



Figure 17.2: A combination of long-reach machine and hand excavation within a shaft to the base of the peat, Belvedere Power Station site, Bexley (October 2007). Photo courtesy of Historic England



Figure 17.3: Machine 'open-cast' excavation of peat deposits, Crossness Sewage Treatment Works, Bexley (September 2007). Photo courtesy of Historic England

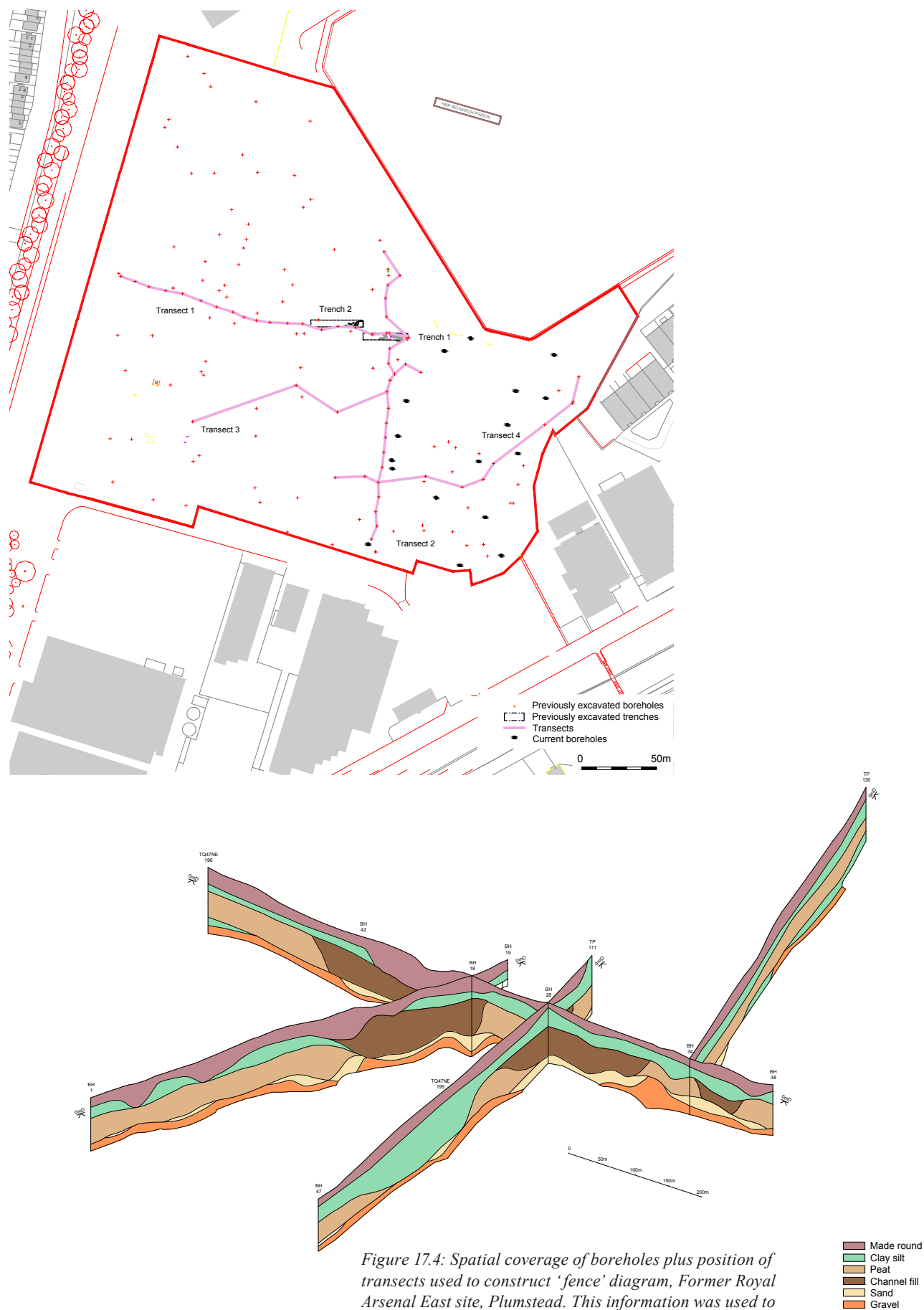




Figure 17.5: A view of the two archaeological mitigation staggered trenches, Former Royal Arsenal East/Belmarsh West site, Thamesmead (September 2008).
Photo courtesy of Historic England



Figure 17.6: A view of the hand-excavated peat at the east end of the eastern trench, Former Royal Arsenal East/Belmarsh West site, Thamesmead. The plate shows the baulk left along the side of the trench to provide a continuous 65m record of the detailed changes identified within the peat sequence (September 2008).
Photo courtesy of Historic England

