advance of groundworks to allow more of the areas to be investigated. However, as the groundworks were already underway, valuable time was saved by the removal of the upper oxidised sediment within the borrow pit and ditch excavation areas; this facilitated targeted augering in areas where much of the dry sediment (which is time consuming to hand-auger through) above the peat had already been removed.

It is hoped that this model will allow further targeted investigations to be carried out on the Peninsula, enabling the collection of data that could be analysed with the aim of refining further the deposit model. From that perspective, it should be emphasised that the methodology that has been applied here as a post-excavation tool could be applied equally effectively to pre-application stage projects.

Acknowledgments

The author would like to thank Jon Sygrave and Jim Stevenson at Archaeology South-East for their support during the duration of the project and staff from the Environment Agency and Van Ord for their assistance on site. The project was funded by the Environment Agency.

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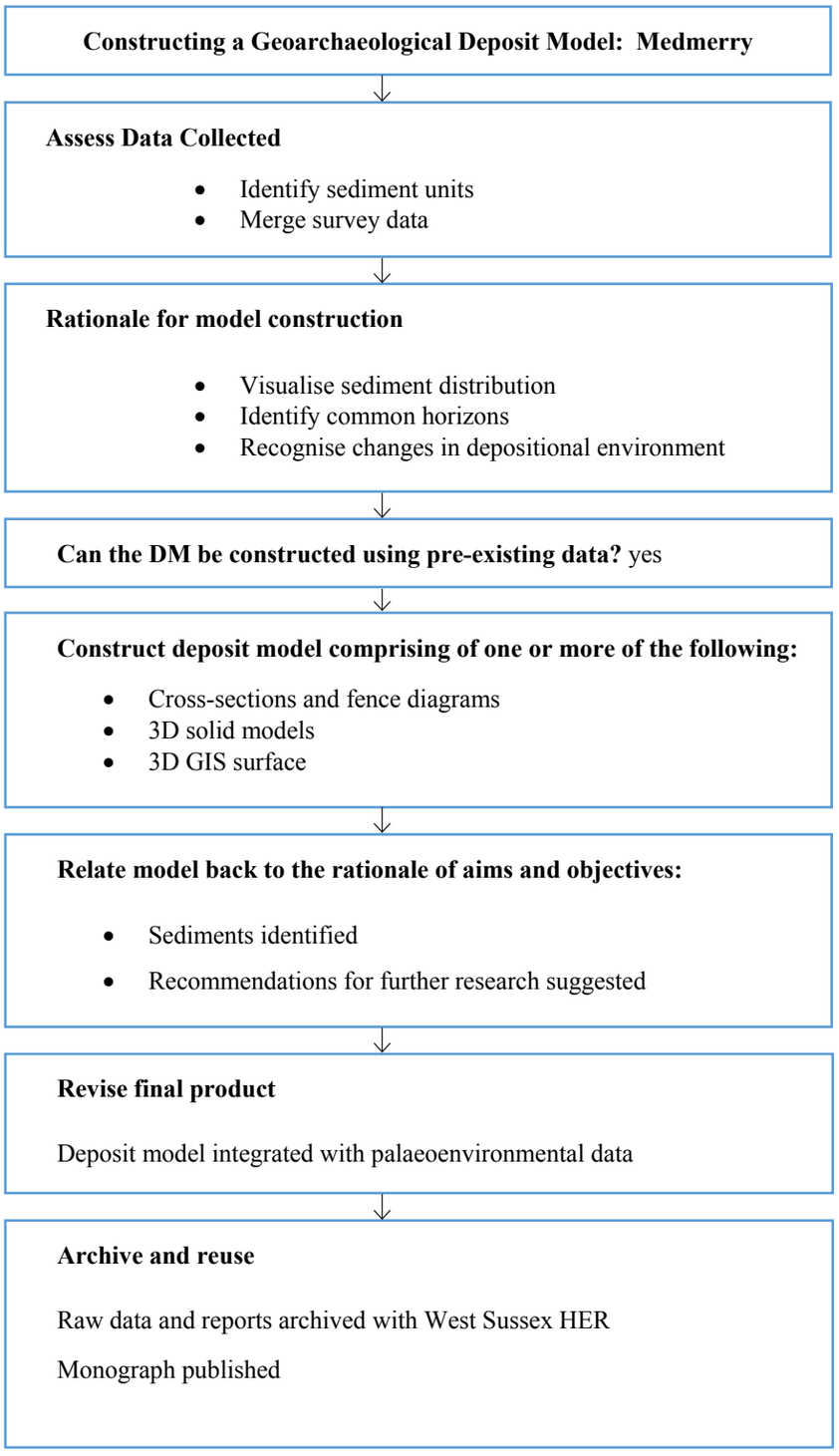
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Constructing a Geoarchaeological Deposit Model: Medmerry
Assess Data Collected
Identify sediment units
Merge survey data
Rationale for model construction
Visualise sediment distribution
Identify common horizons
Recognise changes in depositional environment
Can the DM be constructed using pre-existing data? yes
Construct deposit model comprising of one or more of the following:
Cross-sections and fence diagrams
3D solid models
3D GIS surface
Relate model back to the rationale of aims and objectives:
Sediments identified
Recommendations for further research suggested
Revise final product
Deposit model integrated with palaeoenvironmental data
Archive and reuse
Raw data and reports archived with West Sussex HER
Monograph published

13. Geoarchaeological deposit modelling in the heart of London

Mary Nicholls[1, 2], *Graham Spurr*[1], *Jason Stewart*[1] *and Virgil Yendell*[1]

[1]MOLA (Museum of London Archaeology), Mortimer Wheeler House, 46 Eagle Wharf Road, London, N1 7ED; [2]presently, Senior Consultant, Archaeology and Heritage, WSP, 6 Devonshire Square, London, EC2M 4YE

Abstract

Redevelopment in the City of London between 2010 and 2014 of the area of the Walbrook valley where the 3rd century AD temple of Mithras was discovered previously provided an opportunity to excavate the most extensive and significant Roman remains in the modern city for 20 years. The deeply buried nature of the site and deep urban stratigraphy required the design of an innovative mitigation strategy that included development of a geoarchaeological deposit model. Constructed in Rockworks and ArcGIS, the model used a combination of sedimentary descriptions transcribed from test pit and borehole records carried out for geotechnical and geoarchaeological purposes, as well as information from archaeological trenches. The deposit model made an important contribution to the project in providing a view of the pre-Roman landscape, interpretation of the prehistoric deposits and inferring the story of Holocene valley evolution, which provided the template for Roman occupation.

Comparative data table of this deposit model	
Deposit model location	City of London
Depositional environment	Urban
Size of deposit model	*c* 520 data points over *c* 600,000m^2 (60 ha)
Data collection strategies	Archaeological trenching, geoarchaeological and geotechnical borehole analysis and review of British Geological Survey records
Position in the archaeological process	Pre- to post-excavation
Reason for deposit model construction	To inform on archaeological potential, landscape reconstruction, deposit characterisation and interpretation
Archaeological question	To consider the distribution of archaeological remains and the palaeoenvironments coeval with such remains
Software and modelling process	RockWorks 15; ARCGIS 10.1
Outputs from the deposit model	Models illustrating thickness and palaeotopography of key units and palaeolandsurfaces. Images for use in reports, publications and landscape reconstruction illustration

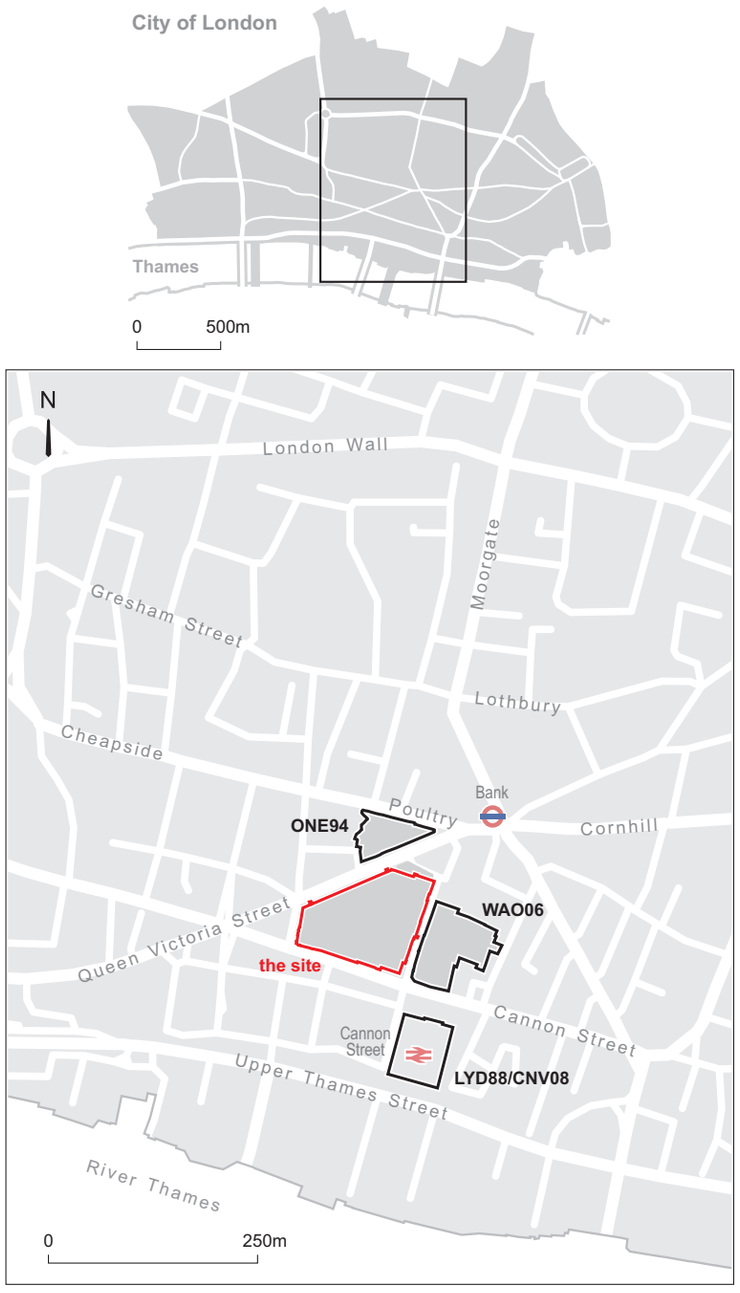


Figure 13.1: Bloomberg London (BZY10) site location with surrounding sites marked (ONE94, WAO06 and LYD88/CNV08) and Roman city map

13.1. Introduction

Bloomberg, London, in the heavily urbanised core of the City, became famous in the 1950s through the discovery of the 3rd century AD temple of Mithras (Grimes 1968; Wilmott 1991; Shepherd 1998). Development between 2010 and 2014 involved the most extensive and significant archaeological excavation of Roman remains in the modern city for 20 years and yielded finds of international significance (Marshall and Wardle in prep; Tomlin 2016). Part of this developer-funded archaeological work involved the construction of a geoarchaeological deposit model, which aimed to use existing and new sedimentary data from the site to visualise the evolution of the past landscape. This was achieved by:

- Reconstructing the underlying prehistoric terrain, which would have formed the landscape template for construction of the Roman city;
- Identifying the likely course of the Walbrook stream, which although now a largely subterranean feature, would at the time of Roman occupation have formed a major north bank tributary of the Thames;



Figure 13.2: View of excavation in progress at Bloomberg London in 2012 looking north with 1 Poultry to the left and St Stephen Walbrook to the right of the site

- Characterising and interpreting the deposits to allow elucidation of the litho- and chronostratigraphic sequences.

The geoarchaeology team was involved early on in the project from the evaluation stage. Test pits and borehole surveys were carried out for archaeological, geotechnical and geoarchaeological purposes (using machine excavators for the test pits and a variety of drilling rigs, a power auger and a hand-held percussion hammer [HHPH] for drilling boreholes). An initial deposit model was produced in 2011. At the start of excavation in late 2011–2012, 170 boreholes were drilled by power auger and recorded by the geoarchaeological team around the site perimeter in order to clear archaeological obstructions for sheet piling. Geotechnical information was gathered later from further boreholes drilled in the southern part of the site and from trench sections; these data points and associated descriptions were added to the constructed model and used during the post-excavation assessment stage of the project. In advance of the forthcoming monograph publication, the model has been revisited and information derived from sites in the surrounding areas has been incorporated in order to contextualise more widely the recorded archaeology.

The model made an important contribution to the project in providing a view of the pre-Roman landscape, interpretation of the prehistoric deposits and inferring the story of Holocene valley evolution, which provided the template for Roman occupation. Key archaeological information from the surrounding area was obtained from a number of sites, including No 1 Poultry (site code ONE94; Hill and Rowsome 2011), the Walbrook Building (site code WAO06; MoLAS 2010a) and Cannon Place (site codes LYD88, CNV08; MoLAS 2010b; Figures 13.1 and 13.2).

13.2. Methodology

Modelling was undertaken using a combination of borehole logging software (Rockworks 15) and a geographic information system (ArcGIS 10.1). Geological and archaeological data for the area held by MOLA included information on sedimentary deposits derived from developer-funded boreholes drilled for geotechnical and geoarchaeological purposes, together with records

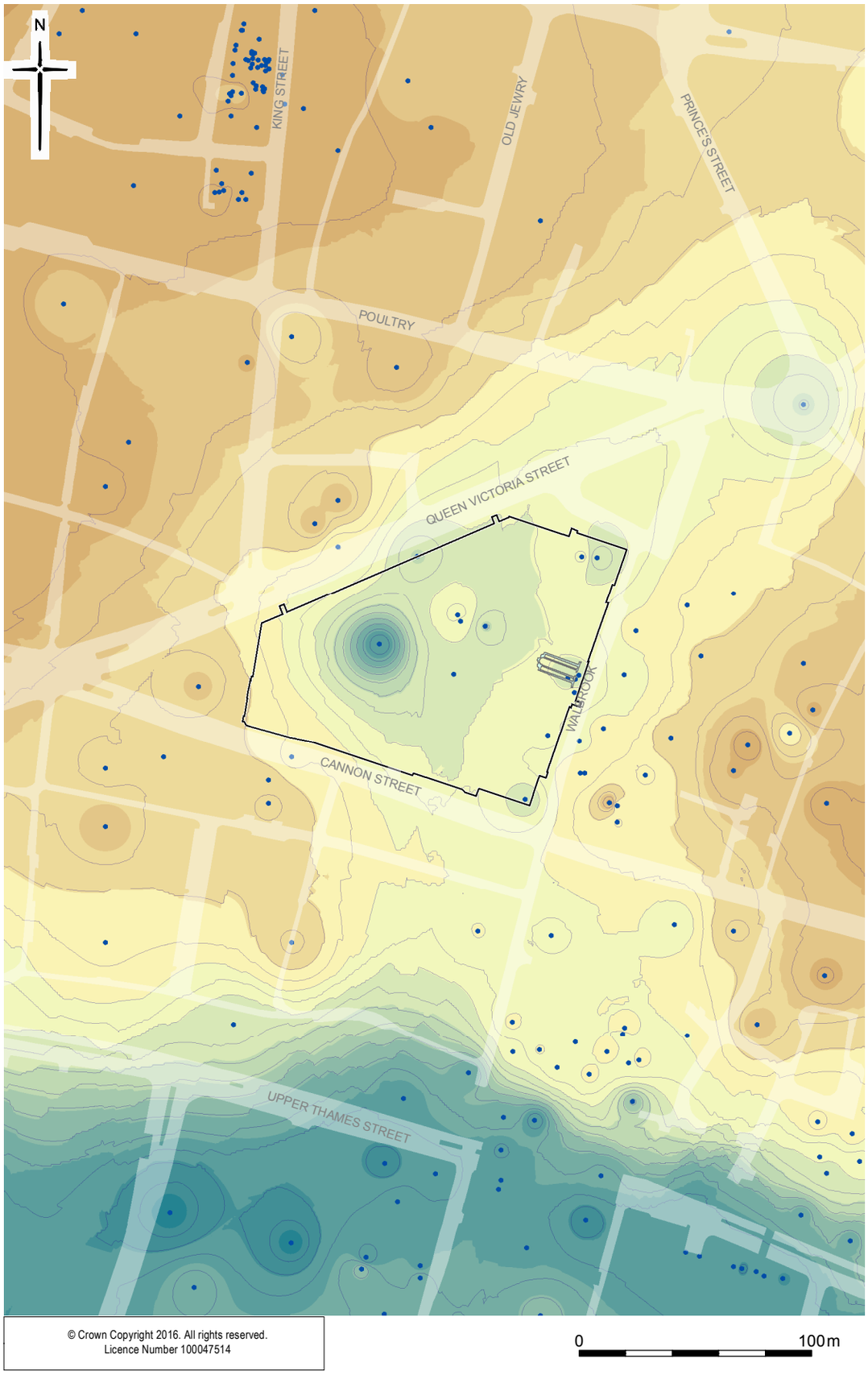
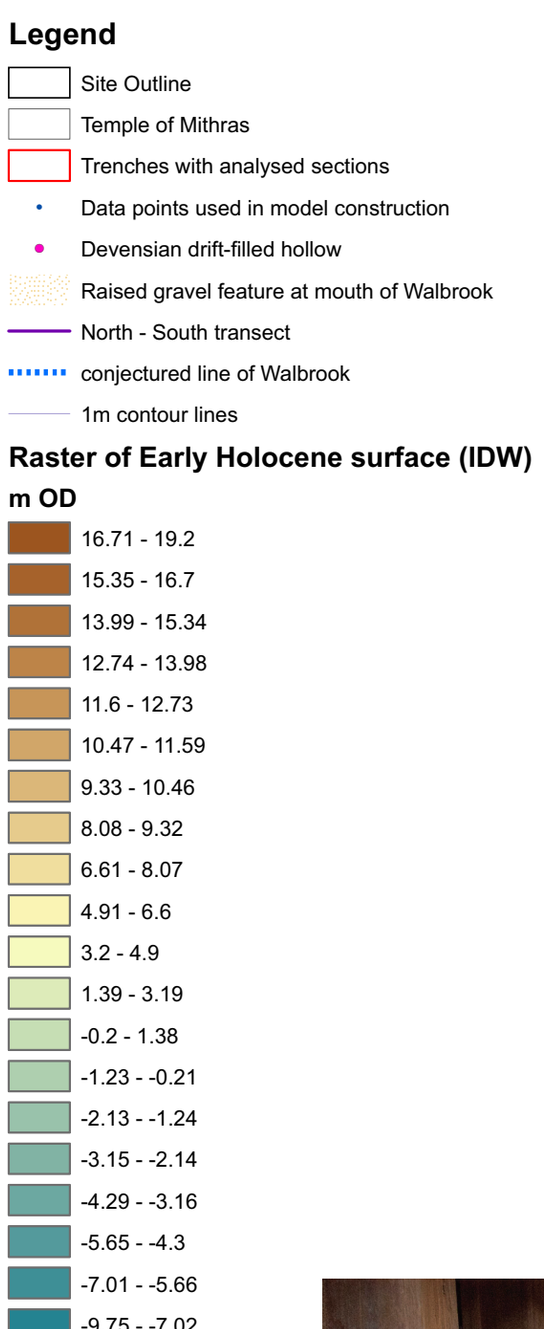


Figure 13.3: Initial deposit model undertaken in early 2011 following site work under site code BBU05 (and in advance of 2011–12 borehole drilling programme). The model is based on an average of 132 points in a c 200m radius from the centre of the site



Key to Figures 13.3, 13.5 and 13.6

held by the British Geological Survey (BGS) and sediment descriptions captured through archaeological interventions. Borehole and archaeological data for the development site and adjacent areas was reviewed and interrogated, allowing construction of a preliminary (basic) stratigraphic model depicting a series of 'working transects'. Reviewed and interpreted data informing the construction of this preliminary model was tabulated, and included information on individual borehole locations (coordinates and elevation data in metres relative to Ordnance Datum), lithological (sediment) descriptions, stratigraphy and mode of origin.

The stratigraphic information included the identification of a key marker horizon denoting the 'Early Holocene surface' (EHS) and reflecting the interface between archaeological deposits and Quaternary drift (terrace gravel or brickearth) or London Clay bedrock. Identifying this horizon allowed the modern ground and archaeological deposits to be stripped away to reveal the contours and topography of the prehistoric landscape, providing thereby a baseline from which to model depositional patterns and provide insights into landscape evolution and urban development. Above the EHS, two stratigraphic units were identified in the early stages of modelling, namely Walbrook channel deposits and other fluvial deposits. The overlying archaeological deposits were treated as a single unit due to their complexity.