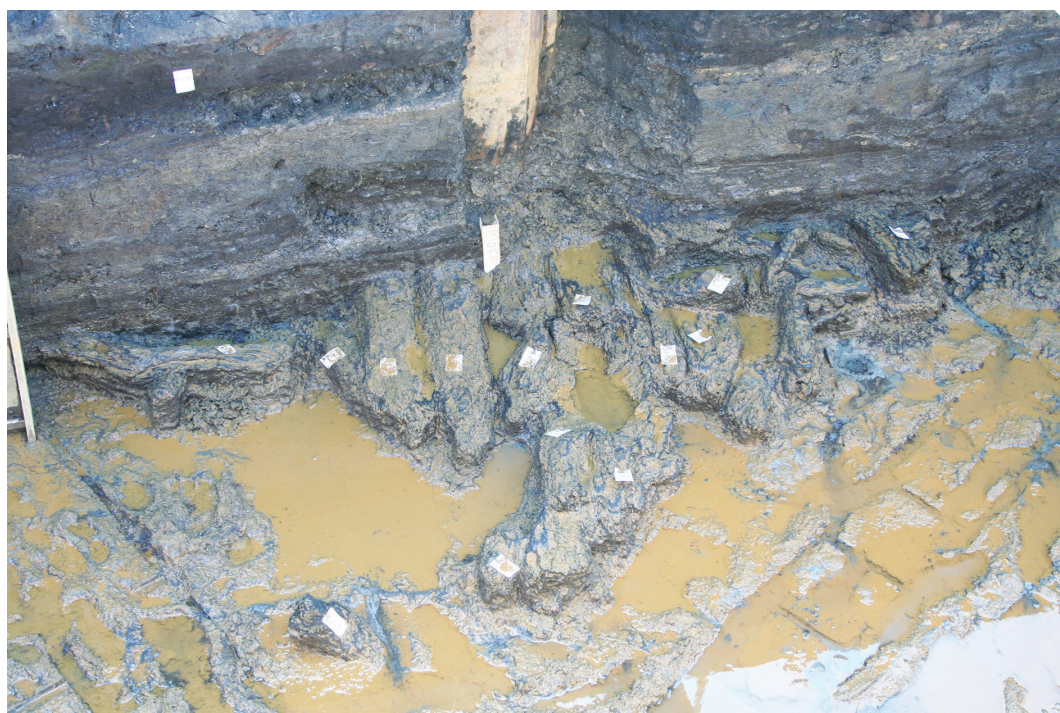


Figure 17.7:
Neolithic wood
remains identified
close to the base of
the peat horizon,
Former Royal
Arsenal East/
Belmarsh West site,
Thamesmead. The
remains consisted
of split timbers laid
in pairs.
Photo courtesy of
Historic England

need for the previous health and safety measures, as well as ensuring that any gas emitted by the exposed organic-rich sediments would quickly dissipate. Interestingly, the cost of the two approaches was broadly comparable, but the open-cast approach proved more efficient as time was not required for the insertion of sheet piles before the commencement of each shaft excavation. Although the open-cast approach was good for recording sediments, as relatively large exposures of *in situ* deposits could be seen in section, it is a comparatively crude method for the retrieval of artefacts. It also required sufficient space for excavation and for storage of the large volume of spoil that was generated.

Geoarchaeological investigations were also conducted towards the western edge of Plumstead Marsh on the site of Royal Arsenal East: a cluster of sixty-six 20th century buildings next to Belmarsh Prison that was scheduled for development as a juvenile detention centre (Fasham 2008). Following full building recording and demolition, the geotechnical data was reviewed; geoarchaeological boreholes were drilled to sample significant gaps in the spread of geotechnical boreholes and to investigate areas of interest or anomalies that were identified in the geotechnical record (Krawiec and Bates 2013). The resultant deposit model identified where site-wide transects would be desirable (Figure 17.4). In total, two transects consisting of 41 geoarchaeological boreholes spaced at 10m intervals were drilled. The cumulative result of this work was the identification of three locations where trenching was perceived to have a high potential for *in situ* archaeology. Following discussions with the contractors and their client, two 4m-wide trenches were excavated in areas that were deemed to have the highest

potential for the preservation of archaeological remains. These staggered trenches extended for 30m and 35m, and were set at right-angles to the edge of an identified palaeochannel. The cost and time involved in excavating these deep trenches, which sampled less than 0.5% of the site, meant that this was to be the only mitigation approach that would be applied to this site prior to development (Figure 17.5). However, this detailed work did permit the identification of *in situ* Bronze Age and Neolithic remains, enhancing thereby our understanding of the site and the potential for neighbouring sites (Figures 17.6 and 17.7; Hart *et al* 2015). The identified archaeology led to a revision of the foundation design to permit preservation *in situ* of the archaeology within the site. Such positive results would not have been achieved by random shallow trenching, but they were made possible by a staged programme of boreholes, geoarchaeological assessment and modelling.