Deposit modelling was achieved by combining Rockworks tables within the project GIS. The Spatial Analyst tool was used to build contoured surfaces from the point data of the EHS by means of the Inverse Distance Weighting (IDW) method. Raster images of the contoured surface that represents the prehistoric landscape were produced, and can be represented in 2-dimensions or pseudo-3-dimensions.

13.3. Interpretation

The model developed from the early stages of the project was used by the archaeological and geoarchaeological

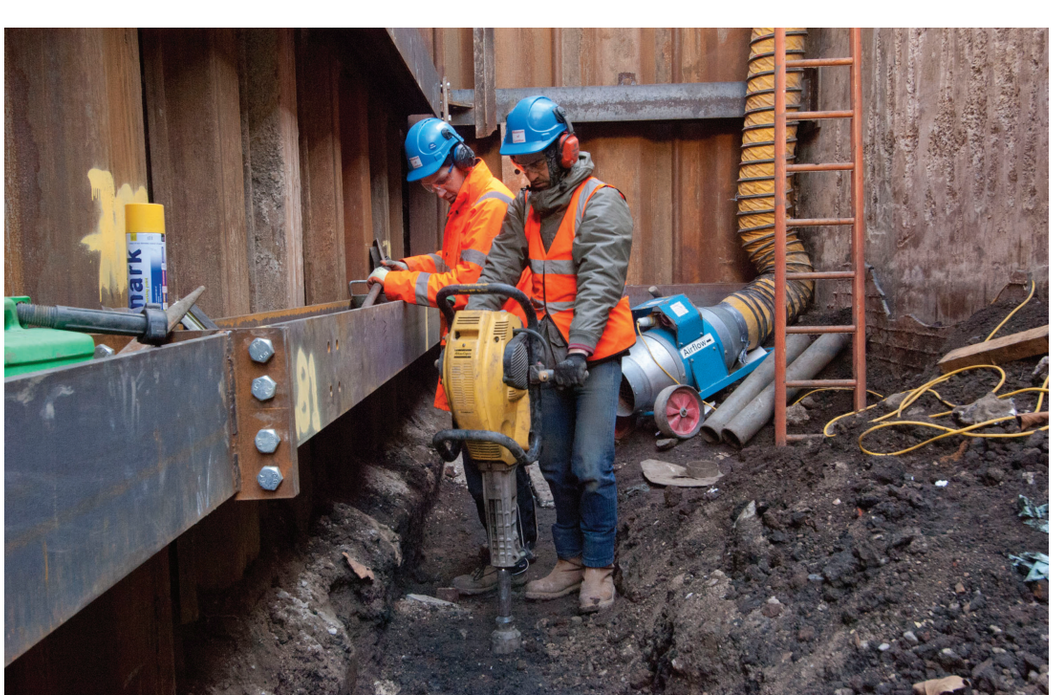


Figure 13.4: Drilling auger holes at the northern perimeter of the site during early phases of excavation 2011–12

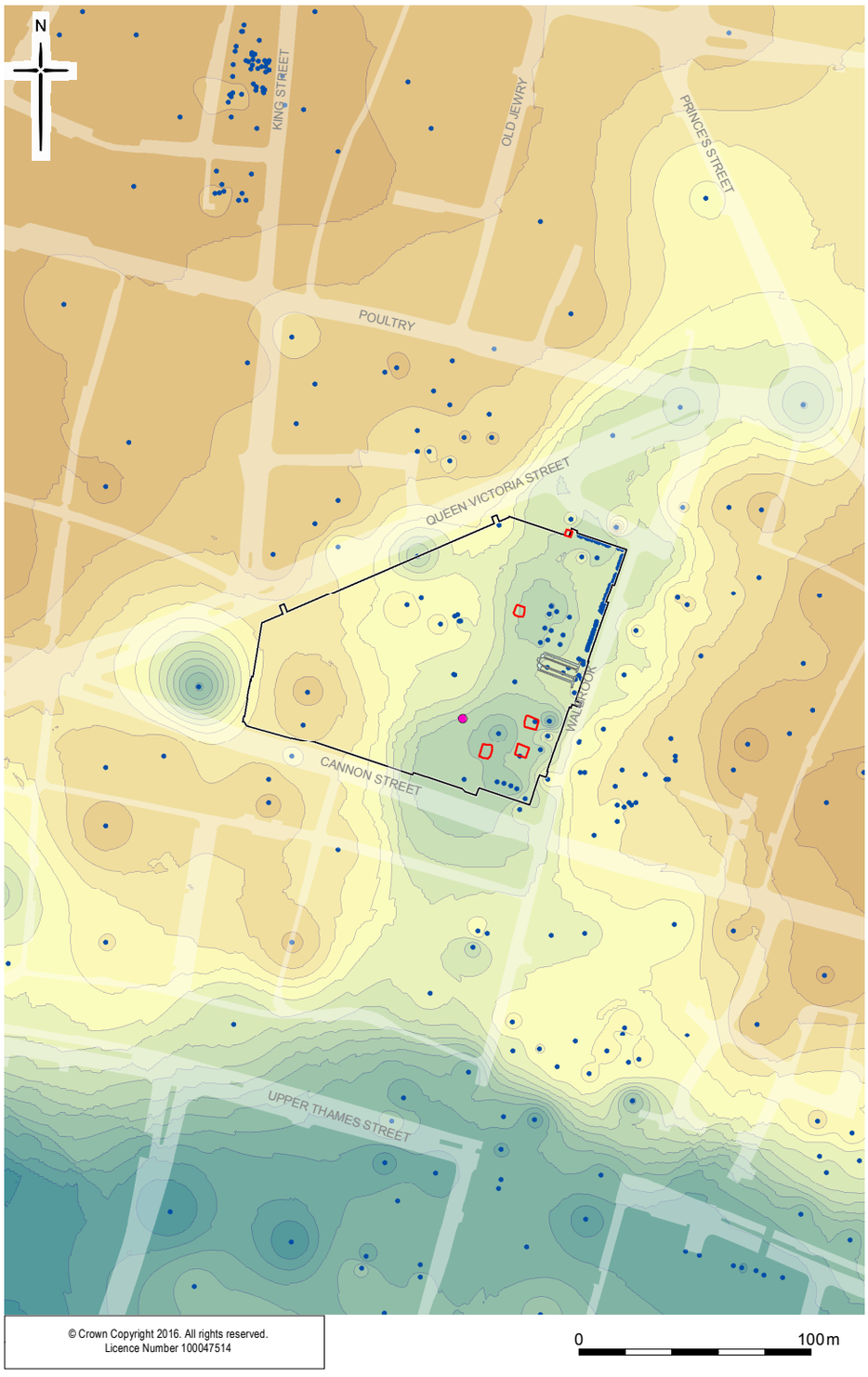
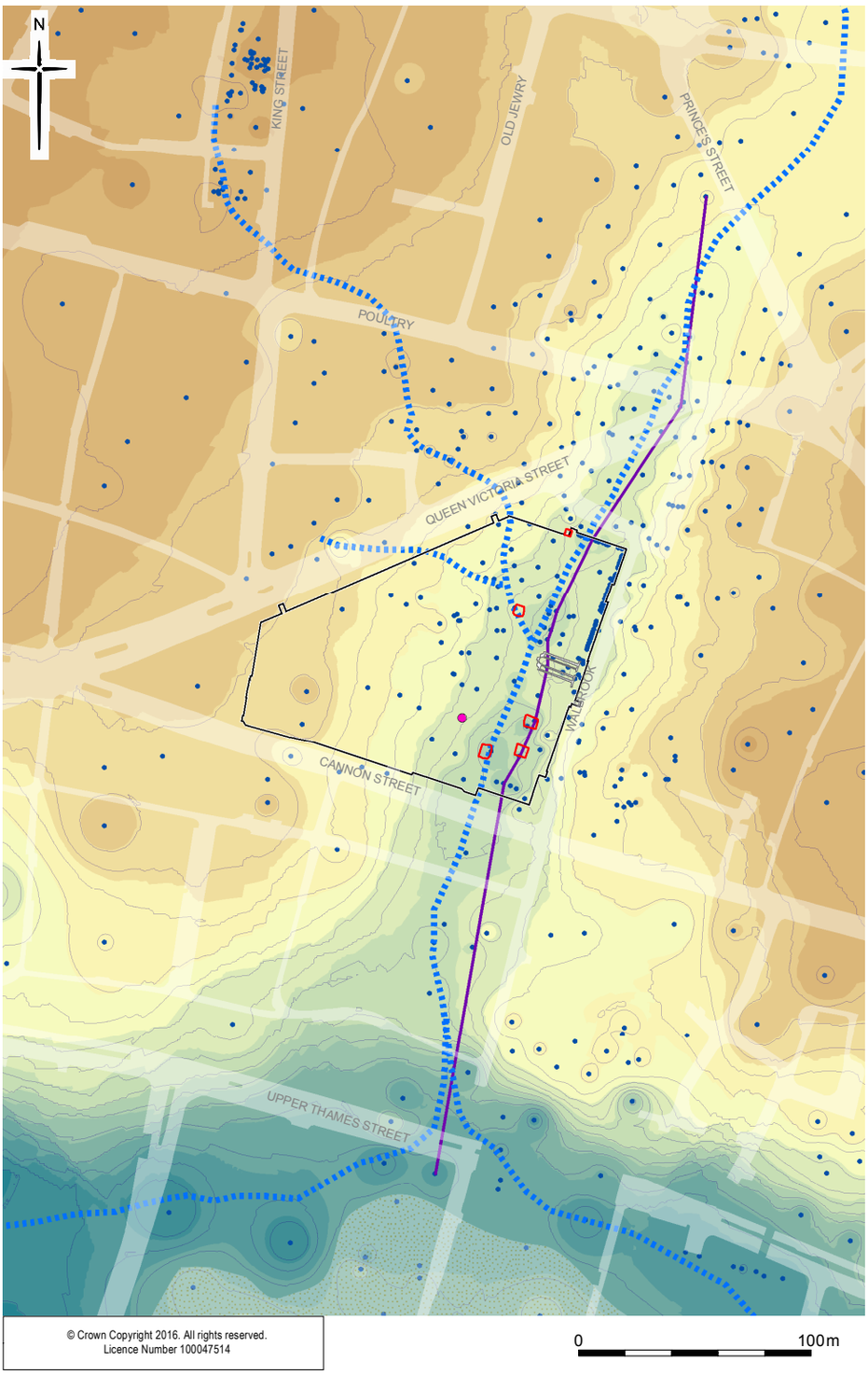


Figure 13.5: Deposit model 2013 including information gathered for the post-excavation assessment report. This model is based on an average of 301 points in a c 200m radius from the centre of the site



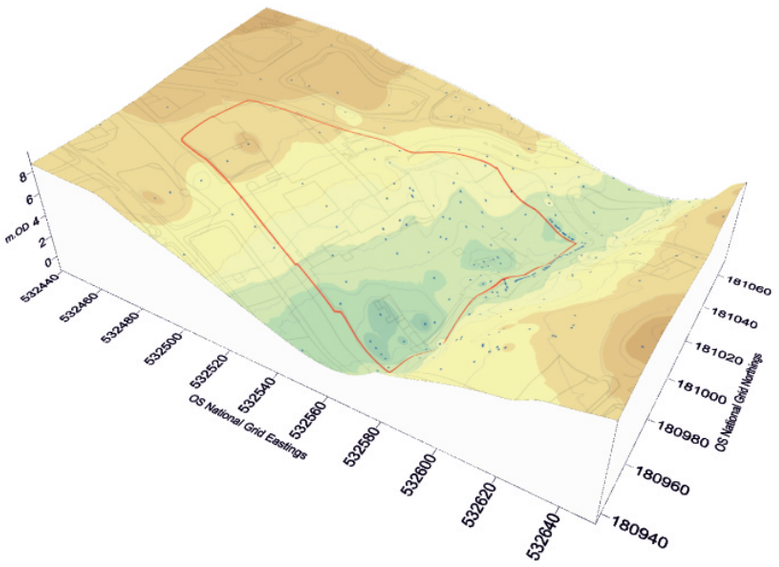


Figure 13.6a: Deposit model 2015 updated for forthcoming monograph publication including contour data derived from excavations at ONE94. This model is based on an average of 452 points in a c 200m radius from the centre of the site;
Figure 13.6b: pseudo-3D representation (Surfer 13) of the 2015 model

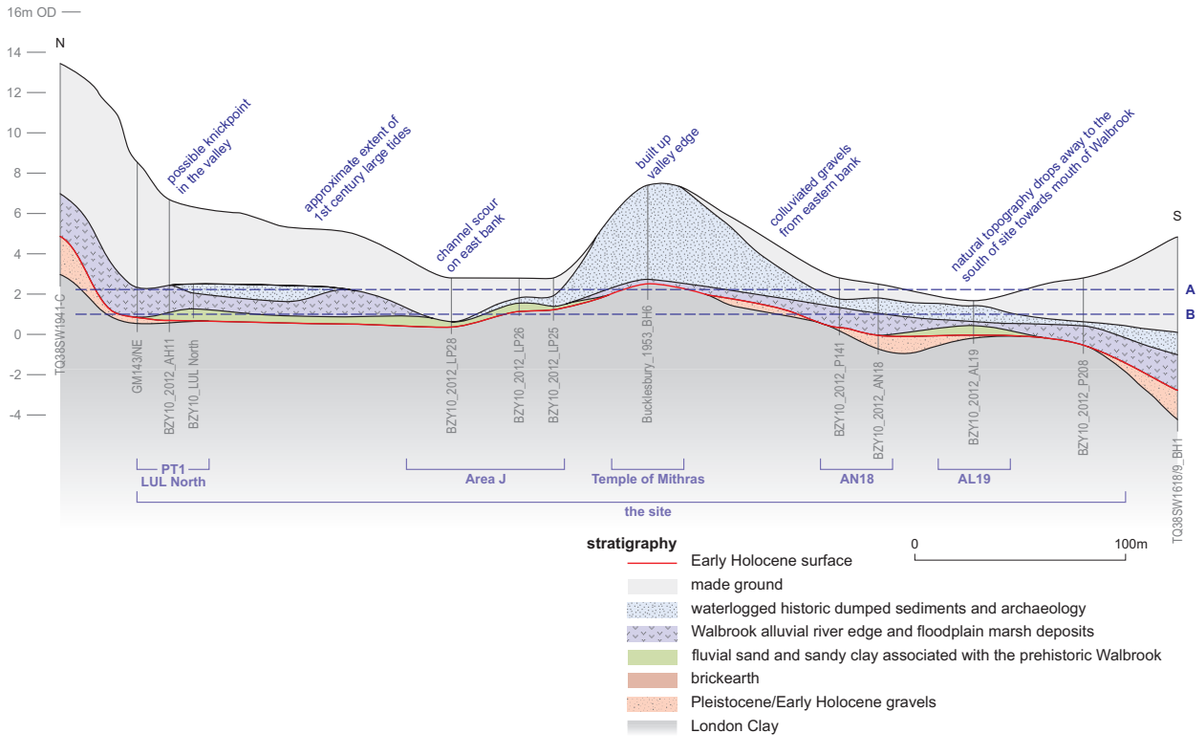


Figure 13.7: North–south cross section intended for forthcoming monograph publication

teams, mainly in the post-excavation phase. Three versions of the model as it evolved are presented here. The first was produced prior to the large borehole drilling campaign of 2011–12 (Figure 13.3). The EHS surface was re-modelled for the post-excavation assessment report, with the inclusion of the results of HHPH boreholes (Figure 13.4), and a selection of on-site profiles was described and sampled by geoarchaeologists during excavation (Figure 13.5). Following environmental assessment, where a handful of profiles was analysed for microfossil content (pollen, diatoms and ostracods) and sediment properties were investigated (soil micromorphology, phosphate analysis, loss on ignition and magnetic susceptibility), the model was refined as a product for publication (Tomlin 2016; Bryan *et al* in prep) (Figures 13.6a, 13.6b and Figure 13.7).

The model was useful as an interactive tool: at each stage of the excavation process the modelled results had an influence on archaeological interpretations, and in post-excavation acted as a guide for sample selection for palaeoenvironmental investigation.

In broad terms, the contour plot shows how the prehistoric topography strongly influenced important aspects of landscape development and urbanisation: for example, through the character of the underlying substrate and its influence on ecology and land-use. Whilst it could be argued that the general shape of the prehistoric valley floor was well known before this study and the application of deposit modelling, the ability through this process to build models that can be revised, updated and viewed from multiple angles and as discrete stratigraphic layers is clearly advantageous from a research perspective.

13.4. Conclusions

Model achievements and outcomes

The model achieved its aims of producing a detailed palaeogeography of the lower Walbrook as a working tool for archaeologists to view the historic landscape and underpin cultural and environmental interpretations. The concept of using the EHS as a key stratigraphic marker is not, however, without its problems; natural erosion and historic quarrying (for example, of brickearth) play an unquantifiable but perhaps significant role in shaping the palaeotopography and character of this surface.

The model aimed originally to identify the course of the Walbrook stream, but, as the scale and rapidity of Roman landscape change became clear, it was realised that the natural prehistoric stream and its urbanised Roman successor should be considered separately. The valley was cleared of vegetation and infilled by the 1st century AD, with the remnants of prehistoric sediment largely lost through erosion and evacuation through the river system. Roman canalisation created an entirely artificial watercourse that bore no relationship to the deepest (and lowest) part of the valley system. Inevitably

then, the pre-Roman topography did not influence the line of the Roman stream and for this period any model of the landscape would be informed by the archaeology rather than *vice versa*.

This anthropogenic influence caused the model to focus upon the single (early Holocene) surface and pre-Roman timeframe. However, even the position of the pre-urban stream channel was not apparent during excavation of the deepest parts of the valley and it appears that after the valley shape was initially established (presumably during the Devensian Lateglacial), the stream migrated west across the floodplain. It remains unclear whether the evidence for the immediately pre-Roman stream, which would have formed a sluggish tidal creek, was removed in the deepest parts of the valley by sediment erosion associated with prehistoric deforestation or whether it lay to the west of the excavation area.

Model data, benefits and limitations

The data upon which the model is based is held in Rockworks in a series of related tables, and is backed up as Excel spreadsheets. The benefits of using tables and GIS include the capacity for model revision, growth and replication and the ease of creating contoured plots. The dataset forms part of a London-wide deposit model and is constantly in use within MOLA, assisting desk-based and field staff working on sites across the capital.

In general, sediment erosion and historic truncation have an impact on the reliability of models, but these issues can be overcome if they are taken into account when interpreting the primary datasets used to construct a model and its illustrative outputs. Also important to the accuracy and fidelity of a model is the number (density) and, crucially, distribution of points. Although the limitations of constructing models appear substantial, they are outweighed by the benefits both in terms of a model's predictive capacity and its contribution to understanding the landscape and interpreting the archaeological record.

The modelling at Bloomberg provided an overview of the prehistoric landscape, while the interactive approach led to a significant improvement in the mapping of the subsurface stratigraphy, Despite this, integrating the results of borehole drilling with archaeological knowledge on anything but a coarse scale presented an undertaking that could not be justified within the limits of the project. The use of stratigraphic knowledge remained largely dormant therefore at the assessment level, with the EHS being the operative marker horizon used to influence strategy. In addition, logistical challenges arose from the deployment of a large and diverse team over a lengthy time period. The fieldwork, assessment, analysis and modelling were carried out by different people and, had it been possible, would have profited from coordination by a single staff member.

Acknowledgements

MOLA geoarchaeology gratefully acknowledges the support of Bloomberg LP and their on-site team (archaeologists, engineers, architects, developer and construction team) including Stanhope PLC, Sir Robert McAlpine, Foster & Partners, AKTII and McGee. Additional thanks go to Kathryn Stubbs, Assistant Director Historic Environment at the City of London, Sylvia Warman, Historic England Science Advisor for London and Jackie Skipper (Geological Consulting Group).

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Constructing a geoarchaeological deposit model: Bloomberg

Assess pre-existing data

- Sections from 1950's excavation reports (original archaeological excavation of the site)
- Other geoarchaeological and archaeological fieldwork records (boreholes and sections) from site and surroundings
- Published information about pre-Roman Walbrook topography and drainage
- Geotechnical records from British Geological Survey and client

Develop rationale for model construction and key aims and objectives

- Reconstruct immediately pre-Roman topography
- Identify likely course of the pre-Roman and Roman Walbrook stream

Commission further ground investigations, including:

- Model not done for predictive purposes. Instead, it was constructed during and after phased excavation that examined all surviving deposits on the site. The model was progressively updated to make use of this information during the fieldwork and post-excavation stages.

Can the deposit model be constructed using pre-existing data?

Yes, but its reliability increases as each phase of new data is added.

Construct deposit model comprising of:

- Working transects drawn through all available data-points
- Key marker horizon (Early Holocene Surface) – approximating to pre-Roman topography
- Distribution of Walbrook channel deposits;
- Distribution of archaeological deposits.

Ground truth deposit model through fieldwork and relate back to rationale of commission, aims and objectives

- Deposit model used to select environmental samples for assessment during post-excavation stage
- Close working with archaeological stratigraphic team to interpret results.

Revise final product

Clear limitations of the modelling for mapping the canalised Roman Walbrook, but updated model useful for publication illustration of immediately pre-Roman river and topography.

Archive and reuse

Rockworks tables and Excel spreadsheets held by MOLA and form part of a London-wide deposit model that is constantly in use and regularly updated by MOLA geoarchaeology team.

14. Deposit modelling of a Roman and later urban landscape: St Mildred's Tannery, Canterbury, Kent

Simon Pratt

Canterbury Archaeological Trust (CAT), 92A Broad St, Canterbury, CT1 2LU

Abstract

Development of a heavily contaminated, brownfield site straddling the river Great Stour in Canterbury provided an opportunity to reconstruct the Roman and later urban landscape using deposit modelling, aided by reference to previous archaeological investigations. The deposit model was constructed using bespoke software designed by the author, which helps produce 2-dimensional or 3-dimensional representations of site stratigraphy, simplified synoptic views and/or fence diagrams. Since 2004 the approach used at this site has been adopted by CAT for other archaeological interventions in Canterbury and its environs. This methodology helps to design better-targeted and more cost-effective evaluations, determining beforehand where external specialists can best be deployed, and enables the examination of archaeological and geoarchaeological deposits beyond and below the usual limits of excavation.

14.1. Introduction

Developer-funded work by Canterbury Archaeological Trust (CAT) ahead of residential redevelopment on 3.5ha of land at and adjoining St Mildred's Tannery, Canterbury (Figure 14.1), commenced with a desk-based assessment in 1999–2000. This was followed by preliminary trial-trenching in 2001 and watching briefs on geotechnical site investigations in 2001 and 2002 (Pratt and Sweetinburgh 2004).

The site straddled a branch of the river Great Stour and was mostly situated within the modern floodplain; this comprised fine-grained alluvium underlain by late Pleistocene sands and gravels. However, there were higher areas within the site, underlain by 1st terrace sands and gravels sealed by brickearth. Pre-existing archaeological evidence indicated that the site was crossed by significant Roman features including the London-Dover road (Watling Street), by an existing street with a Roman predecessor and by the line of the Roman and later defences. Roman buildings, partially overlain and surrounded by peats, had also been found in two trenches during previous investigations (Blockley 1987; Pratt 1992). Following the Roman period, a charter of AD 804 (Sawyer 1968, S160) granted the Abbess of Lyminge a 'refuge' here and rentals record mixed usage, including the presence of a mill by the late 12th century (Urry 1967); much of the site was later farmed by Franciscans. In the mid-19th century, industrial-scale tanning took place on the site, leaving up to four metres of contaminated waste over much of the area. This scale of contamination had a significant influence on construction design and groundwork methodologies, which in turn impacted on the nature and scale of archaeological interventions. Furthermore, when construction began in 2004, a strategy was adopted of preservation of archaeology *in situ* where possible; attempts were made, therefore, to limit excavation and the recording of stratigraphy to service trenches and other infrastructure interventions, although where groundworks extended beyond these features additional recording was undertaken by watching briefs.

Given the lack of large-scale surface excavation across the site (Figure 14.2), the most effective approach to investigating and reconstructing the spatially extensive archaeological record was to use deposit modelling to explore how geology, palaeotopography, and floodplain development influenced the location and nature of human activity during Roman and later occupation (Pratt 2009).

Comparative data table of this deposit model	
Deposit model location	Canterbury, UK (NGR: 614500 157700)
Depositional environment	Floodplain of the river Great Stour, adjoining 1st Terrace sands and gravels and overlying brickearths
Size of deposit model	Site *c* 3.5Ha
Data collection strategies	Review of pre-existing site investigation (SI) logs, watching briefs (WBs) on SI boreholes, test-pitting and other groundworks (including piling), purposive mechanized augering , evaluation trenching and limited excavation
Position in the archaeological process	SI data review included in desk-based assessment but not formally modelled. Deposit model developed in tandem with archaeological fieldwork, which involved evaluation between two pre-application SI WBs, with phase plans produced. WBs on later SI's, along with augering prior to each piling campaign, in parallel with various other WBs and limited excavations
Reason for deposit model construction	To test and develop conjectural reconstructions of Roman and later topography based on limited excavation
Archaeological question	What influence may palaeotopography, geology and floodplain development have had upon Roman and later human activity and occupation?
Software modelling process	Data importable from several formats but usually input using custom-built (in dBase) software. This constructs formatted logs and CorelDraw script for draft pseudo-sections along transect lines. To these, stratigraphic sections, interpretative groups, phases and other information are added manually. Group numbers and phasing is passed back to the database and added to formatted logs. CorelDraw script generated to draft stratigraphic group matrix. Data and blanking files generated for Surfer are used to check for anomalies that may represent data error, algorithmic artefacts, misinterpretation of data or overlooked features. Such problems are addressed and individual group descriptions are added to the database; this regenerates formatted logs and collates group descriptions with other information. The main report text is written and all other outputs finalized
Outputs from the deposit model	Datasets suitable for other systems. Formatted text logs and structured group text. Phased stratigraphic group matrix. Detailed pseudo-sections projected onto nominal transect lines, usually with an exaggerated vertical scale, and simpler synoptic sets of these, usually with less or no distortion. Fence diagrams can be constructed manually using the latter, but data density is usually too great for this to be useful. Borehole and test pit pseudo-sections scaled as overlays for conventional section drawings. Distribution and contour maps (sometimes overlain) and 3-dimensional surfaces of selected contexts, groups or phases: contours and 3-dimensions can show Ordnance Datum or Below Ground Level values for the top or bottom or overall thickness of the selected unit(s)

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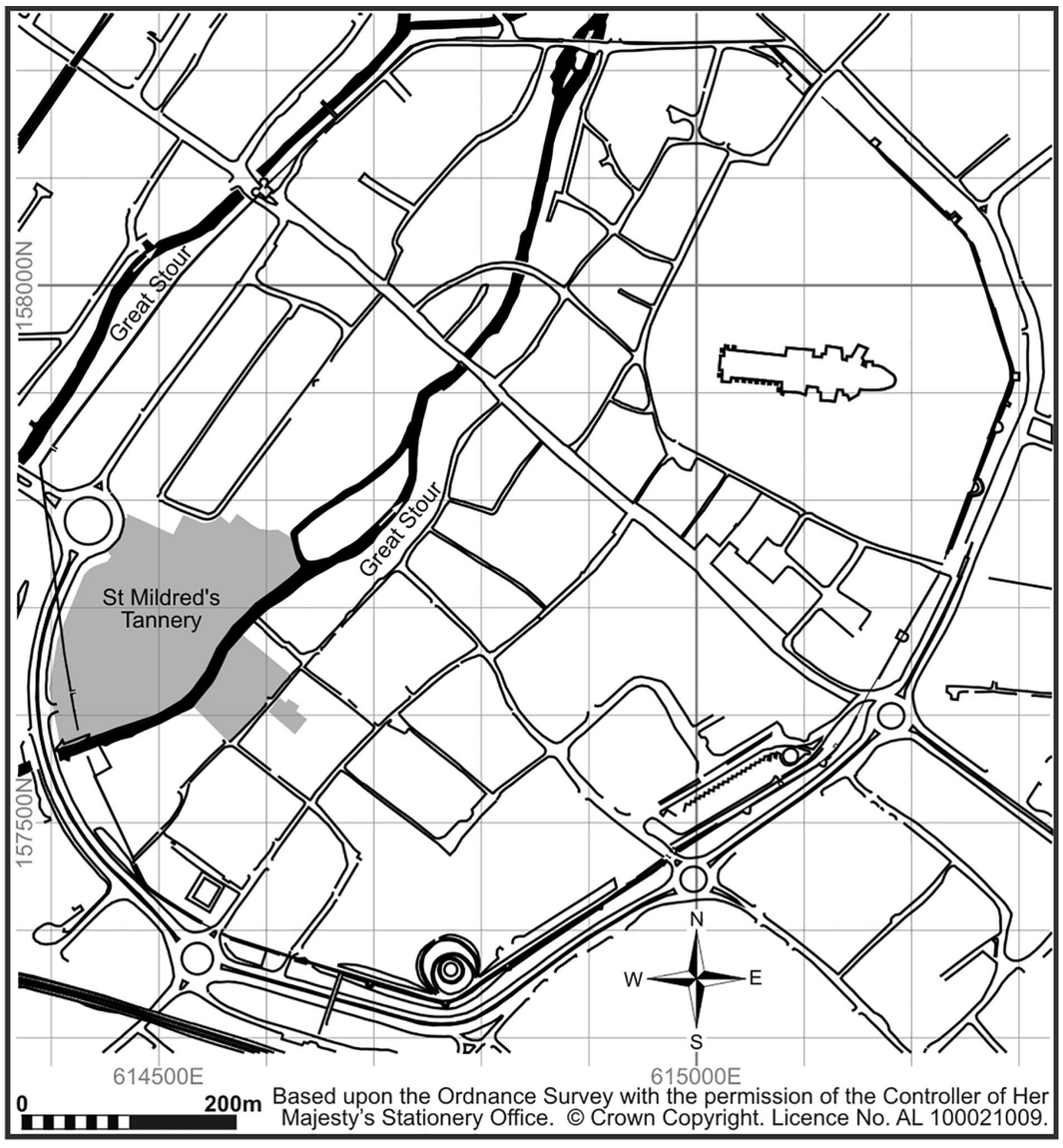


Figure 14.1: Site location in relation to the walled city and river

14.2. Data Collection

Data for deposit modelling were captured from sediment descriptions collected during geotechnical or archaeological augering, watching briefs and limited excavations (Figure 14.3). Piling plans were compared to existing archaeological data and conjectural site stratigraphy, and some of the positions were selected for investigation by windowless sampling. Most positions were chosen to create transect lines or to enhance existing transects. The resulting 1m long core liners or, in some cases, loose samples were bagged and labelled. Samples retained within plastic tubes were opened and the sediments were described and photographed; representative material was sub-sampled for further analysis (Figure 14.4).

To facilitate deposit modelling, bespoke software was written by the author in dBase. Drilling logs and other sediment descriptions collected during excavations and watching briefs were transcribed into a main (context) .dbf file. Coordinates, ground levels and dating evidence were added and the data were used to draft formatted text logs for each position. These logs were reviewed and each context was assigned a colour code representing a general sediment/cultural horizon type; cross-sections were then reconstructed along transect lines (Figure 14.5). Re-scaled trench sections were added manually to the transects to enhance the understanding of site stratigraphy. Each context was assigned to a general lithological group, but for transparency and to facilitate potential re-analysis, field interpretations were retained in the detailed logs. Group numbers were added to the database and each

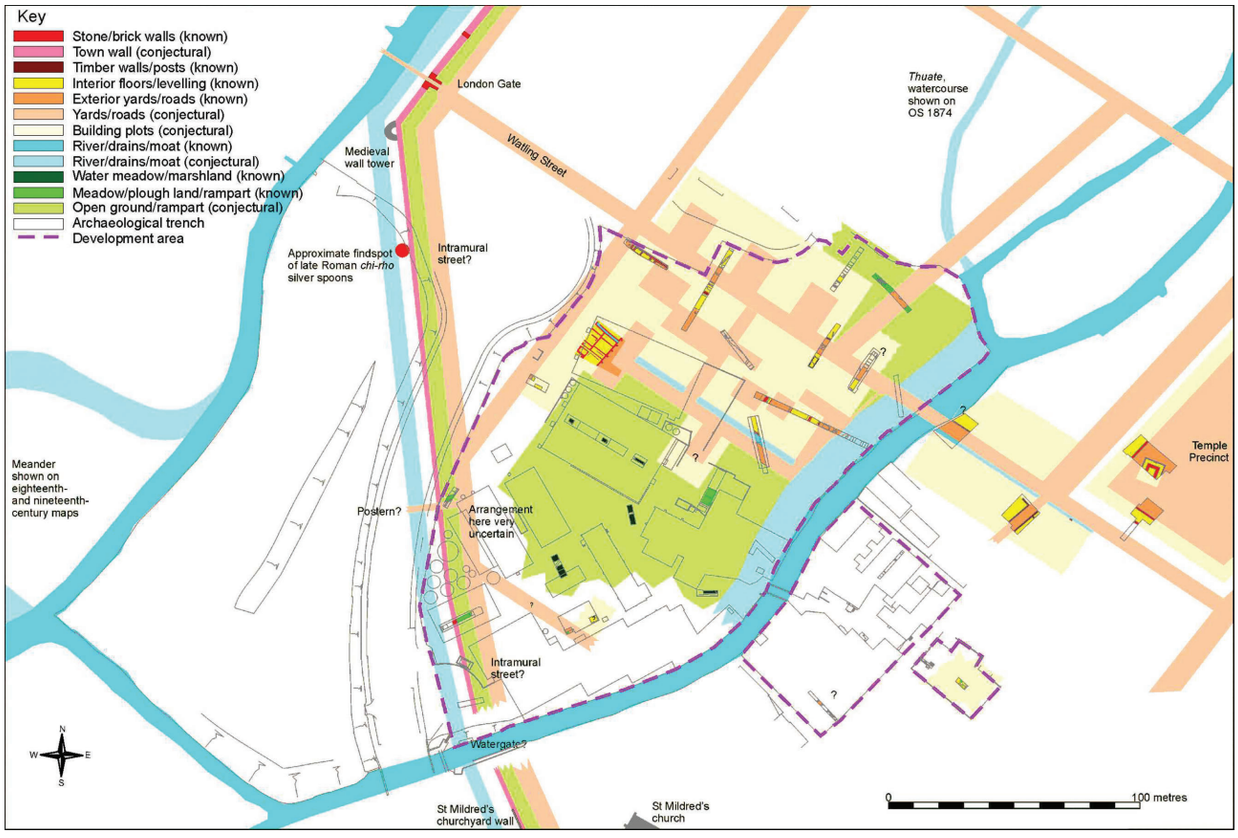


Figure 14.2: Roman reconstruction prior to deposit modelling

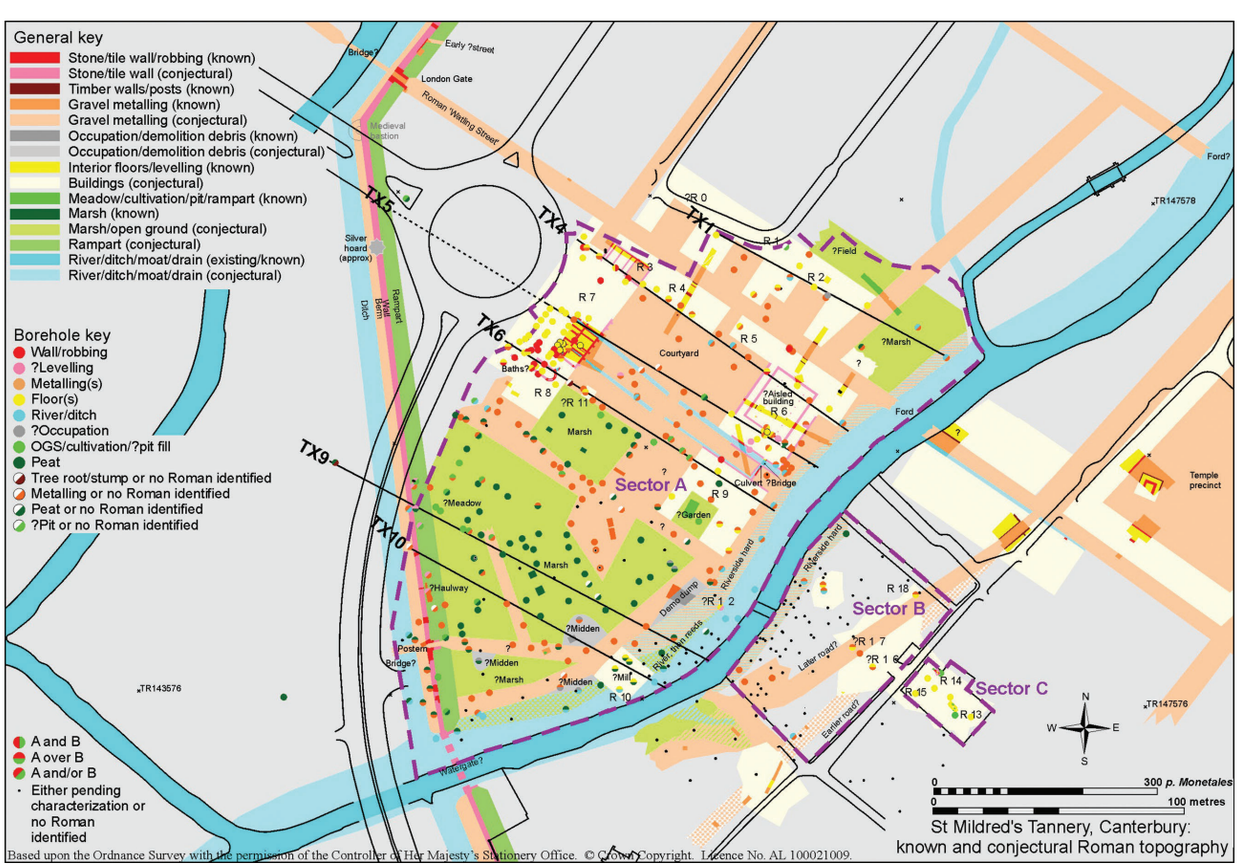


Figure 14.3: Roman reconstruction following deposit modelling. Note how R6 has altered, R9 migrated south and the putative intramural street lost. TX lines indicate transects shown in Figure 14.6



Figure 14.4: Logging table and a detail of its trough, holding a windowless-sample of a Roman wall

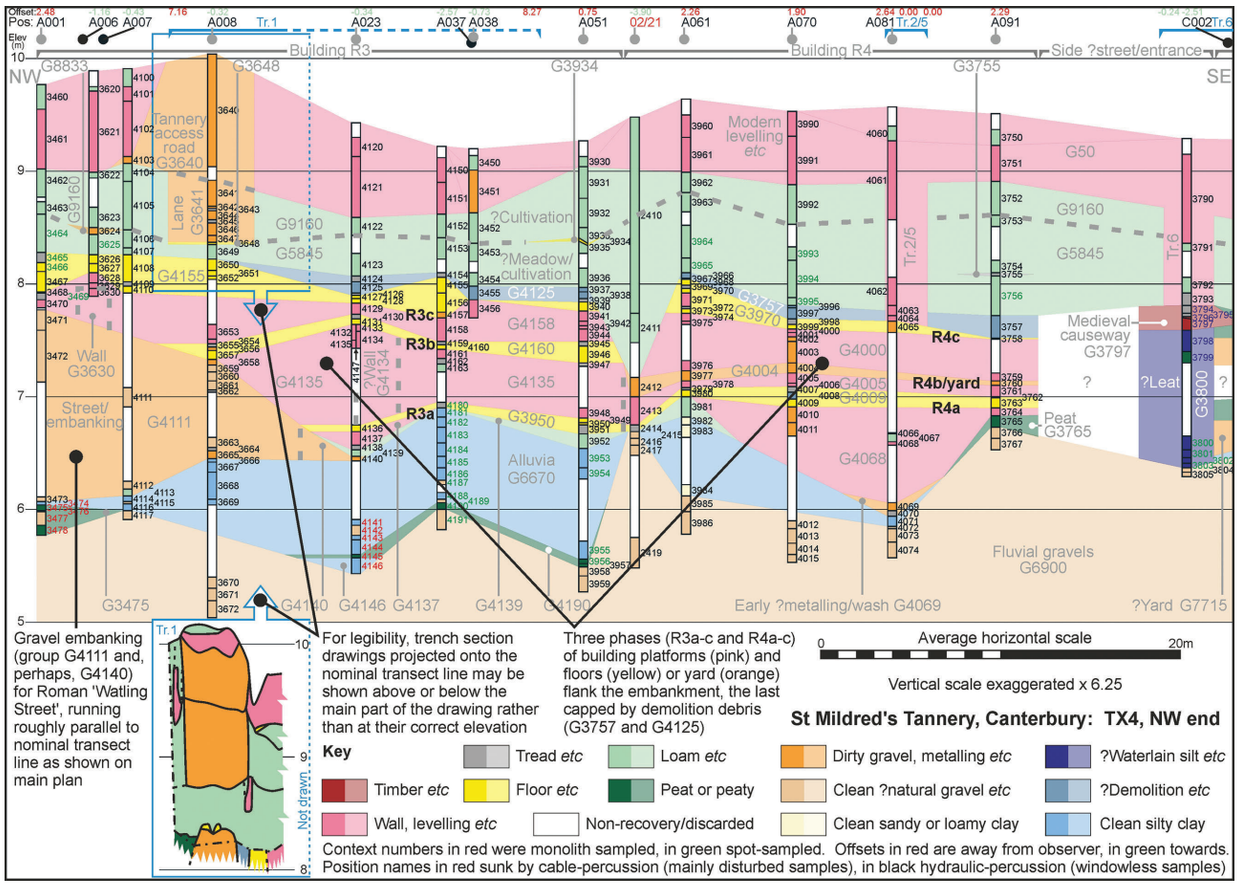


Figure 14.5: North-west end of transect TX4: although this level of detail may be unnecessary for the final report, it is all of use during analysis

group was phased. Phase and site summaries were written for the main report text, with logs and group descriptions appended. Multiple cross-sections were combined to produce simplified synoptic views and/or fence diagrams (Figure 14.6). The software was also used to export files for Surfer to produce 2-dimensional or 3-dimensional representations of the top, bottom, thickness or 'below ground level' depth of selected contexts, groups or phases (Figure 14.7).