17.3. Case study 2: Greenwich Peninsula

This c 80ha peninsula in the Royal Borough of Greenwich was the subject of a Masterplan developed in 2004 by Meridian Delta Ltd; in response to this document, Historic England (then English Heritage) submitted an archaeological brief to address the potential of the site. As part of the Masterplan application documentation, MOLA (Corcoran 2002) had prepared a detailed deposit model of the peninsula using the records of hundreds of geotechnical boreholes and information from previous archaeological investigations (Figure 17.8). This approach worked up to a point, but it did not permit the deposit model to be maintained as a live and evolving database.

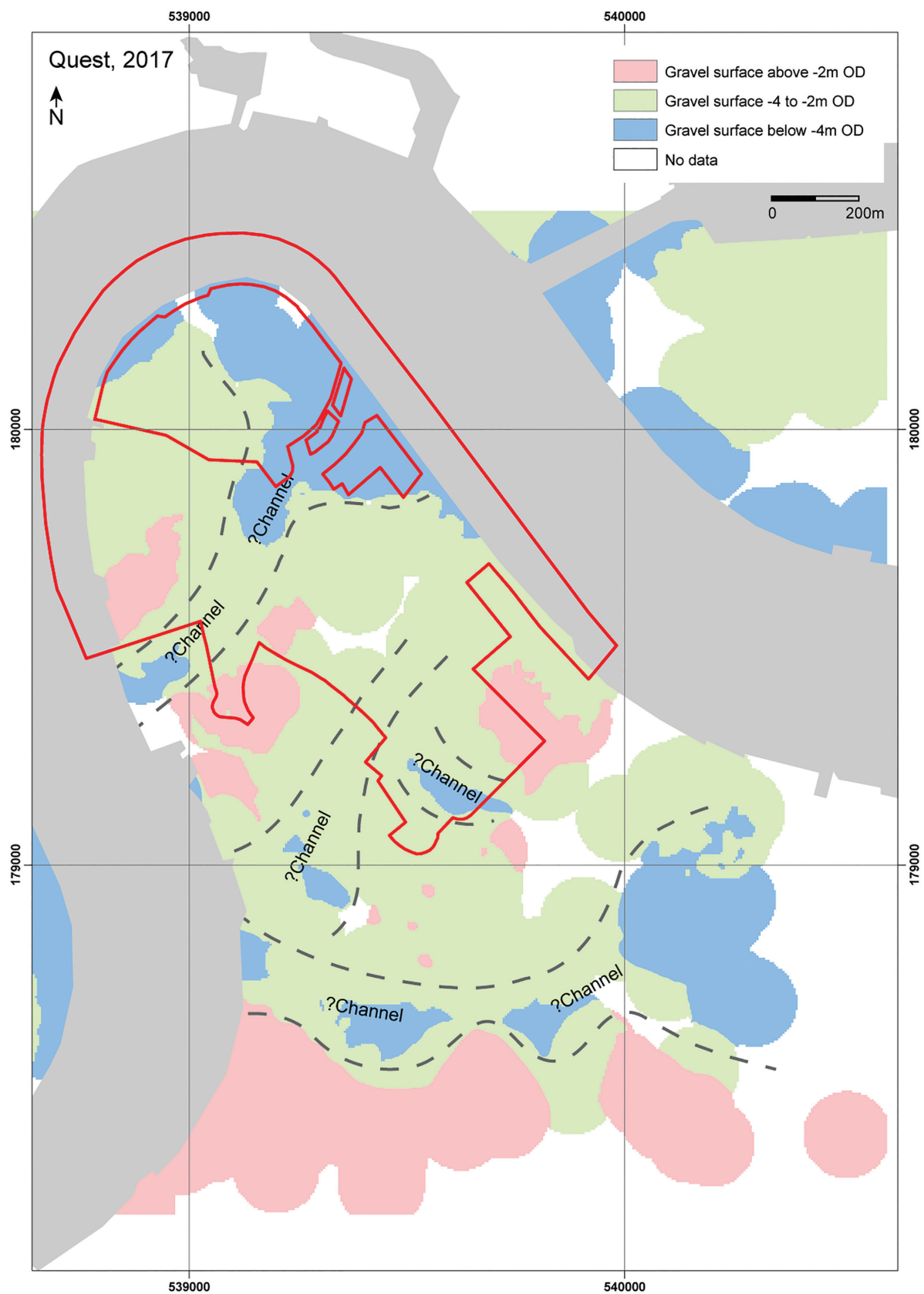


Figure 17.8: Outline in red of the Greenwich Peninsula Masterplan area superimposed with the 2017 version of the Quest deposit model (© Quest). The model shows the buried ancient landscape with suggested channels dissecting the area. The model was generated by using 100m radius of interpolation around each borehole record, rather than a standard 50m radius routinely used by Quest. This decision with respect to interpolation was taken to better visualise the broad topographic features, though a 50m interpolation will be used to evaluate additional data

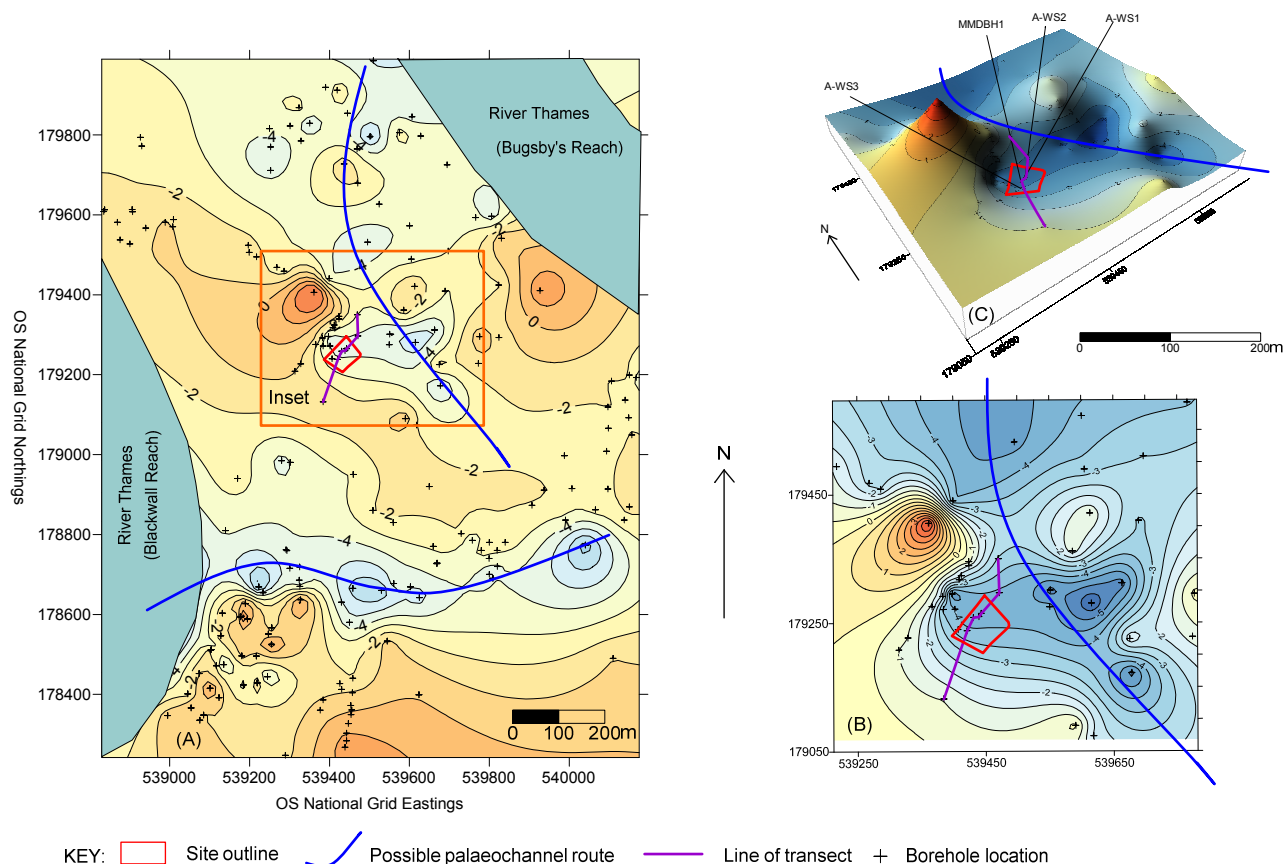


Figure 17.9: Deposit model of Plot 401, Greenwich Peninsula, placed within its immediate area, an amalgam of geoarchaeological and geotechnical data (© MOLA)

Furthermore, the archaeological brief set a trigger level of 5% of a site's footprint that needed to be impacted by piling before archaeological intervention was required. Investigation of potentially deeply buried gravel highs was therefore unlikely. This was frustrating, as the modelling suggested 'islands' of higher gravel beneath the floodplain alluvium that might have served as potential foci of past human activity. Plot 401 (Figure 17.9) is a case in point; here, deposit modelling provided clear evidence of the area's potential, although the options available for further investigation were limited (Spurr 2016).