14.3. Interpretation

Modelling of the site indicated that the pre-Roman ground level was probably around the height of the contemporary floodplain water-table, allowing shallow peats to form in some places. By dovetailing the results of deposit modelling with evidence from earlier excavations and desk-based assessments, it was possible to reconstruct the Roman and later topography of this part of the city (Figure 14.3). This work also highlighted the challenges of living within the floodplain, some of which are described below.

Deposit modelling demonstrated that a gravel embankment carried Watling Street across the valley floor; this feature dipped towards the river suggesting the presence of a ford. Attempts appear to have been made to build up soggy ground on some parts of the floodplain by laying gravel surfaces, some of which subsequently formed the foundations of yards, side-streets and buildings. The high water-table undoubtedly created problems for the inhabitants; for example, previous excavation (Blockley 1987) of building R7 demonstrated three main phases of construction, with each floor set significantly higher than its predecessor to alleviate the impact of a rising water-table. Further evidence for rising water levels was provided by peat layers mapped across the site, which have demonstrable relationships to Roman remains including drains, leats and floor levels.

A cluster of clay and gravel surfaces sealing thick deposits of organic and inorganic silt was identified projecting into the former river channel; these surfaces were tentatively interpreted as evidence for a Roman or Anglo-Saxon mill (R10). This (mill) structure suggests that rising water-tables did not entirely restrict activity on the floodplain. 9th century pins were recovered from a gravel surface above Building R6 on what was interpreted as an island of higher ground that may have been partially cultivated during this period. The surrounding peat deposits appear to have formed in two discrete phases;

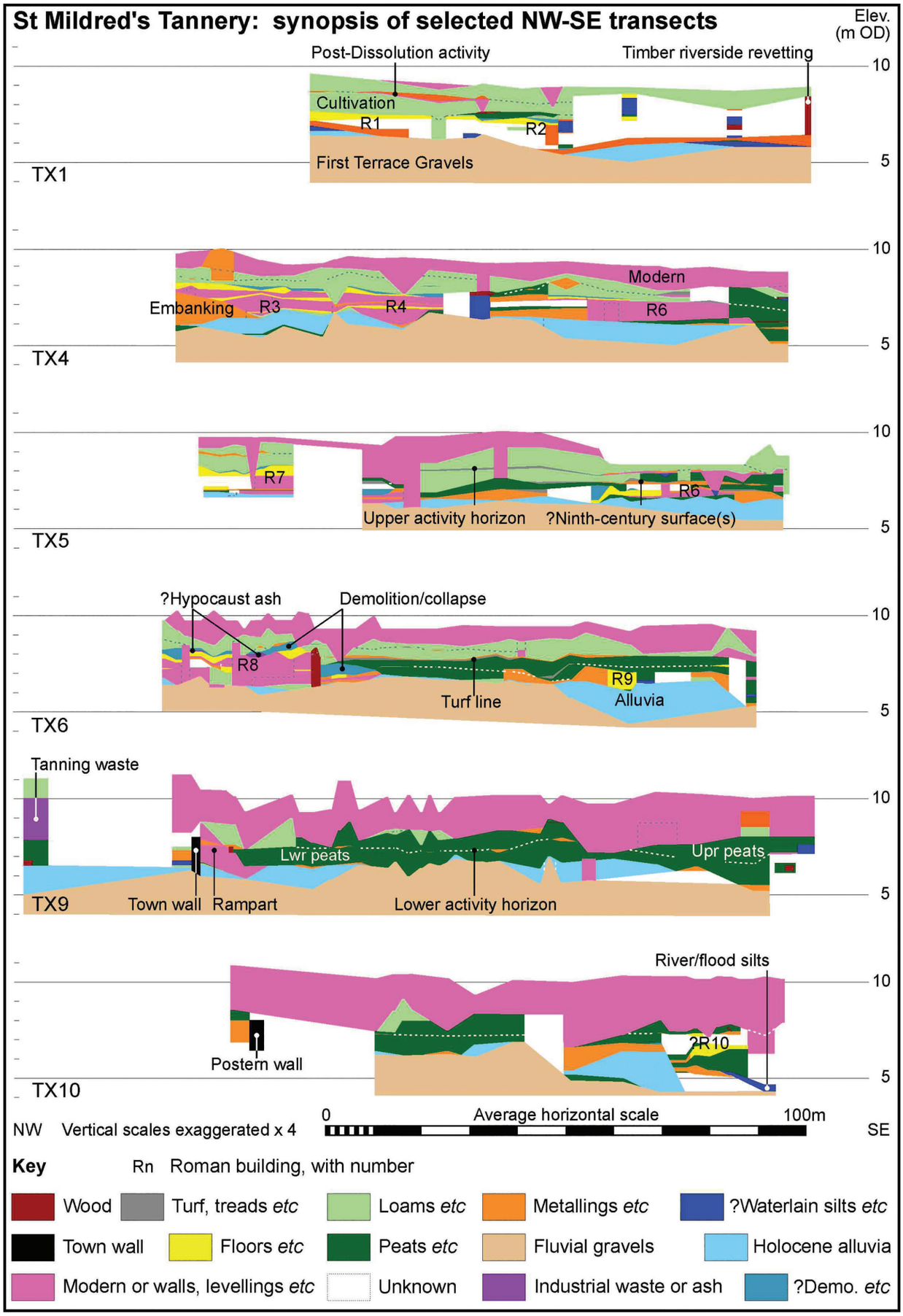


Figure 14.6: Synopsis of selected transects: the horizontal scale is averaged as individual boreholes are represented by an exaggerated width and some are slightly repositioned for legibility in the detailed versions

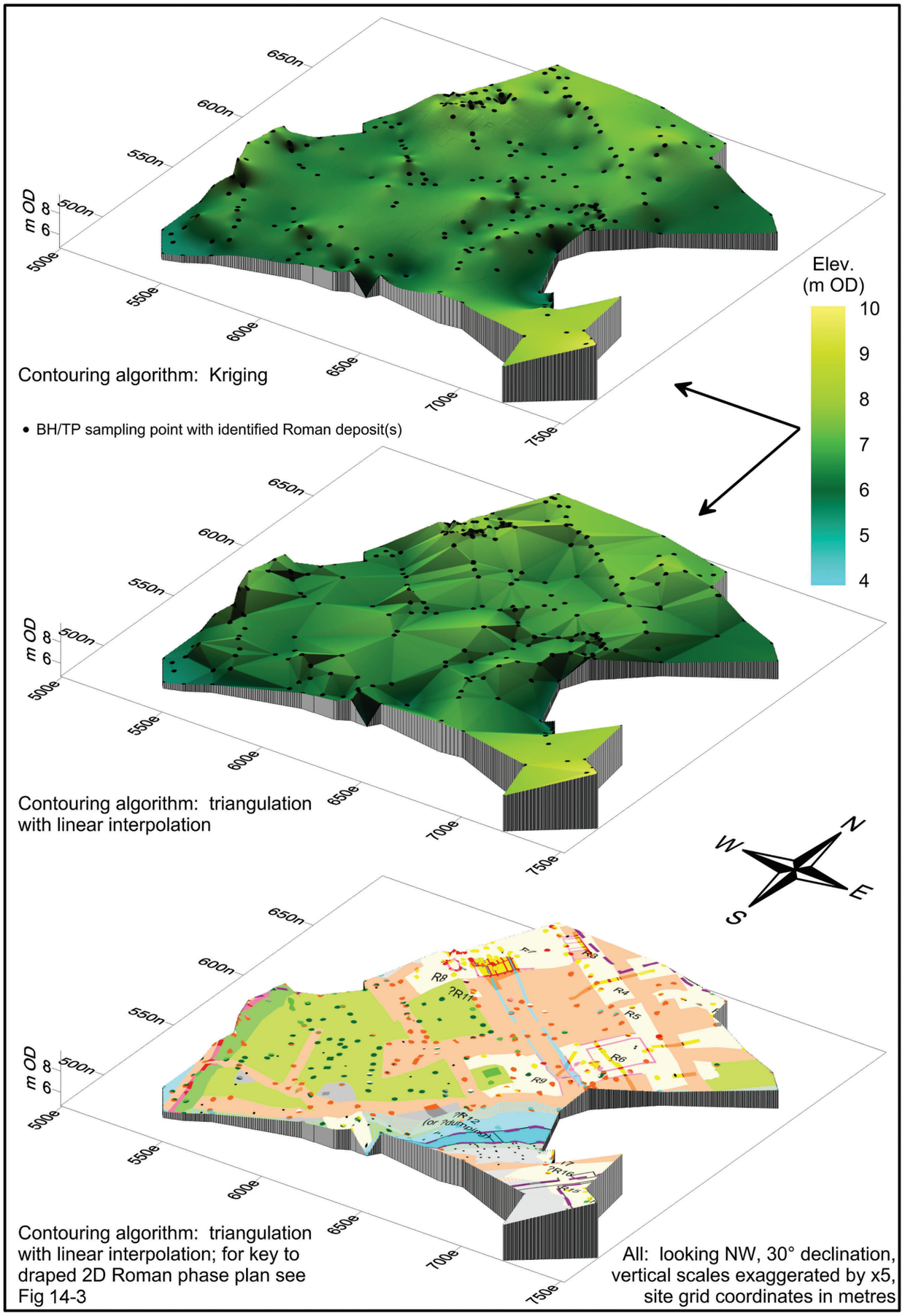


Figure 14.7: 3-dimensional images of the final Roman surface using two contouring algorithms: without expending considerable labour creating break lines or false coordinate triplets, neither will match more detailed 2-dimensional representations very closely

these were separated by an 'activity horizon' marked, variously, by a brushwood trackway, light metalling, trodden surfaces or simply a thin layer with significantly more flint, tile and bone than the surrounding sediments.

14.4. Conclusions

Data collection began with site investigation watching briefs in 2001–2002, but only with the start of purposive augering in 2004 was deposit modelling adopted as a form of preservation by record and as a means to target more effectively future evaluation trenching. It has proved to be a significant analytical tool, enabling CAT to contextualise many otherwise isolated excavations and observations and to produce relatively detailed, albeit conjectural, topographic reconstructions. This approach was cheaper than conventional excavation over such an area with challenging ground conditions, yet it provides curator and researcher alike with enough information to be useful, and enough uncertainty to be interesting. Where it has been tested by subsequent augering or excavation, the model has proved reasonably robust. The purposive augering was based upon relatively tightly spaced linear transects, but in hindsight, more evenly distributed sample locations may have been preferable for some locales. In addition, although post-excavation changes to field interpretations were not separated initially, they now occupy their own field and are differentiated in final logs.

Since adopting this methodological approach, data elucidating depositional environments and associated archaeological activity in Canterbury, especially for the Historic Period, has accumulated rapidly. Detailed 2-dimensional and 3-dimensional geoarchaeological models similar to the one described here have been produced for small areas of Canterbury and beyond, and are being used increasingly to inform mitigation strategies and the use of other techniques: for example, targeted optically-stimulated luminescence dating. These deposit models and their source data, including the one described here, form part of the permanent site archives and are available digitally for reinterpretation or inclusion in wider models of Canterbury and its environs.

Acknowledgements

Archaeological investigations at St Mildred's Tannery were overseen by a steering committee representing CAT, Historic England, Canterbury City Council, Bellway Homes (principal developers), their design and engineering consultants, and by Martin Biddle and Birthe Kjølbye-Biddle (archaeological consultants). Bellway Homes are thanked for providing funding for the vast majority of this work.

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SECTION 7

Modelling as an aid to sustainable resource management

14681 - Deposit Modelling and Archaeology.indb 179 22/03/2018 15:10:34

15. Characterising the waterlogged deposits beneath Nantwich, Cheshire: the application of deposit models beyond simple stratigraphic analysis

Tim Malim

SLR Consulting Ltd, Oxon Business Park, Hermes House, Holsworth Park, Bicton Heath, Shrewsbury, SY3 5HJ

Abstract

This paper describes the approach taken to investigate the urban waterlogged deposits in Nantwich, Cheshire, in order to establish a baseline and management strategy for continuing preservation of organic remains (Phase 1), funded by Historic England and Cheshire County Council. In order to characterize the physical and chemical nature of the deposits, and to map their extent, depth and chronology, a programme of borehole drilling was undertaken in 2007 to retrieve cores for detailed description and sub-sampling. The study showed that up to 4m of archaeological deposit had accumulated in parts of the town, and that the onset of widespread waterlogging occurred in the Late Saxon period and continued into the 13th century. Although preservation conditions varied over the 10Ha of 'urban wetland' some exceptionally good preservation was recorded uphill from the River Weaver, contrary to the logic of wet conditions in the floodplain providing the most likely location for waterlogging. The reasons for this are explained below, as well as the techniques and methodology adopted to gather and analyse the data. A subsequent programme of monitoring from 2011–2016 (Phase 2) is reported elsewhere.

15.1. Introduction

Nantwich is an ancient salt-working town located on the River Weaver in central Cheshire (Figure 15.1). The survival of archaeological remains within the town is of similar national importance to those in Berwick-on-Tweed (Derham 2013), Bristol (Wilkinson *et al* 2013), Carlisle (Zant *et al* 2013) and York (Holden *et al* 2009) due to the depth of accumulation and the condition of preservation. Basal geology comprises Mercia Mudstone Formation with glacial till above, which is present across wide areas to the east and west of the River Weaver and forms the main geology beneath Nantwich. The river terrace deposits which overlie the clay consist of sandy silts with clay and gravel, which can extend to 3m–5m in thickness. Above the natural geological strata, anthropomorphic



Figure 15.1: Location map: Nantwich and selected waterlogged sites in England

Comparative data table of this deposit model	
Deposit model location	Nantwich, Cheshire, UK (NGR: 364961 352403)
Depositional environment	Urban build-up across Holocene valley floor and adjacent Pleistocene glacial and river terrace deposits
Size of deposit model	Incorporates data over a *c* 20Ha urban area
Data collection strategies	Review of information collected previously during geotechnical investigations and archaeological interventions. Drilling of 30 purposive boreholes with a windowless percussive rig to characterise the mineralogy and geochemistry of the sediments and to collect samples for dating and palaeoenvironmental analysis. Dipwells were fitted in borehole voids to expedite any future monitoring study
Position in the archaeological process	Part of a funded research study to inform future planning decision-making within the historic urban area
Reason for deposit model construction	To establish the sedimentary character, 3-dimensional urban stratigraphy and hydrological and geochemical pathways through the deposits
Archaeological question	Can a best practice methodology which will inform future management and preservation strategies for the investigation of waterlogged urban deposits be established?
Software and modelling process	Borehole logs were plotted using gINT. Surfer was used to create 3-dimensional surfaces. Stratigraphic sections were constructed by hand and converted to digital format using Adobe Illustrator. GIS was used for spatial analysis
Outputs from the deposit model	A series of images including stratigraphic cross-sections, an isopach map of dissolved oxygen content and zones of preservation were created to aid visualisation. Project metadata was archived with the ADS

deposits have accumulated up to *c* 4m in depth from the current ground surface, comprising organic-rich silts, as well as archaeological horizons with carbonized organic remains, and more recent made-ground. Salt-working and flooding, as well as domestic and stable waste, have contributed to the build-up of deposits, which at times are interspersed with redeposited mineral-rich horizons.

Previous discoveries had revealed deep waterlogged deposits which date from Iron Age times, but the *Nantwich Waterlogged Deposit Study* has identified a significant growth of accumulation during the Late Saxon and medieval periods through a programme of radiocarbon dating (SLR 2009, 65). This richness of material posed a problem to development control as regeneration pressures were high within the historic core of the town. Cheshire County Council's Historic Environment Team (later Cheshire Shared Services) persuaded Historic England (at the time, English Heritage) to fund research into these deposits so that a well-informed management strategy could be formulated.

A project design and specialist team was provided by SLR Consulting with support from York Archaeological Trust and Palaeoecological Research Services. This included an archaeologist (the author), a geological engineer, a hydrogeologist, a GIS technician and illustrator, a conservation scientist and a palaeoenvironmentalist. Although the initial project, completed in 2007, comprised a desk-based assessment of available information, this was followed by field collection of bespoke data and environmental analyses through a programme of coring, sampling and analysis described more fully below (Section 15.3). The project was advised by a Steering Group comprising representatives from Historic England and Cheshire Shared Services (Archaeology).

15.2. Aims and objectives

The specific aim of the project was the development of a best practice methodology for the investigation and characterisation of waterlogged deposits, using Nantwich as a case study. Specific objectives were to: (1) determine the physical and chemical parameters governing the preservation of the organic deposits at Nantwich; (2) map their extent spatially and vertically and establish a chronological framework; and (3) establish how they had formed and how they had continued to be preserved over the centuries.

14681 - Deposit Modelling and Archaeology.indb 182 22/03/2018 15:10:34

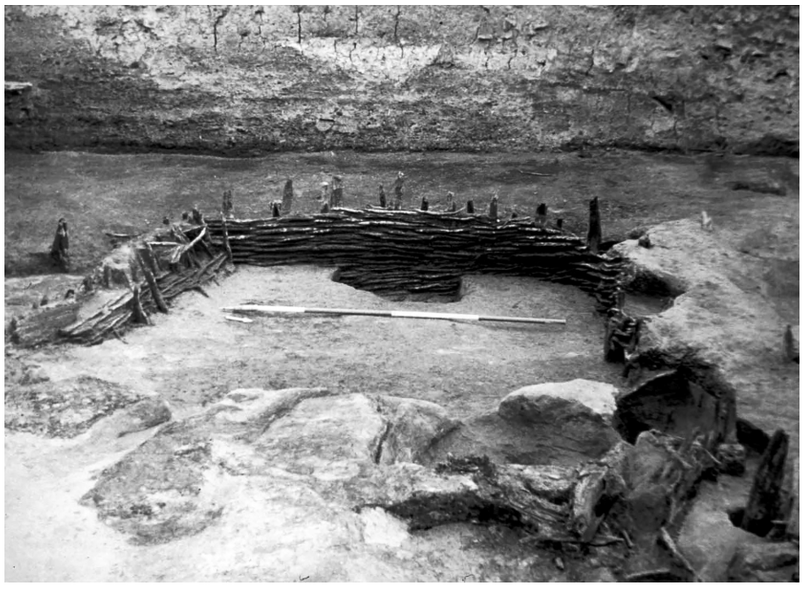




Figure 15.2: Waterlogged deposits and well-preserved organic remains: 2a wattle-walling for a wych house (Robina McNeil excavations 1970s), 2b tub-staves and planking (Tim Malim, Lamb Hotel 2003), 2c salt-barrels and salt-ship under excavation (EAS 2003)



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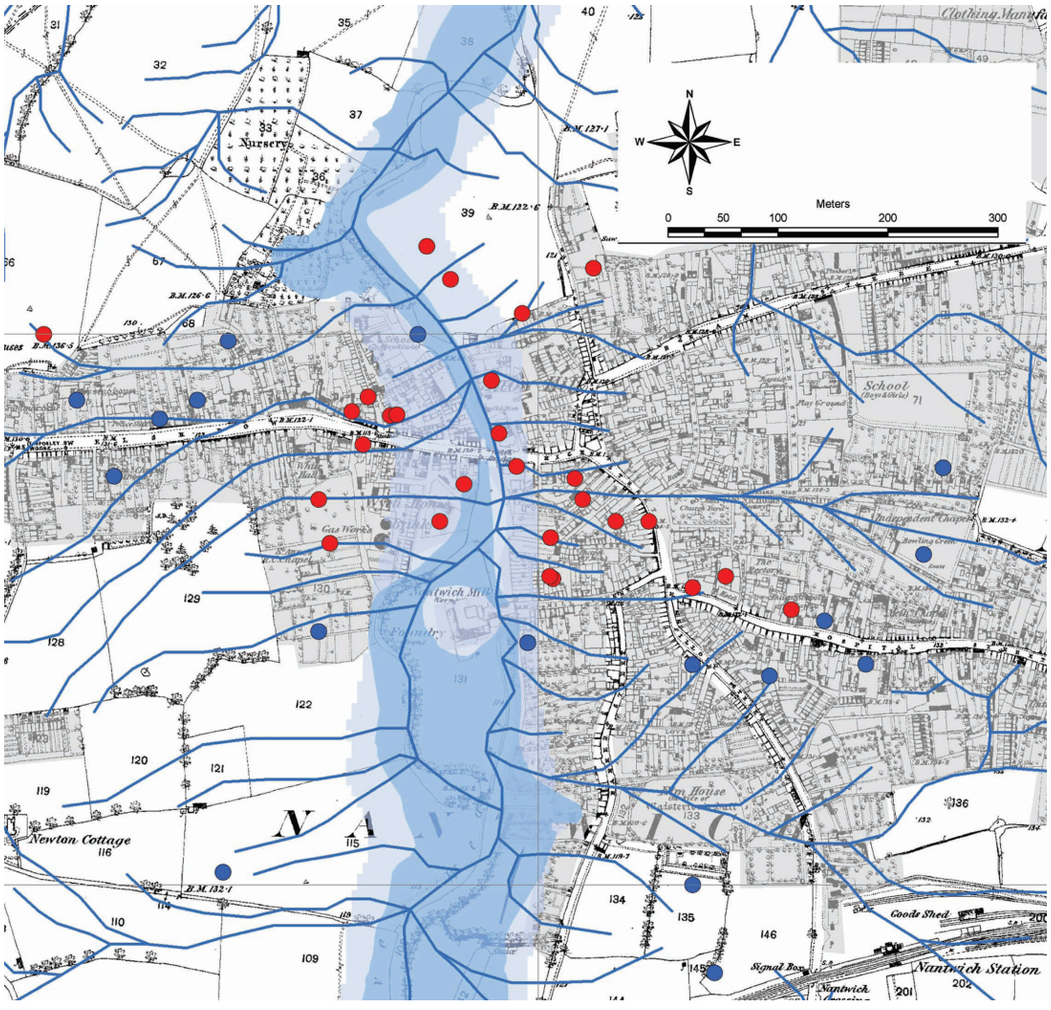


Figure 15.3: Nantwich with 1st edition OS map and natural flow accumulation paths superimposed (red dots waterlogged deposits from previous excavations, blue dots show excavated evidence for no waterlogging)

15.3. Methodology

Prior to the inception of the project, information had derived from watching briefs and excavations during the 1970s and 1980s, and PPG 16 developer-funded investigations thereafter (see for example Earthwork Archaeological Services 2006; Hayes 2005; Hutchings 1985; Le Quesne 1995; McNeil 1983; Reid 2004; SLR 2007 Table 1 and p.15-17) (Figure 15.2a-c), as well as some borehole data (Cheshire County Council Geotechnical Services logs for Snow Hill and Kingsley Fields [see SLR 2007 Table 1 and p.18]). The quality of this information was variable. Few of the over 100 boreholes had geotechnical records surviving for analysis as they had not been retained after permission had been granted for development. Even when boreholes for infrastructure projects such as road schemes were available, these failed to contain much geotechnical data that was sufficiently detailed to aid the desk-based study. Reports from archaeological interventions also often failed to contain heights above Ordnance Datum or even reliable national grid coordinates, further hampering their use.

The initial desk-based study in 2007 incorporated what was of value from these site investigation sources, and supplemented them with bespoke data collection. This latter stage consisted of drilling 30 boreholes across the historic core of the town to retrieve cores for detailed sediment description and sub-sampling for dating and environmental analysis.

Background data included contemporary Ordnance Survey (OS) mapping, historic OS and other older maps that could be georeferenced, geological data, hydrogeological data and hydrological natural flow accumulation paths to help understand the subsurface topography and hydrology (Figure 15.3). Digital terrain models were created using these datasets, thereby allowing information to be reviewed and analysed within a 3-dimensional environment. Baseline conditions were established in 2007 with a programme of geochemical and palaeoenvironmental sampling, using cores extracted by

a windowless percussive rig (Figure 15.4). Each core (1m long and 100mm diameter) was recovered in a Perspex sleeve, which was sealed rapidly and stored in cool and light-free conditions before processing. The lithology of each core was described before sub-sampling to identify the degree of preservation of plant macrofossils, pollen, diatoms, insect remains and wood. Material that would be suitable for radiocarbon dating was also identified.

Analysis included permeability testing of the sediments and lithological descriptions; geological descriptions followed British Standard 5930 and Norwegian protocols (Riksantikavaren 2008). Once described in detail, the descriptions and urban stratigraphy were simplified to establish a small number of categories to aid the study of typology and expedite geochemical analysis of the sediments. Some of these analyses had formed part of the proposed research design before the project started. Others, however, had to be adapted and incorporated as the project progressed in order to provide standardised and comparable results or to answer specific research questions which arose during an iterative process of data collection and interrogation (including determination of the chronological framework).

Data analysis was aided by a variety of different software. Borehole logs were plotted using gINT (https://www.bentley.com/en). Surfer (http://www.goldensoftware.com/products/surfer) was used in an attempt at 3-dimensional modelling since trials using geographical information systems were found to be unsuccessful because of too few data points. Adobe Illustrator was used to convert digital graphic modelling diagrams into publication standard illustrations (Figure 15.5a,b,c). However, in spite of the availability of a range of software packages, experiment showed that the best method of data analysis was actually to plot results by hand and then convert into digital images by use of Illustrator. Furthermore, the process of undertaking manual transcription of the data required significant engagement with the data during analysis and interpretation and provided a means of identifying and correcting processing faults introduced into the raw data.

The methodology was designed especially for this project, although it adapted techniques deployed for investigations of other sites with waterlogged deposits, mostly from rural contexts. Some of the approaches had been pioneered by environmental investigations from the 1930s to the 1980s in the fenlands of East Anglia (Waller 1994), where peat and silt deposits had been sampled through auger survey and trial excavation. More recent techniques were adapted from monitoring of sites such as Fiskerton (Lincolnshire; Williams *et al* 2008) and Star Carr (North Yorkshire; Boreham *et al* 2011), the Norwegian World Heritage Site at Bryggen (Bergen; de Beer and Matthiesen 2008; Matthiesen *et al* 2008), and a number of Danish meres and bogs (Gregory *et al* 2002). As previously indicated, the Nantwich methodology evolved as the project progressed. For example, the second stage was divided during execution into two sub-stages, enabling lessons learned during the first campaign of borehole drilling to inform the methodology employed during the second stage. This revised methodology included a modification to install dipwells in the borehole voids, in case a further stage of deposit monitoring might be proposed beyond the initial baseline characterization. Since the Nantwich project has been running, Historic England has drafted guidance on urban waterlogged deposits, which proposes a three tier process: i) desk study; ii) ground investigation for baseline characterisation and assessment; and iii) updated assessment following monitoring (Historic England 2016).

The basic approach to methodology and analysis that was developed here was employed by SLR on several other sites during the course of the Nantwich project, including the timber platform at Must Farm in the Flag Fen basin near Peterborough (Cambridgeshire) (Malim *et al* 2015a); Kings Delph and land adjacent to Must Farm (Cambridgeshire); Trident Park (Cardiff); and East India Dock (London).



Figure 15.4: Windowless-sampling rig in operation: getting permission from many land-owners was a major problem. Note the steel liner and Perspex sleeves

15.4. Interpretation

Analysis of the data was undertaken in various ways, including physical description and assessment of sediment permeability, laboratory quantitative analysis for different chemical species, rapid assessment of organic remains through species identification, loss on ignition (total organic carbon) quantification, wood substance (state of preservation) testing, radiocarbon dating of selected samples from top and base of sedimentary sequence, and identification of the character of aqueous deposition through diatom analysis.

Interpretation of the data was an iterative exercise at several levels, and drew on multiple strands of evidence. Multi-disciplinary dialogue and rationalization of terminology were beneficial to clarify the meaning of some datasets and interpretations. Different disciplines use words and phrases in different ways, and achieving understanding and harmonisation across various disciplines can be a challenge because the nuances are not appreciated. Misunderstandings can thus develop quickly between members of the team and external scrutineers. For example, to a layman sediment moisture levels of 50% would not seem to indicate saturation, but to a hydrologist

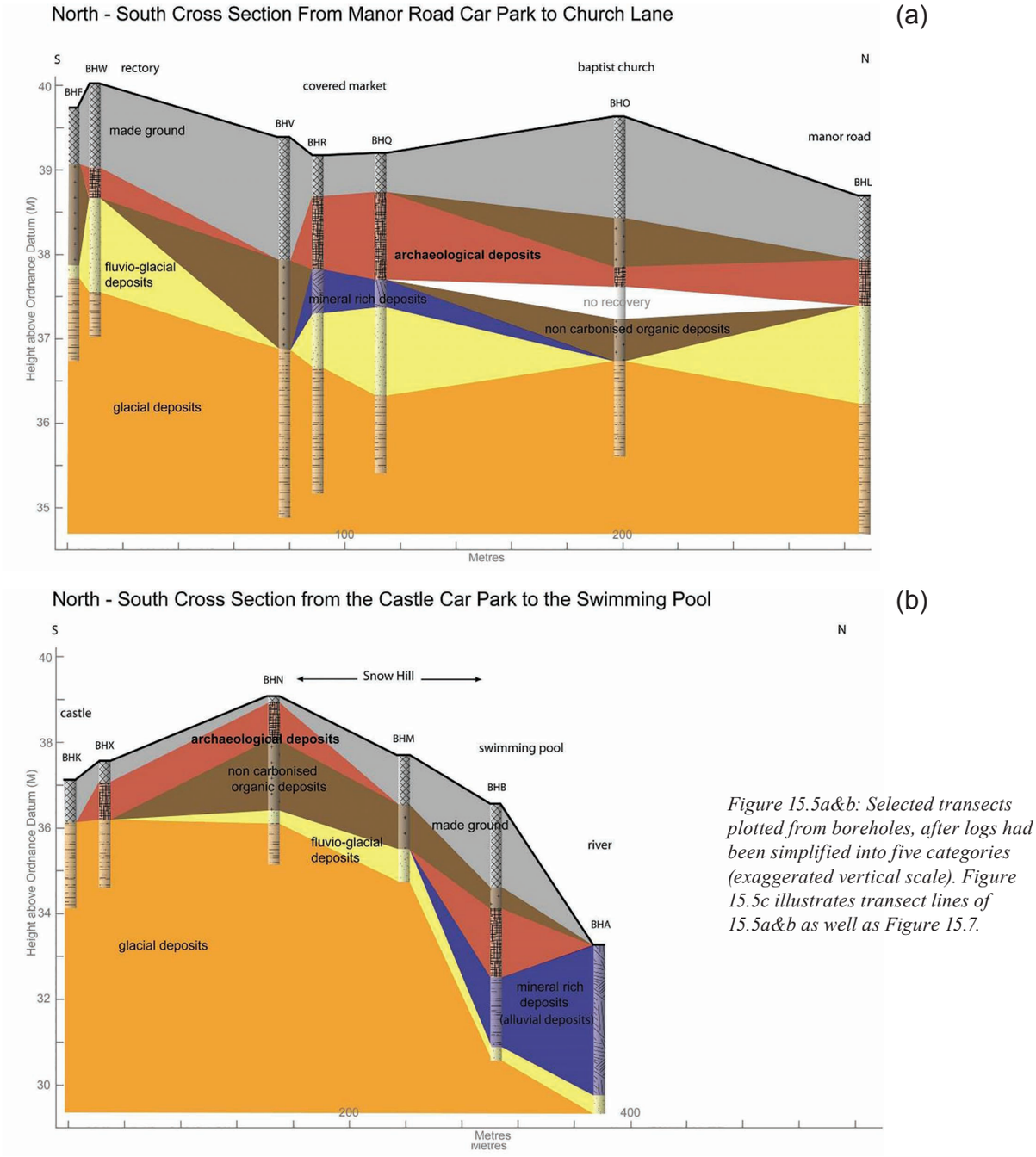


Figure 15.5a&b: Selected transects plotted from boreholes, after logs had been simplified into five categories (exaggerated vertical scale). Figure 15.5c illustrates transect lines of 15.5a&b as well as Figure 15.7.

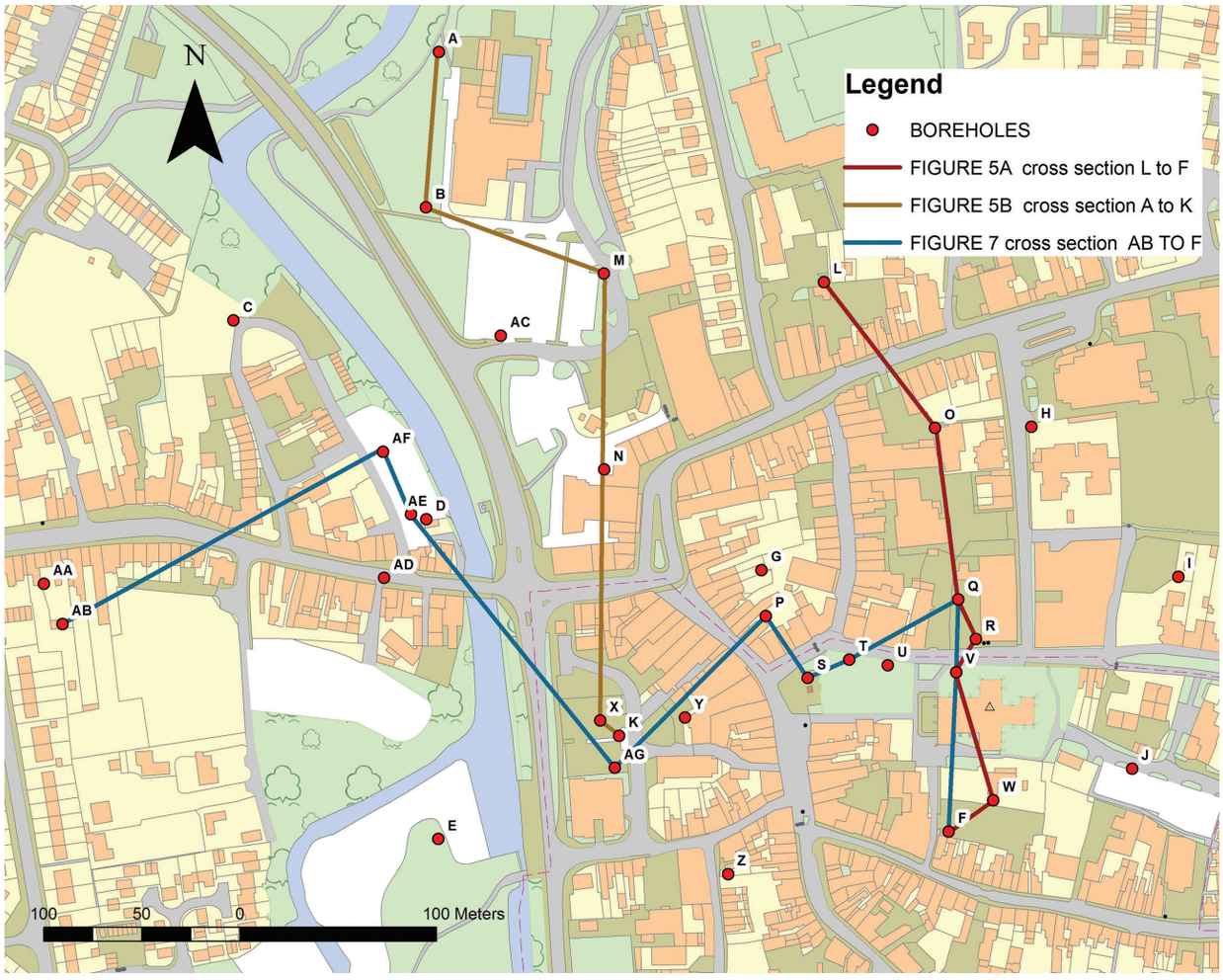


Figure 15.5c

typical expected porosity values for silt (ranging between 35% and 50%) and clays (ranging between 40% and 70%) mean that fully saturated conditions would occur with moisture values of between 50% and 70%.

Basic sediment description can also be susceptible to variations in interpretation, and at Nantwich the need for a valid measure of comparison between borehole logs required a simplification of the detailed geological descriptions. This resulted in a classification of five categories of deposit to which the more complex physical descriptions of the cores could be assigned, thereby allowing transects to be mapped across the historic town as continuous sequences (Figure 15.6a&b).

As a result of the detailed recording of the borehole cores, complicated and diverse horizons and lenses were identified that were often not consistent with other boreholes (Figure 15.6a). Migration of this detailed information to standard borehole logging designed for British Standard 5930 (which categorises all archaeological contexts simply as 'made ground'), complicated the presentation and interpretation of the results and comparison between boreholes. It was decided, therefore, to assign individual lenses from the detailed logs into groups that conformed to one of three categories (organic-rich, mineral-rich or archaeological), to an uppermost 'made ground' category including material of 18th century and later date, or to a 'fluvio-glacial' deposit that represented a sub-division of the lower mineral-rich deposit [see Figures 15.6b and 15.7]):

- Made ground: records from the higher part of the borehole which included brick, mortar, modern materials, or identifiable inclusions datable to the 18th–20th centuries;
- Archaeological deposits: silts, clays and sands, black to light grey in colour, which contained evidence of human activity such as ash, charcoal, pottery and bone;
- Organic-rich deposits with a sulphide smell: non-carbonized plant-microfossils, wood, leather and plant debris;

(a)