The peninsula Masterplan was updated in 2015 when the majority of the area remained undeveloped. This provided an opportunity to reappraise the geoarchaeological approach and to revise continually the deposit model strategy, enabling archaeological trench evaluation of identified key locations. An archaeological brief was produced by Historic England (Stevenson and Warman 2016). It was imperative that the developer's archaeological consultant was fully engaged during the process of the briefs' production. As a first stage of the new brief, the MOLA model of 2002 was to be updated by Quest with geotechnical and geoarchaeological information obtained through the investigation of a number of development sites on the peninsula as part of a

wider model (Green *et al* in prep). This site-wide deposit model, using 797 borehole records in conjunction with information from the Greater London HER, would enable a preliminary assessment of the archaeological potential of each of the individual development 'plots' that had been identified across the peninsula. As a result, some would be flagged for further geoarchaeological investigation, while others would be excluded on the basis of having sufficient data to determine no discernible on-going potential. This assessment would occur before plot specific development applications were submitted for determination by the Royal Greenwich Borough Planning Authority. Given the outline nature of proposed developments and underlying geology, it is expected that the main archaeological impact would be/will be from piling but could also include the excavation of basements and/or attenuation tanks.

In essence, this strategic approach is more responsive to the archaeological potential of the peninsula, as it is underpinned by a staged strategy that is locked into the planning process. This was achieved when the applicant's consultant submitted to the Royal Greenwich Borough Planning Authority, as part of a planning response, their Masterplan-wide Method Statement that referenced the Historic England Brief (Blatherwick and Batchelor 2017). Following initial assessment, subsequent work might

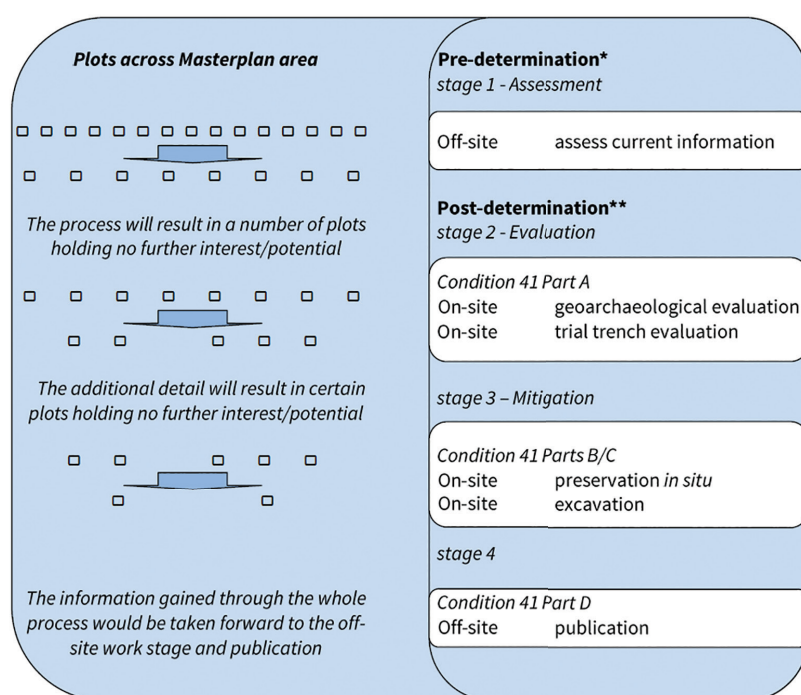


Chart 1: Indicative representation of the process by which the archaeological consideration of the plots can be concluded

Chart 2: Illustration of the sequence of actions to satisfy the archaeological interest.

Figure 17.10: The planning chart from the Historic England Greenwich Peninsula Brief that maps the staged archaeological approach designed to lead to the early identification of the key geo/archaeologically important development plots as well as those plots that hold no further geo/archaeological interest. Such information is critical for developers

include purposive geoarchaeological borehole surveys to provide additional information to fill gaps in spatial data coverage and/or to investigate areas of interest identified from existing geotechnical records. This new data would be fed back into the site-wide deposit model (held and managed by the Masterplan archaeological consultant), and would therefore facilitate an update of the bigger picture; it would also identify any archaeological or environmental potential, which could then be considered for targeted archaeological evaluation. Given the potential depth of made ground, this stage of further work would need to be tightly focused and could represent the sole mitigation response for a specific development plot. It is anticipated that only a small number of the original suite of development plots would require limited area excavation. In such cases, the proposed work would be considered in the context of the whole 80 ha site rather than the size of the specific plot under investigation, enabling economically sustainable mitigation (Figure 17.10).