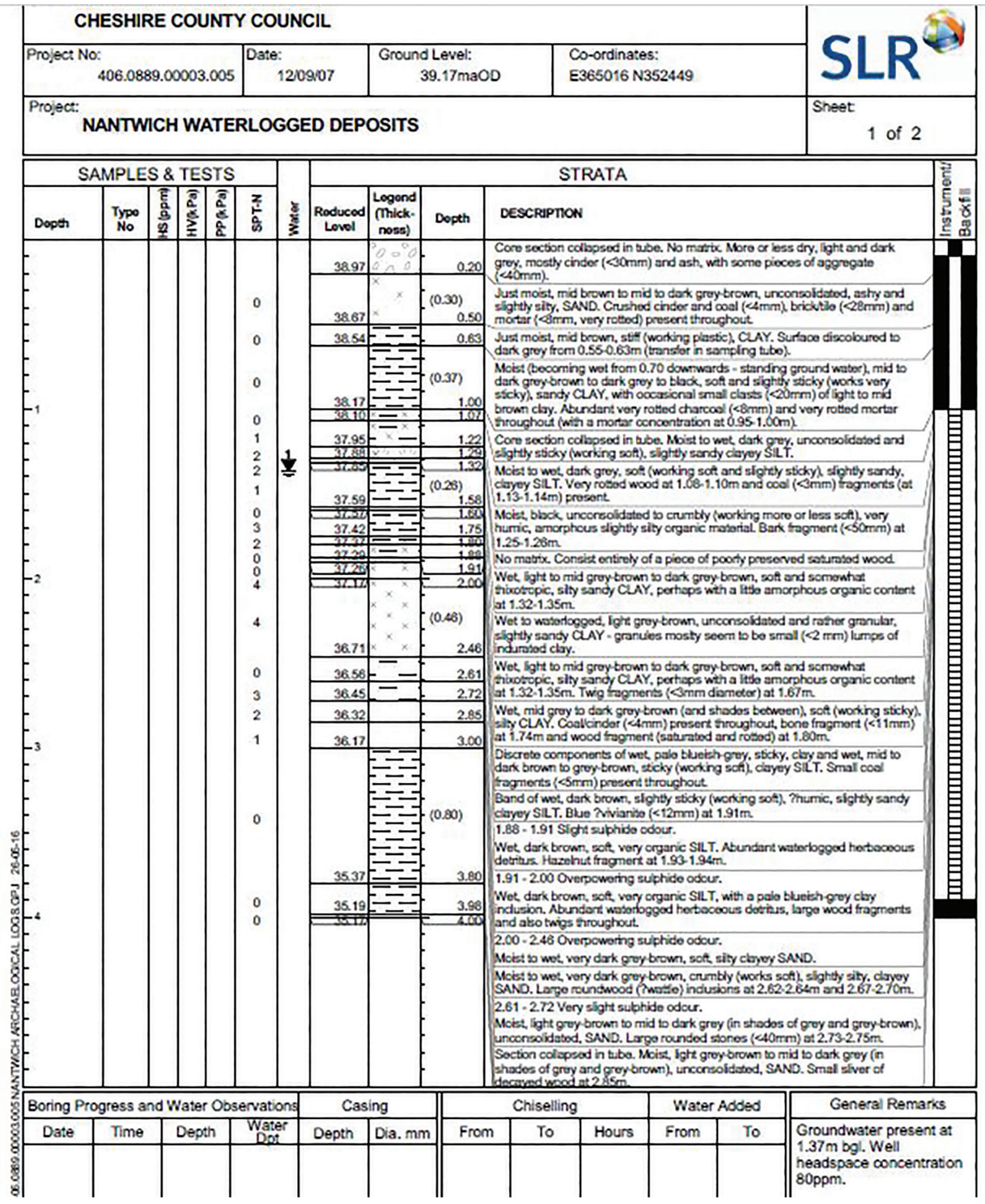
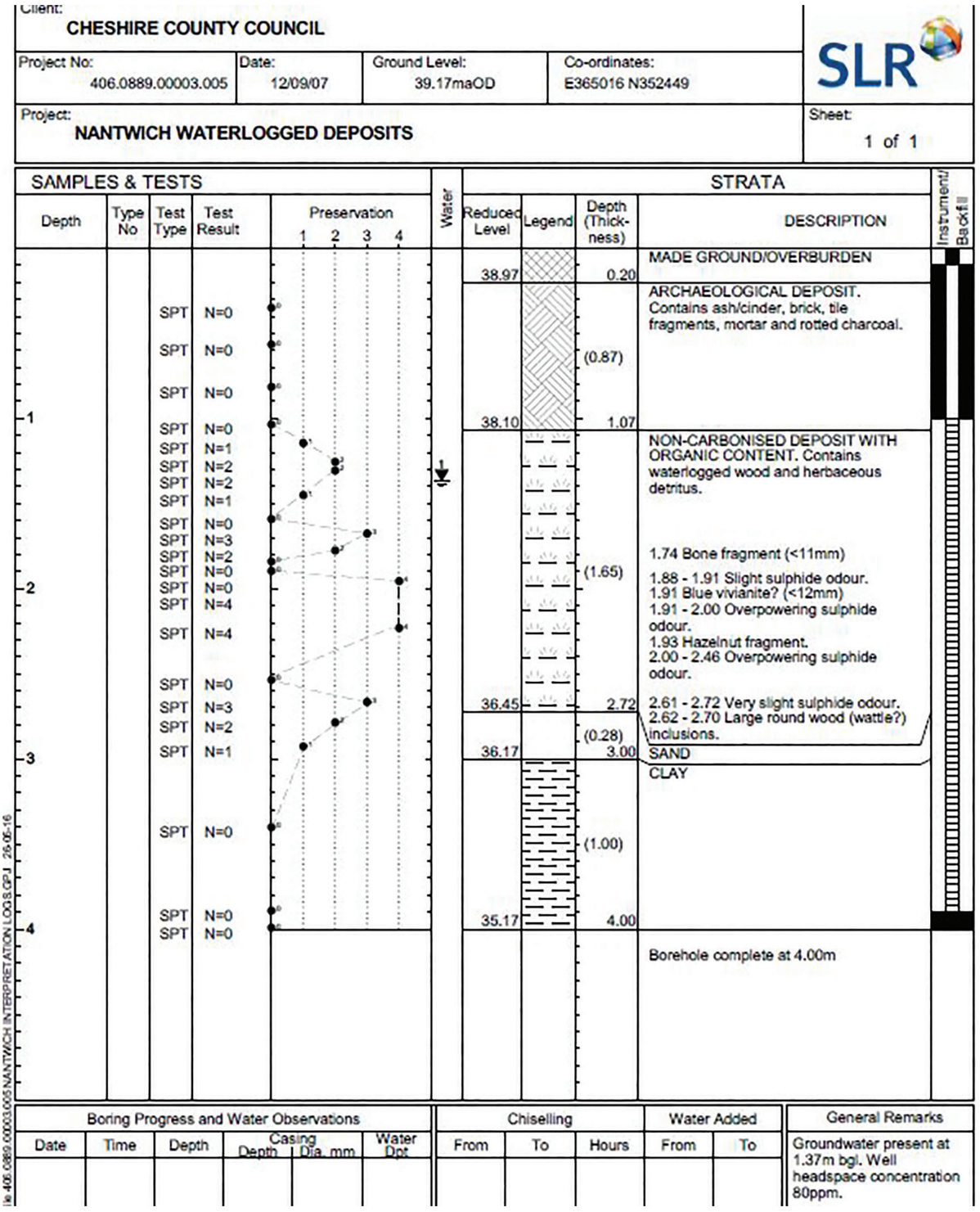


Figure 15.6a&b: Comparison between detailed archaeological recording of the lenses (6a) in BH N, and simplified version after interpretation into five categories (6b)

(b)


Client:
CHESHIRE COUNTY COUNCIL
Project No:
406.0889.00003.005
Date:
12/09/07
Ground Level:
39.17maOD
Co-ordinates:
E365016 N352449
SLR
Project:
NANTWICH WATERLOGGED DEPOSITS
Sheet:
1 of 1
SAMPLES & TESTS
Depth
Type No
Test Type
Test Result
Preservation
Water
STRATA
Reduced Level
Legend
Depth (Thick-ness)
DESCRIPTION
Instrument/ Backfill
MADE GROUND/OVERBURDEN
38.97
0.20
ARCHAEOLOGICAL DEPOSIT. Contains ash/cinder, brick, tile fragments, mortar and rotted charcoal.
(0.87)
38.10
1.07
NON-CARBONISED DEPOSIT WITH ORGANIC CONTENT. Contains waterlogged wood and herbaceous detritus.
1.74 Bone fragment (<11mm)
1.88 - 1.91 Slight sulphide odour.
1.91 Blue vivianite? (<12mm)
1.91 - 2.00 Overpowering sulphide odour.
1.93 Hazelnut fragment.
2.00 - 2.46 Overpowering sulphide odour.
(1.65)
2.61 - 2.72 Very slight sulphide odour.
2.62 - 2.70 Large round wood (wattle?) inclusions.
36.45
2.72
(0.28)
36.17
3.00
SAND
CLAY
(1.00)
35.17
4.00
Borehole complete at 4.00m
SPT N=0
SPT N=1
SPT N=2
SPT N=3
SPT N=4
Boring Progress and Water Observations
Date
Time
Depth
Casing Depth
Casing Dia. mm
Water Dpt
Chiselling
From
To
Hours
Water Added
From
To
General Remarks
Groundwater present at 1.37m bgl. Well headspace concentration 80ppm.
406.0889.00003.005 NANTWICH INTERPRETATION LOGS.GPJ 26-06-16

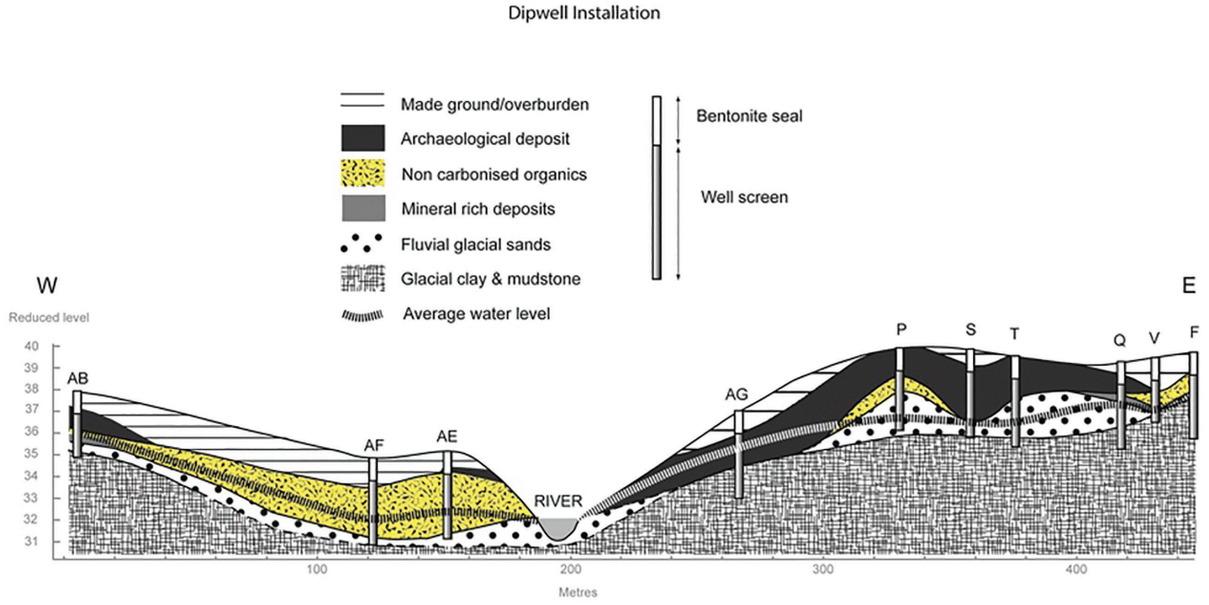


Figure 15.7: Cross-section across river valley plotted from boreholes (interpreted logs) showing saturated sand basal deposit. See Figure 15.5c for location.

- Mineral-rich deposits: grey clays, silts and sands that contained no organic or archaeological inclusions but were not part of the natural superficial geological sequence;
- Fluvio-glacial deposits: records from the lowest part of the borehole, describing sands that represent the top of the natural geological sequence.

A key objective of the project was to identify and map the extent and formation processes for waterlogged deposits and thus the potential for the preservation of organic remains. The identification of surviving organic remains was clearly an important factor. However, other investigations, such as the identification of preservation conditions from geochemical analysis, provided information of equal or greater importance for study of the potential for long-term organic survival in deposits yielding no direct evidence for organic preservation or where associated organic remains had disappeared through decay. The wider inclusion of deposits that preserved more marginal organic content was essential; together with comparison to archaeologically excavated evidence, this helped to identify formerly organic-rich layers in a state of active decay and provided invaluable information on the threats facing well-preserved deposits that survived elsewhere in the town.

A simple summary of 'zones' of potential preservation based on the borehole locations has been established, although additional data points (cores) would undoubtedly help to refine this model in the future. Currently, three categories are recognised:

- Known preservation (where organic preservation is seen to exist);
- Potential preservation (where organic preservation is not necessarily recorded, but where suitable conditions for preservation can be shown or inferred: for example, by a consistently high groundwater level or suitable chemical conditions, and by analogy with other similar deposits);
- No preservation (where organic preservation is not recorded and conditions for preservation are poor suggesting absence).

15.5. Reporting and dissemination

Several papers have been delivered at national and international symposia, together with a number of publications (Malim and Panter 2012; Malim *et al* 2015b; Malim *et al* 2016a) These provide interim statements and comparative studies with related types of site and deposits and complement the final report on completion of the five year programme of monitoring (Malim *et al* 2016b). In addition, five interim reports have been produced to record the results from the monitoring programme annually (SLR interim reports 2011–2015); these reports have been peer-reviewed by the project steering group, which was established at the outset of the project. The need for data compilation and interim report presentation has been extremely beneficial as, together with the challenge and review sessions, it has provided an iterative process; this tested the effectiveness of the methodology and posed research questions as the project progressed, assisting the development of an

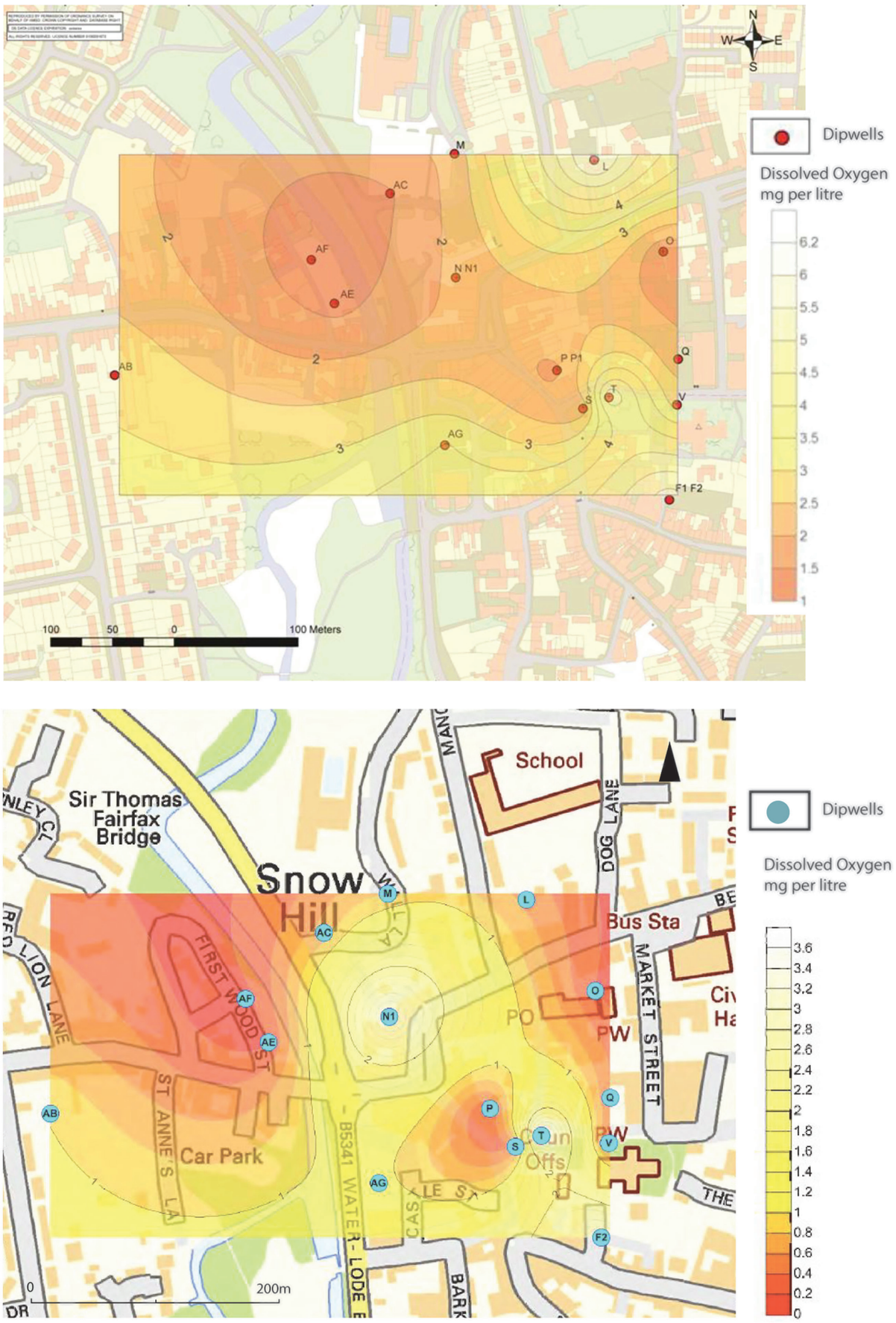


Figure 15.8: Example of data presentation: Plot of gas emissions from monitored dipwells. Upper image is from February 2014; lower image is from December 2015

enhanced methodology and the creation of more robust datasets.

The five years of monitoring have produced a large corpus of data, which is summarised in the appendices of the final report (Malim *et al* 2016b) and remains available for consultation as metadata through hosting on the Archaeological Data Service website (http://archaeologydataservice.ac.uk/). The final report focused on analysis of trends in the data and the interpretations deriving from that analysis. The monitoring data have used proxy indicators to help interpret the degree to which the burial environment enables agents of decay to act on ancient organic remains. These indicators include the degree of saturation within sediments, water quality parameters and the ratios of oxygen-reducing chemical species on a scale from aerobic to anoxic conditions (Figure 15.8).

15.6. Management strategy

The data gathered during the baseline and monitoring programme has provided the foundation for a more detailed understanding of the diverse burial environments of Nantwich. This has enabled development of a sufficiently robust evidence base for design of a management strategy, documented in a Supplementary Planning Document (SPD; Malim 2016). The latter has been endorsed by East Cheshire Council as a supporting document for its Local Plan. The emphasis of this strategy is upon a holistic approach from spatial planners, engineers, developers, utility companies and others whose activities may cause subsurface disturbance and changes in hydrological conditions; this will ensure management of rainfall and run-off in order that water can be stored and absorbed into the ground (Figure 15.9) rather than channelled away from the deposits and contribute to flood risk (de Beer *et al* 2015). By preventing gradual desiccation of the waterlogged archaeological deposits, the strategy will not only help in preserving archaeological remains but will also help prevent subsidence of the built heritage within Conservation Areas such as those of Nantwich. As appropriate, any future development permitted within the Area of Special Archaeological Potential would be required to investigate and monitor the deposits, and data recovered by these means would help to enhance and revise the existing model derived from the project to date.

15.7. Summary and conclusions

The grid of boreholes drilled over the historic core of Nantwich has successfully characterized the deposit sequence for the town, although this interpretive model would benefit from refinement and enhancement as further site investigations take place in the future.

Results from the borehole coring programme and assessment of sediment samples recovered have helped in defining the limits and depth of the waterlogged organic deposits, as well as characterising their physio-chemical condition. Two distinct zones of preservation dependent on local (urban) hydrology have been identified from the geochemical assessment. These comprise a low-lying zone adjacent to the river, in which well-preserved organic remains have been recorded, and a secondary zone along the higher slopes, where organic preservation has been detected but active decay appears to be in progress (Figure 15.10). The evidence for conditions within this latter zone derives from poorly preserved invertebrate and diatom remains, as well as high sulphate and nitrate levels in the deposits liable to fluctuation above the measured groundwater level. Within this zone, however, it was also noted that sulphate levels decreased and sulphide levels increased with depth; below the water-table, therefore, favourable conditions for preservation continue to exist.

Geoarchaeological investigations at Nantwich have pioneered the adaptation of established methods of investigation to establish a baseline for long-term monitoring and study of the dynamic conditions which characterise many urban waterlogged deposits. The project has achieved successfully its objectives and has provided a robust corpus of scientific data that is available for future interrogation and detailed study. It demonstrates how deposit modelling can be taken beyond the study of local stratigraphy and archaeological potential and can inform wider debates focused on the historic environment.

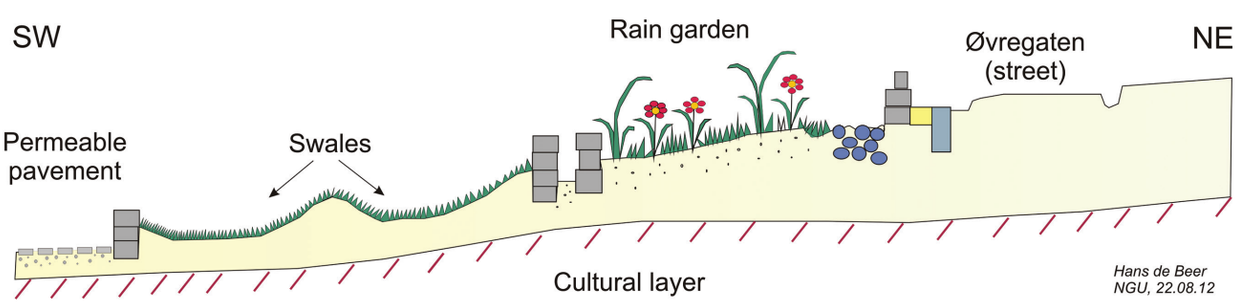


Figure 15.9: Diagram of methods for rainwater capture and recharge in waterlogged deposits, reproduced by permission of Hans de Beer and Anna Seither (de Beer and Seither 2015, Fig. 8.11)

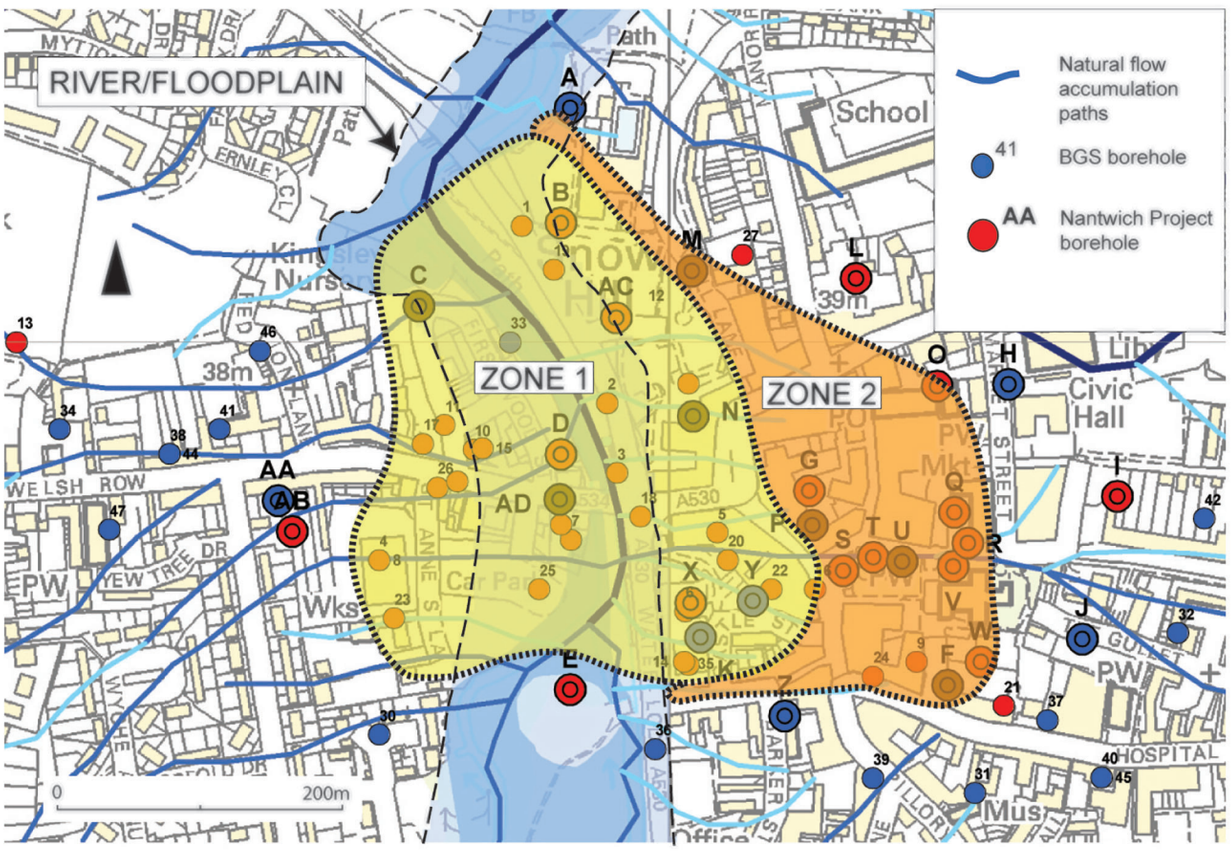


Figure 15.10: Map of Nantwich showing two zones of preservation identified from baseline deposit modelling and dipwell monitoring, with natural flow accumulation paths shown

Acknowledgements

Many thanks are due to Jennie Stopford and Sue Stallibrass (Historic England), and to Dr Jill Collens and Mark Leah (Cheshire Archaeology Planning Advisory Service Cheshire Shared Services), who funded and masterminded the project, steering it throughout Phase 1 (2007–10) and during the five years of monitoring (2011–15). Thanks are also due to all those colleagues who contributed to the project's success, especially John Carrott, Grace Chillingworth, Caroline Malim, John Meadows, Phil Murphy, Ian Panter, Claire Parsons, and especially Mark Swain who played such a major role in designing and executing the borehole and sampling programme.

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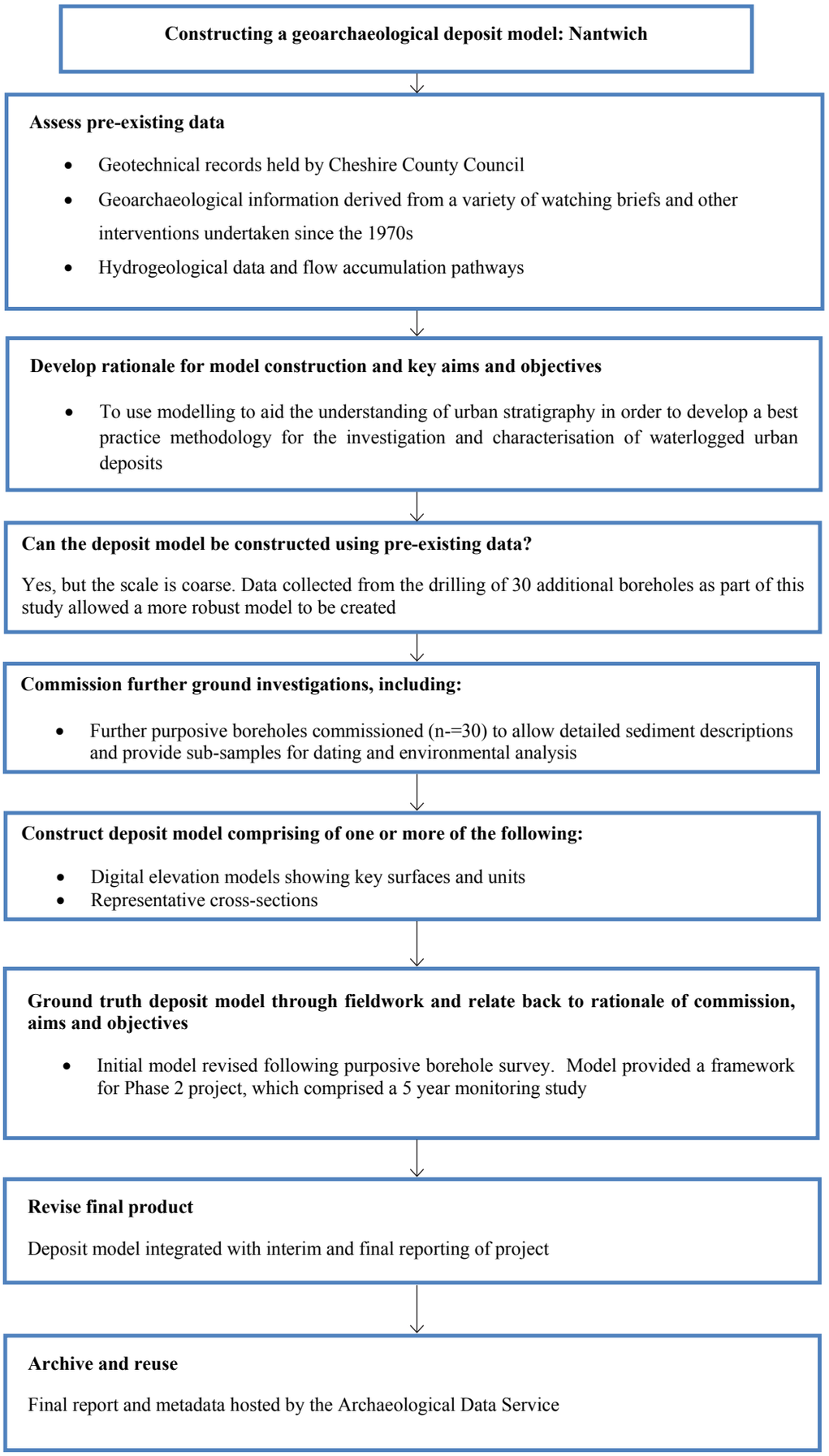
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Constructing a geoarchaeological deposit model: Nantwich
Assess pre-existing data
• Geotechnical records held by Cheshire County Council
• Geoarchaeological information derived from a variety of watching briefs and other interventions undertaken since the 1970s
• Hydrogeological data and flow accumulation pathways
Develop rationale for model construction and key aims and objectives
• To use modelling to aid the understanding of urban stratigraphy in order to develop a best practice methodology for the investigation and characterisation of waterlogged urban deposits
Can the deposit model be constructed using pre-existing data?
Yes, but the scale is coarse. Data collected from the drilling of 30 additional boreholes as part of this study allowed a more robust model to be created
Commission further ground investigations, including:
• Further purposive boreholes commissioned (n-=30) to allow detailed sediment descriptions and provide sub-samples for dating and environmental analysis
Construct deposit model comprising of one or more of the following:
• Digital elevation models showing key surfaces and units
• Representative cross-sections
Ground truth deposit model through fieldwork and relate back to rationale of commission, aims and objectives
• Initial model revised following purposive borehole survey. Model provided a framework for Phase 2 project, which comprised a 5 year monitoring study
Revise final product
Deposit model integrated with interim and final reporting of project
Archive and reuse
Final report and metadata hosted by the Archaeological Data Service

SECTION 8

Modelling to aid curatorial decision-making

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16. A review and case study of deposit modelling in York

Kurt Hunter-Mann[1] *and John Oxley*[2]

[1]63 Wilton Rise, York, YO24 4BT; [2]City Archaeologist, City of York Council, West Offices, Station Rise, York, YO1 6GA

Abstract

Arup and selected partners created a deposit model for the historic core of the City of York in 1989. This model now requires revision and updating. In order to evaluate the scale of work required to update the deposit model, the primary author carried out a sample study looking specifically at the geoarchaeological evidence that could be extracted from grey-literature reports on archaeological interventions in the Bishophill area of York. This case study has demonstrated the significant potential of an enhanced deposit model for expediting effective management and curation of the City of York's archaeological and environmental resource.

16.1. Introduction

The existence of extensive areas of deeply stratified, waterlogged archaeological deposits beneath the City of York, rich in organic artefacts and fragile

Comparative data table of this deposit model	
Deposit model location	City of York (NGR: 460230 451565)
Depositional environment	Urban build-up across Holocene valley floor and adjacent Pleistocene glacial and river terrace deposits
Size of deposit model	Arup study (1991) dataset encompassed an area of approximately 460 Ha. Bishophill pilot study area *c* 18 Ha
Data collection strategies	Review of information collected previously during geotechnical investigations and archaeological interventions reported in the grey literature
Position in the archaeological process	Part of a pilot research study to inform future planning decision-making within the historic urban area
Reason for deposit model construction	To understand the pre-settlement (Roman) topography of York and its influence on human activity and sedentism
Archaeological question	Can geoarchaeological information collected in grey literature over the last 25 years be used to augment and enhance the understanding of the pre-settlement (Roman) topography of York
Software and modelling process	New geoarchaeological information captured from grey literature transcribed into the City of York Historic Environment Record. Data relating to Roman levels exported to ArcGIS where Spatial Analyst function was used to create a Digital Elevation Model (DEM)
Outputs from the deposit model	A series of images was created to aid visualisation of palaeolandsurfaces

palaeoenvironmental remains, has been recognised since the mid-1950s (Richardson 1959). Deposits of this nature have been excavated and recorded in York from as long ago as the late 19th century, but it was only in the later 20th century, particularly following the creation of York Archaeological Trust in 1972, that their extent, quality and archaeological research potential became fully apparent (Hall *et al* 2014). Over the past 40 years, numerous archaeological investigations in the city have encountered such deposits, notably in the valleys of the Rivers Ouse and Foss but also on higher ground, particularly within the area of the Roman legionary fortress; the latter is enclosed by a largely impermeable stone wall, which although buried beneath the medieval defences and modern streets, survives for much of its circuit to a height of 2-3 metres and more (Ottaway 1993).

16.2. The history of deposit modelling in York

A deposit model was created for the city in order to provide a predictive tool for the management of cultural remains within the broader framework of the sediment archive. The model formed a key element of the York Development and Archaeology Study, which was carried out in 1989 and 1990 by Arup, the University of York and Bernard Thorpe and Partners (Arup 1991). The deposit model allowed consideration of the historic core as a single entity and created opportunities for predicting the presence of deposits ranging from prehistoric to modern date. The deposit model was constructed from a database of over 2000 data points derived primarily from archaeological and antiquarian sources, supplemented by stratigraphic information obtained from engineering boreholes. All information within this 3-dimensional archive was tied to Ordnance Datum (metres AOD). The results of this research were presented as a series of maps within the Arup report.

The deposit model formed the foundations for a subsequent University of York doctoral thesis (Miller 1997). Modelling for this subsequent work was carried out using ESRI GIS software (ArcInfo) to create a series of pseudo-3-dimensional land surfaces of key archaeological periods; each surface was illustrated by a 'wire-frame' mesh which was modelled using the TIN module (within ArcInfo; Miller 1997). Data points for this work were inevitably patchy, and in some areas very sparse, but no attempt was made to refine the model with reference to detailed consideration of other sources of information such as the modern topography or historic map data. In terms of mapping waterlogged (organic-rich) strata, the collected data offered a simple choice between identifying such deposits as being present or absent; this provided no indication of different degrees of organic preservation within discrete waterlogged units, the wider sediment stack or spatially across the city.

Work on the wider landscape of the Vale of York was undertaken as part of the *Archaeological Visibility and Preservation in the Vale of York Project* (Whyman and Howard 2005) and has expanded and refined our understanding of the stratigraphy of Holocene deposits in the City, including those which are waterlogged. The assessment has provided useful insights into the character and surface morphology of the late Pleistocene and early Holocene sediments that underlie the urban archaeological deposits of the 1st and 2nd millennia AD. These glacial and riverine landforms, which include river terraces, palaeochannels, meres and kettle holes appear to correlate strongly with areas of waterlogging and in some cases have been shown to preserve significant organic deposits.

These new observations suggest that the extent of waterlogged deposits and levels of organic preservation in York are closely linked to the pre-settlement landscape template, which includes landforms that act as significant sediment traps and contain deposits that retain moisture. It is essential therefore that the York deposit model, which in its earliest form is now over 25 years old, is expanded and refined in order to understand more fully and precisely the natural landscape template and the character and origin of overlying deposits, including organic remains.

16.3. A revised deposit model for York

To meet these challenges, the City of York Council is developing a comprehensive and holistic set of management tools for the historic environment in the city. These include the: *City of York Historic Environment Strategy* (in draft, City of York Council 2017); *City of York Local Plan* (in preparation; City of York Council 2017); *City of York Heritage Topic Paper Update* (City of York Council 2013); *York Central Historic Core Conservation Area Appraisal* (Baxter 2011); *City of York Historic Environment Characterisation Project* (City of York Council 2013); and an updated deposit model. The evidence base for these management tools, including the deposit model, is provided by the City of York Historic Environment Record (CYCHER).

The CYCHER uses the Historic Buildings, Sites, and Monument Records (HBSMR) software produced by Exegesis Spatial Data Management (https://www.esdm.co.uk/) to hold data pertaining to the historic environment; this appears as event, monument and source records. Deposit model data is held as event, point and source records in a custom-built table (termed *Stratigraphy*). This data table contains all of the fields that were devised during the collection of information for the 1991 Arup report. HBSMR is linked to ArcMap to provide the GIS component of the CYCHER. In theory, this would allow the data to be visualised and analysed within the 3-dimensional modelling components of ArcMap, but this facility is not currently available within City of York Council.

The City of York Council is currently evaluating the content, software, presentation and interactivity of

the CYCHER and as part of this work has prepared a project proposal to update the deposit model data within the CYCHER. In order to evaluate the scale of work required to update the deposit model, the primary author carried out a sample study looking specifically at the geoarchaeological evidence that could be extracted from grey-literature reports on archaeological interventions in the Bishophill area of York. This area, immediately south-west of the River Ouse and within the city walls, is thought to be the site of the Roman civilian settlement (*colonia)*. This case study, which includes the development of a deposit model, is described in the following section with the aim of demonstrating the potential of renewed research into the 3-dimensional stratigraphic archive of the city.

16.4. The Roman *Colonia:* topographic study and deposit modelling

Archaeological data, particularly relating to the Roman period has been added to the CYCHER since 2013 in order to improve knowledge of the Bishophill area and to enhance understanding of the relationship between human activity and the pre-settlement topography. The study commenced with a review of data in the HBSMR and linked GIS that had been collected during the Arup project. This was followed by a stage of inputting data assembled from archaeological grey literature reports, most of which have been compiled since 1990 in response to interventions undertaken as part of the planning process.

In order to construct a new deposit model, each data point was recorded in the HBSMR as a separate event. Boreholes and small trenches within each site were treated as separate 'intervention' events within the overall site event. Some trenches generated multiple deposit model entries, thereby increasing the data density (down to 5m intervals where possible). The original deposit model tended to contain one data point for each site or trench, or where possible used a 10m grid to capture deposit model data points. This generated a limited number of data points and therefore a sparse data distribution that impacted on the final resolution of models. Period-specific 'interpretation' data with height (Z) values AOD were then added to the individual intervention events (Figures 16.1 and 16.2).

In order to produce a visualisation of this new data, the Roman data points were supplied to the geoarchaeology team of Museum of London Archaeology. Virgil Yendell (MoLA) writes: *The 'Roman levels' data (568 records) in the York HBSMR were transferred to ArcGIS 10.1, where the Spatial Analyst module was used to create a Digital Elevation Model (*DEM; Figure 16.3*). A DEM is created on the premise that the height or variable of an unknown point should be predictable by the examination of neighbouring points. The Inverse Distance Weighting (IDW) interpolation tool was used to create a raster DEM. The power of the interpolation was set to 2 in order to reduce the effect of further data points and to preserve landscape features. The distribution of the data that was used to create the model can be described by a K-function (Multi-Distance Spatial Cluster Analysis) but that has not yet been undertaken. There is, however, a general tendency for data points to cluster around sites and to be widely dispersed between the sites. A more detailed review of archaeological GIS modelling methodologies is supplied in Corcoran et al (2011).*

The general Roman DEM (Figure 16.3) shows a concentration of points in the vicinity of the fortress and *colonia*. However, the data for the surrounding area is sparse, resulting in a distorted topography, even the River Ouse valley is poorly defined.