17.4. Case study 3: Battersea Channel

The area of Battersea/Nine Elms, which lies mainly within the London Borough of Wandsworth, consists of prime riverside land that had been dominated by industrial activity typified by the former Battersea Power Station, (Figure 17.11; Figure 17.12). In 2012, it was defined as one of the Mayor of London's (growth) Opportunity Areas, with the aim of building 20,000 new homes and creating 25,000 jobs (Mayor of London 2012). Permission to build the new United States Embassy within this area provided the catalyst for funding of the Northern Line extension,

which will serve the planned residential developments via new stations at Nine Elms and Battersea Power Station. The sale in a single weekend of the apartments in the Phase 1 Battersea Power Station development prompted a gold-rush of investors, which in turn, accelerated opportunities for redevelopment. This area of intense redevelopment included the buried eastern end of the relict Battersea Channel: a former route of the Thames with significant archaeological and environmental potential that was first studied (and named) as recently as 2006 during the course of a relatively small-scale development on Stewarts Road (Morley 2009).

The frenetic pace of redevelopment in this area provided an opportunity for joined-up thinking by linking the numerous development sites, within a project where the archaeological practices would be invited to collaborate (Figure 17.13). This initiative, termed the Battersea Channel Project (BCP), provided a viable framework for individual interventions to be considered as part of the greater whole by pooling of site data into the BCP post-excavation programme. The Project was facilitated by Historic England (then English Heritage). Two preceding chapters within this volume (Chapter 7, Payne *et al*; Chapter 11, Yendell) illustrate the approaches undertaken at discrete sites within the BCP area. It is not my intention to duplicate this information here; rather, I wish to provide an overview of how I shaped the process from a planning perspective by developing a Brief for the BCP area that defined a three year data collection phase (2015-17), followed by a year to prepare the outcomes (Stevenson 2014). The two archaeological practices and one consultancy that were already working within the area

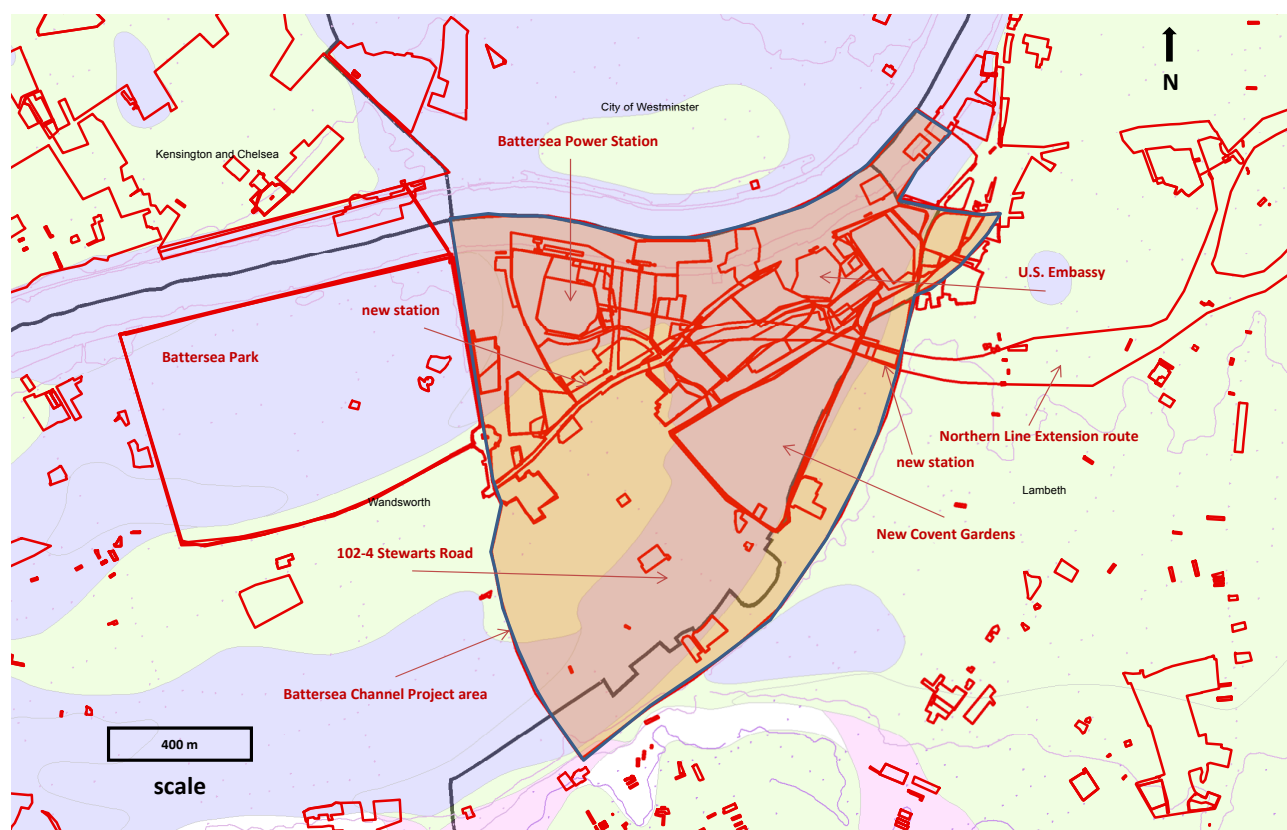


Figure 17.11: Battersea Channel Project (BCP) area shaded salmon pink with some of the key adjacent development sites identified from the Greater London Historic Environment Record