However, the *colonia* part of the DEM, where the additional data has been inputted, shows a much more

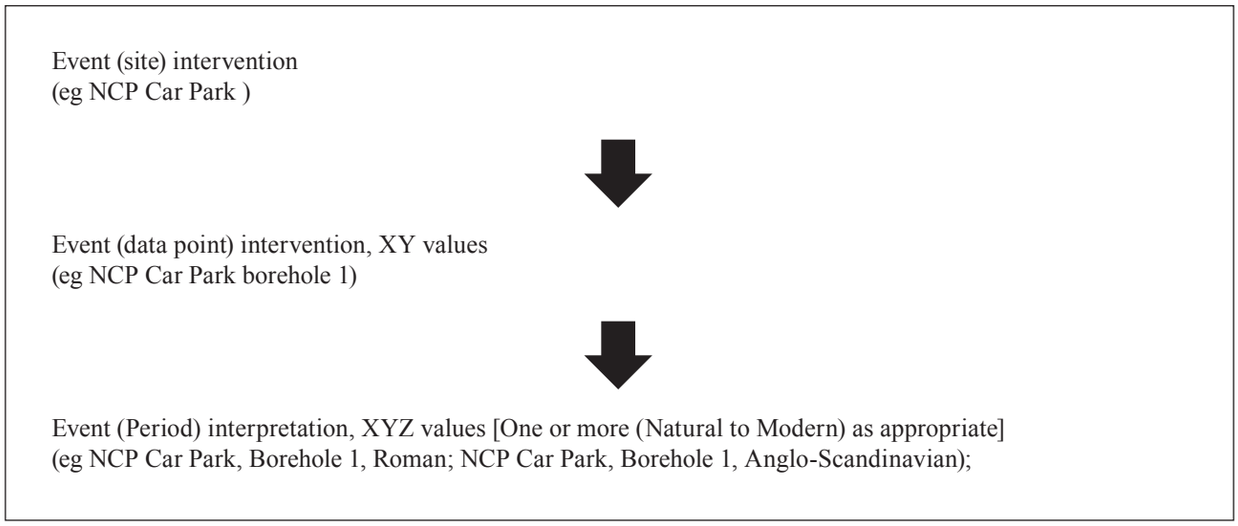


Figure 16.1: Event hierarchy for a deposit model data point in HBSMR

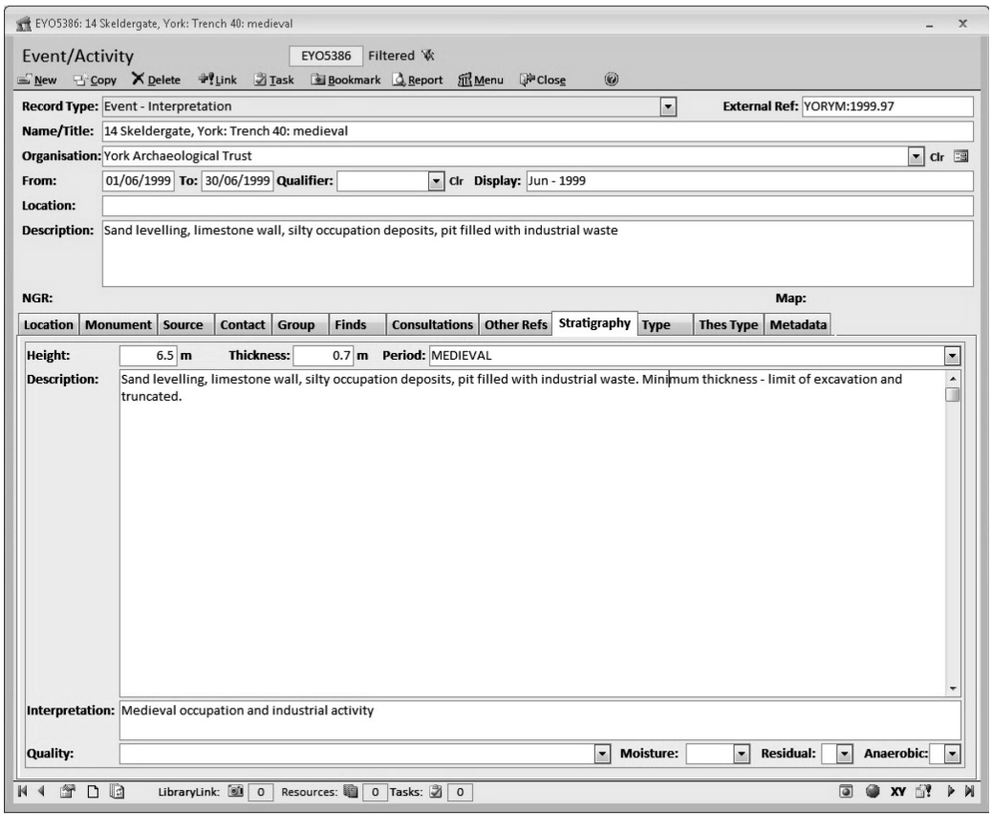


Figure 16.2: Deposit model record in HBSMR

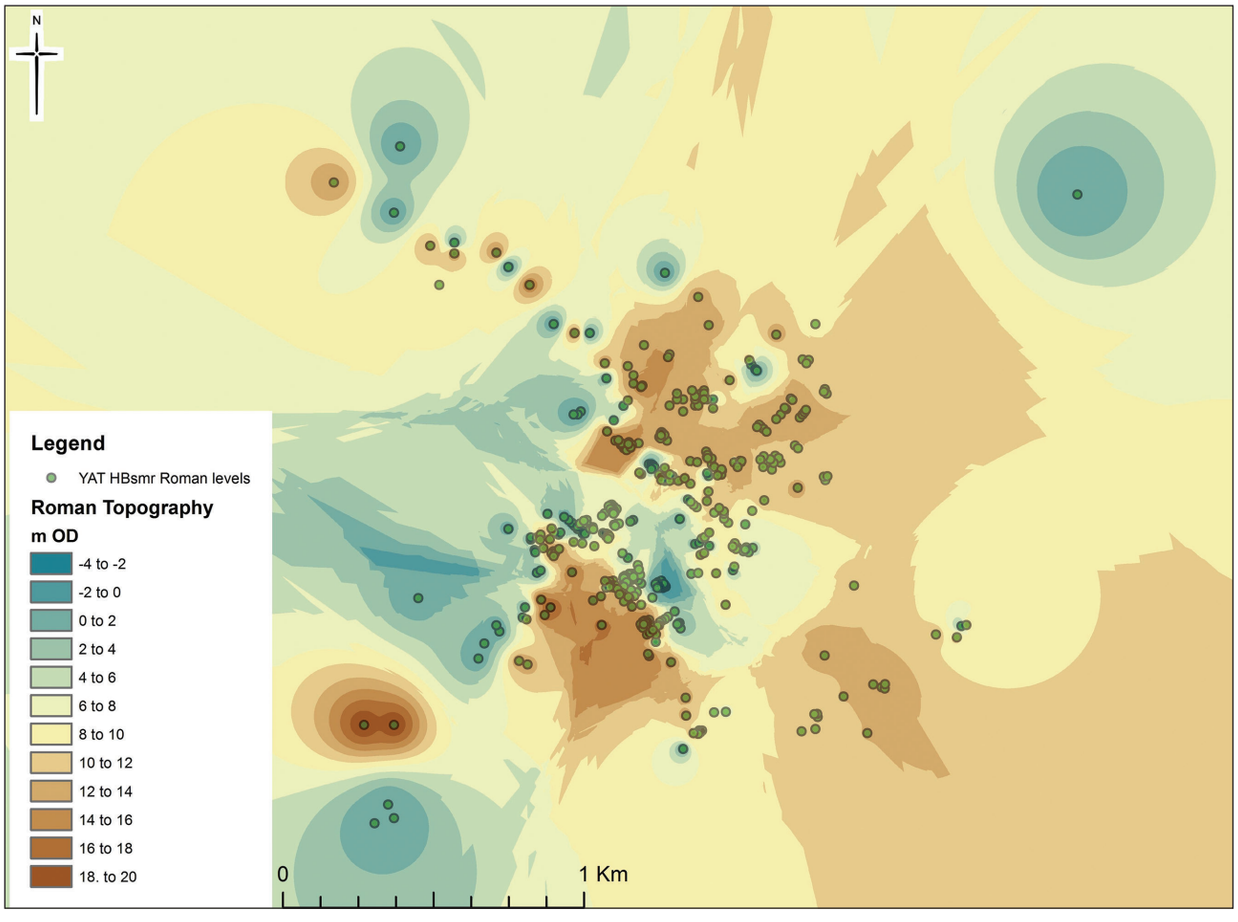


Figure 16.3: DEM of the general Roman palaeolandsurface (working model)

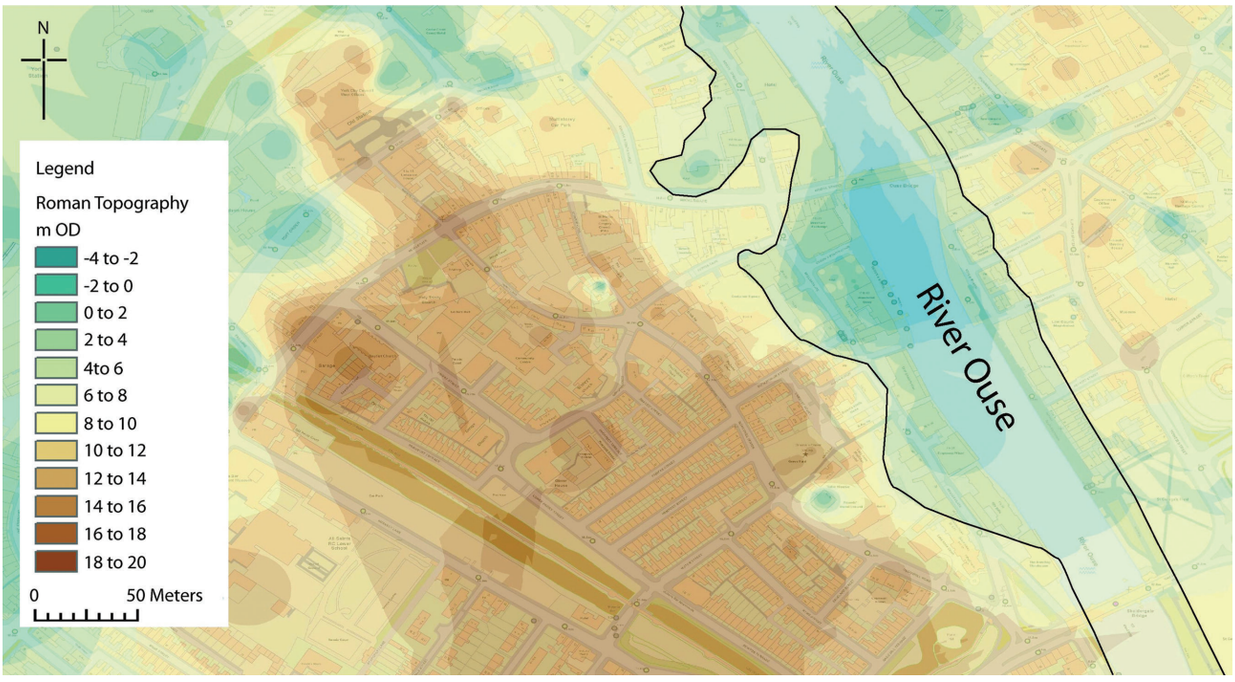


Figure 16.4: DEM of the general Roman palaeolandsurface (working model) Bishophill area, detail

detailed topography (Figure 16.4). It shows a less regular topography than previously thought. The irregular, indented south-west bank of the River Ouse may be due to streams running down from the higher ground. The north-west end of the civilian settlement is generally low-lying, possibly explaining the concentration of early Roman settlement on the higher ground to the south-east. No new data has been added to the north-east of the river during the current study. Such subtleties of the topography, which cannot be observed at the current ground surface, are likely to have influenced the development and character of the Roman settlement as well as the preservation of waterlogged deposits. Identifying areas where cultural and environmental remains are juxtaposed provides real opportunities for reconstructing the archaeological record.

16.5. Challenges for deposit modelling in York

Structure and classification of ArcGIS

Deposits within stratigraphic sequences recorded during archaeological investigations are usually assigned a date that allows them to be considered as part of a discrete archaeological period. Geotechnical records, however, usually have no dating control unless the ground investigations have been commissioned for archaeological purposes (when artefact and/or scientific dating may be applied). Therefore, with the majority of geotechnical site investigations, deposits can easily be assigned incorrectly to cultural periods, especially if deposits are labelled simply as 'made ground'.

The current period structure may allow general conclusions to be drawn from the deposit model including for example, identification of the top of the Roman deposits. However, it does not support more detailed landscape analysis, such as the identification of changes in land-use between the earlier and later Roman periods. The period categories require reviewing therefore if the Holocene development of the river valleys in York is to be evaluated systematically and in detail. The classification of the marginal zone alongside the river also requires consideration in order that the impacts of flooding and tidal processes during the Roman period can be properly assessed.

Quality of fieldwork data

The deposit model for York is based on descriptions and interpretations provided in site reports containing highly variable levels of detail on the character and date of subsurface deposits, thus reducing the value of the dataset for modelling purposes. Firm guidance is required on appropriate levels of recording and analysis, especially during watching briefs (where Ordnance Datum values for subsurface layers are often not recorded), and on the scale of investigation. Borehole data provides a useful basis for deposit modelling, especially if derived from a sampling strategy designed for archaeological purposes, but we would argue that the most reliable evidence for land use and site chronology is provided by excavations of at least 9m^2.

Data distribution

The archaeological data for Roman York is concentrated near the riverside, where most of the recent developments and hence interventions have taken place. There are gaps in the record, often exacerbated by the lack of data underneath existing roads, leaving the possibility of perched organic deposits. Where possible, opportunities should be taken to broaden the distribution of data points as part of site evaluations and ensure the collection of appropriate samples for environmental analysis and dating. Given the small-scale of likely interventions, these will probably take the form of boreholes, but in certain circumstances it might prove necessary to undertake hand excavation to depth.

Data Inputting

The DEM that has been developed as part of this new study is very much a working model and would benefit from further analysis of some data points as well as the addition of more data. For example, several low points, illustrated as blue areas on Figure 16.3 have proved to be artificial interpolations of the data; in the original database zero values had been added to the 'height' cell of some data points where the Roman height value was unknown, whereas they should have been left blank.

16.6. Conclusions

This case study has demonstrated the significant potential of an enhanced deposit model for expediting effective management and curation of the City of York's archaeological and environmental resource. It is also clear that predictive modelling can promote and inform research into York's Holocene deposits, including studies of prehistoric, Roman and later land-use, albeit perhaps on a smaller-scale than is the case in the numerous studies that have been undertaken within urban areas elsewhere, particularly London. It is hoped that it will be possible for future researchers to undertake deposit modelling via the HBSMR, using appropriate software. It is envisaged that the proposed enhancements of the CYCHER and the York deposit model will provide an appropriate and effective framework which can be used to: (a) assist the preservation of deep waterlogged deposits; and (b) deliver significant public benefits by fostering best practice in the recording and analysis of preserved deposits and enhancing understanding of the archaeological and palaeoenvironmental resource.

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17. A planning development management perspective: deposit modelling in south London

Mark Stevenson

Archaeology Advisor, National Planning Group, London (Historic England, 4th Floor, Cannon Bridge House, 25 Dowgate Hill, London, EC4R 2YA)

Abstract

Much of the natural low-lying topography within Greater London, and in particular the Thames floodplain, is invariably obscured by a thick layer of urban archaeology and/or modern made-ground, overlying historic estuarine alluvium; this stratigraphy provides little indication of the prehistoric landscape that lies buried potentially many metres below the current ground surface. In such scenarios, evaluation and where necessary mitigation by geoarchaeological techniques can be of great value. These techniques include the assessment of geotechnical logs; the drilling of purposive geoarchaeological borehole cores; and description and interpretation of sedimentary sequences exposed in deep shafts. On a site by site basis, these approaches can enable a clearer understanding of archaeological potential and, when information is pulled together into deposit models, it can be a powerful

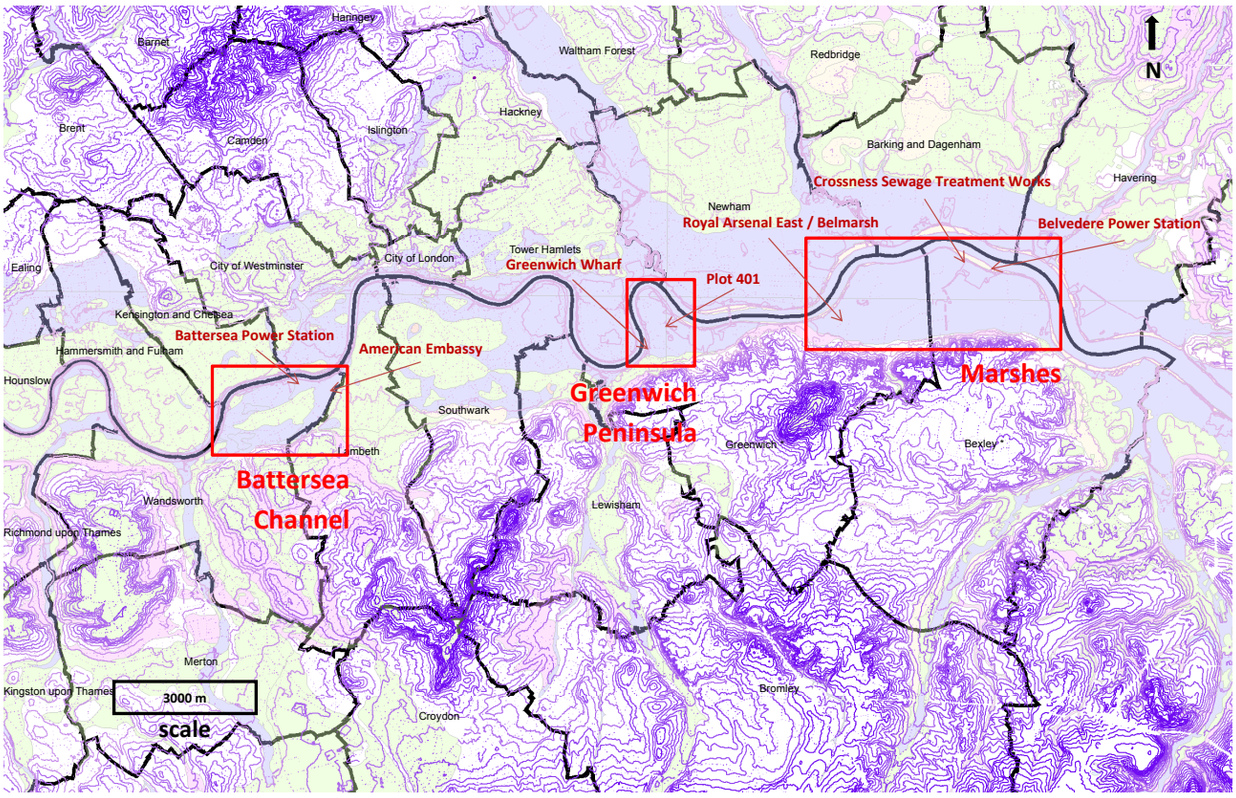


Figure 17.1: The geographic and physiographic context of the three case study areas of south London discussed within the paper, including site specific locations. Information provided by the Greater London Historic Environment Record

tool for understanding the significance of the buried archaeological resource and landscape evolution. Within Greater London, the standard planning conditions can be used with geoarchaeological requirements highlighted when appropriate to ensure such techniques are applied on developer-funded sites. In this paper, I explain why this strategy is justified as one of the standard range of options available to the development control archaeologist in understanding a site's significance and managing its archaeological potential. The staged approach to geoarchaeological investigation and mitigation outlined here has generic application in similar topographic environments beyond London where deeply buried archaeological remains may be recorded.

17.1. Introduction

As an Archaeology Advisor in the London office of the National Planning Group of Historic England, my role is to provide archaeological planning advice to local authorities across nine of the south London boroughs, as well as to developers, consultants, utility companies, national and regional government agencies and local interest groups (https://historicengland.org.uk/services-skills/our-planning-services/greater-london-archaeology-advisory-service/). I am, therefore, able to act when gaps in our understanding of geographic areas or temporal periods become evident, as opportunities arise through development pressure, rather than being confined by client needs to a specific site.

The northern edge of the boroughs that I cover includes a *c* 49 km length of the River Thames and its valley floor. Historically, this area of floodplain has been systematically reclaimed from seasonal flooding by building the land up and extending into the main channel; today, this land is prime 'Real Estate' and in consequence subject to huge redevelopment pressures. Given the complexity of the stratigraphic processes resulting from anthropogenic reclamation and natural patterns of erosion and sedimentation, geoarchaeological advice, including the construction of deposit models, is critical for understanding the archaeological potential of sites within this area. In this paper, I highlight three areas of south London where geoarchaeological techniques have been applied in different ways; each has evolved into an approach of wider generic value (Figure 17.1).

17.2. Case study 1: The Marshes

The extensive floodplain of the lower Thames to the south of the river around Plumstead and Erith Marshes covers some 1,200 ha. Development opportunities immediately across the river to the north, notably in the Lea Valley and its environs in response to regeneration of the 2012 Olympic site, have generated significant volumes of data about landscape evolution and the associated archaeological record. In contrast, I was acutely aware that the southern marshes were by comparison poorly understood. As a result, over a 10–15 year period I have been promoting the combined use of geotechnical and geoarchaeological data on a site by site basis as the means of identifying the potential for cultural evidence. Whilst many of the sites have not yielded significant archaeological evidence, a large body of geoarchaeological data has been amassed which is now sufficient for detailed landscape analysis. A gratifying development in recent years is the growth of independently funded research of this area by Quest at the University of Reading; members of this organisation are currently expanding this body of data with the aim of reconstructing the former landscape and examining its geoarchaeological and palaeoenvironmental potential (R. Batchelor, pers. comm.). Similar work, specifically to reconstruct the buried Early Holocene topography of the Thames and its tributaries in central London, is also being carried out by the Museum of London Archaeology (MOLA) as part of their Crossrail work along the Elizabeth Line (Spurr 2017). The final form and accessibility of these datasets and the models constructed from them, beyond the immediate project teams, is an important issue currently not resolved. While both might be deemed valuable for commercial gain and/or research value, they have considerable potential for wider heritage management; as an aspect of the site archive, the information should be accessible as a layer on the Historic Environment Record (HER), or in some other GIS-based format. While the transfer of such information as point data will enable it to be a live and expanding resource, the planning development archaeologist would prefer an annotated map to inform their planning-related recommendations. A decision may therefore be required of HER managers in terms of whether HERs hold either point data or interpretative maps, although planning archaeologists are more likely to require a combination of the two.

Due to the depth of made-ground, particularly on sites close to the river, investigation of the potential for archaeology by trenching has often proved to be problematic. Pre-Construct Archaeology Ltd investigated two adjacent sites close to the Thames, using different methods in response to the needs of the developer. At Belvedere Power Station, investigation of the subsurface was achieved by the excavation of nine *c* 10m-deep shafts (Mayo 2007a). Three-quarters of each shaft area was machined in spits, while the fourth quarter was dug by hand. This confined work required significant safety issues to be addressed by the use of a personnel cage on a crane; archaeologists were attached to the cage by harness so that in an emergency they could be pulled up quickly as the cage was raised (Figure 17.2). The same depths of sediment needed to be investigated at the neighbouring site of Crossness Sewage Treatment Works (Mayo, 2007b), but at that site an open-cast approach to exposing sediments was adopted (Figure 17.3); this negated the