Figure 17.12: Aerial view looking eastwards of the Battersea Channel Project area (October 2009). The area extends eastwards from the edge of Battersea Park to beyond the distant low square building of the Flower Market, part of the New Covent Garden site. From south of the River Thames and its foreshore, it extends to a line along the Wandsworth Road. Photo courtesy of Historic England



Figure 17.13: Illustration of the frenetic pace of development activity within the BCP area at the US Embassy site, Nine Elms (September 2013). Despite the speed of development, the BCP demonstrated that archaeological site work can be undertaken successfully within such environments if part of a well coordinated and robust strategic framework. Photo courtesy of Historic England



Figure 17.14: Forum meeting, Battersea Channel Project (August 2015). Photo courtesy of Historic England

were invited to respond with a joint Method Statement (Batchelor *et al* 2014). Two documents were submitted to Lambeth and Wandsworth borough planning authorities for their support. A Project Board meeting comprising the two planning authorities and Historic England was held prior to the commencement of the project. A Forum was established that consisted of the three archaeological organisations that drafted the joint Methods Statement and more than ten other organisations that have subsequently undertaken work within the project area (Figure 17.14). The Forum chaired by Historic England meets once or twice a year for roundtable discussions, depending upon the rate of accumulation of new data. Collaboration is such that primary data is exchanged before it is presented in ‘grey literature’ reports to fulfill planning requirements. The final outputs of the BCP will comprise a series of technical papers and a popular-style publication. The Forum is also exploring the legacy potential for a live database to be hosted by the Greater London Historic Environment Record.

A value-added outcome to the partnership working is that the depth of assessment contained within geoarchaeology site reports has increased, along with the development of ways to represent more effectively the data. It has also fostered a ‘mentoring’ approach by the highly experienced geoarchaeology teams of those companies that are in the process of developing or enhancing their geoarchaeology capability.

17.5. Enhancing planning conditions

The wording of standard planning conditions in Greater London, when expanded, divides into paired statements, the first requiring a written scheme of investigation (WSI) for site work and its execution, and the second a mitigation stage if required. In areas where geoarchaeological data can be expected to form a significant element of site work, the standard planning condition can be enhanced to ensure that the environmental potential of a site is appropriately addressed. This can be achieved by modifying the condition wording to read ‘geo/archaeology’ (Figure 17.15). This approach helped significantly with the monitoring of development sites in the Plumstead and Erith Marshes, while the Greenwich Peninsula 2015 Masterplan provided an effective mechanism for ensuring consideration of a wider area within the context of a single planning application. A standard multi-part archaeological condition was applied, and supplemented by a detailed brief that articulated how the many development plots would be considered as part of the wider area. This brief produced by Historic England, a third-party, would only gain planning status once the site-wide specification (Blatherwick and Batchelor 2017) that referenced the brief had been submitted by the applicant as a document for the first plot-specific detailed planning application. The brief for the Battersea Channel Project included the wording for a multi-part condition that was modified to

contain a specific reference to it; this ensured that all developments within this area had to abide by the Brief and its sister Method Statement and to apply the range of geoarchaeological techniques that these documents required.

17.6. Conclusions

The three approaches described in these case studies show how it is possible to use geoarchaeological techniques as part of a tool-kit approach to understanding past landscapes and their archaeological potential. The risks of development in deeply stratified areas where there is the potential for significant, well-preserved archaeology to be buried at depth can be minimized if development stages include the application of geoarchaeological techniques, which can be seen as a developer’s friend. Geoarchaeology has the ability to assess a site without the need to excavate big, expensive holes; it permits a targeted mitigation strategy to be devised that can be demonstrated to be reasonable, proportionate and appropriate, being based upon demonstrable empirical evidence.

On sites without known, tangible archaeological remains, and in particular where the deposits of archaeological interest are deeply buried and likely to be impacted only by piled foundations, it can be difficult to convince developers and consultants that assessment and evaluation of buried deposits is warranted. The geoarchaeological approach, which will provide new information and enhance our understanding of prehistoric landscapes, can often only be taken forward if justification is provided by appropriate planning controls. In addition to geoarchaeological enhancement of planning conditions, it is recommended that the steps listed below be considered in any brief provided by the planning development archaeologist. This should ensure that geoarchaeological assessments and evaluation are included at the most appropriate stages of a project to inform the archaeological investigation of sites to be impacted by development. It should be emphasised that early consideration of the archaeological potential of sites that may form the subject of planning applications is crucial, as stated in the National Planning Policy Framework (Section 12) and the London Plan (2011 Policy 7.8).

Pre-determination of a planning application

Assessment:

- Assess results of historic geotechnical investigations (including data from adjacent sites), with the aim of producing a draft deposit model at the desk-based stage.

Investigation:

- If not undertaken in parallel with geotechnical survey, which would be ideal, geoarchaeological borehole and /or test pit surveys should be conducted

Reason	Heritage assets of archaeological interest may survive on the site. The planning authority wishes to secure the provision of appropriate archaeological investigation, including the publication of results, in accordance with Section 12 of the NPPF.
Condition	A) No development other than demolition to existing ground level shall take place until the applicant (or their heirs and successors in title) has secured the implementation of a programme of geo/archaeological <i>evaluation</i> site work in accordance with a Written Scheme of Investigation which has been submitted by the applicant and approved by the local planning authority. B) Implementation of a programme of geo/archaeological evaluation site work in accordance with C) A report of the evaluation results will be submitted for approval by the local planning authority which will be given in writing. D) Dependent upon the results secure the implementation of a programme of geo/archaeological mitigation site work E) A programme of archaeological site work in accordance with the Written Scheme of Investigation. F) The site investigation and post-investigation assessment will be completed prior to one year post the completion date of the development as defined by the borough building regulation officer, in accordance with the programme set out in the Written Scheme of Investigation approved under Parts A and D, and the provision for post investigation assessment, analysis, publication via the Battersea Channel Project report and dissemination of the non-Battersea Channel Project archaeological results and archive deposition has been secured.
Informative	1 Written schemes of investigation will need to be prepared and implemented by a suitably qualified archaeological practice in accordance with Historic England Greater London Archaeology guidelines. 2 The Battersea Channel Project is defined by the Historic England over-arching brief supported 10 June 2014 by Wandsworth and Lambeth Local Planning Authorities. 3 Only Section F of the archaeology condition will remain after the completion of the geo/archaeological site work stages.

Figure 17.15: Multi-part condition with the inclusion of a reference to geo/archaeological programme of work

with the aim of enhancing the available geotechnical site data. This should be accompanied by sampling of significant environmental deposits, examination and assessment of inclusions and collection of appropriate samples for dating, followed by refinement of the deposit model; specific cores identified through assessment would only be taken to full analysis if the subsequent stages of site work show this to be appropriate.

- If necessary, further targeted geoarchaeological site investigations (eg borehole and test pit transects across palaeochannels), sample collection and assessment should be conducted, followed by refinement of the deposit model.
- If the potential for nationally or regionally important archaeological remains has been demonstrated, the site may also require further intrusive investigations.

Post-determination of a planning application with the geo/archaeological interest secured by condition

- If impact is only to be from piling: trench to mitigate for cumulative impact.
- If impact from basement, landscaping and/or other spatially extensive construction activities (eg laying of foundations or attenuation tanks): mitigation by strip, map and record of identified key areas.

The potential effect of decontamination and dewatering will need to be considered during all stages of work. This can have an impact upon the decisions to be taken, as well as affecting adversely the potential of archaeological contexts.

For the past 15 to 20 years, the Greater London Archaeology Advisory Service (GLAAS) planning development archaeology advisors have become increasingly aware of the value of geoarchaeological techniques and especially deposit modelling. We have developed and refined our approaches to planning control to make it a requirement that the approach is correct and considered early in the planning process to permit information to be extracted and interpreted from deeply buried deposits. This evolving approach to the potential offered by geoarchaeology has added significantly to our understanding of the prehistoric landscapes that might otherwise be deemed inaccessible and beyond the remit of archaeological investigation. As archaeological planning development advisors, with support from geoarchaeologists, we are in a key position to identify sites or areas with geoarchaeological potential that can contribute significantly to understanding of the development of past landscapes and societies. However, this work is only of value if it is captured by relevant HERs. More work is needed by the contracting sector, in collaboration with HERs and Historic England, to define the level of geoarchaeological information that should or could be recorded in HERs. This will help to define the resources that will be required by HERs to capture and manipulate this specialist information and thus maximize its potential for developing an understanding of the changing landscape and our consultation response to the next planning development application.

Acknowledgements

I am grateful to the following for their contribution to this paper: Dr C.R. Batchelor, Director, Quest; Dr M Bates, University of Wales, Trinity Saint David; Mr S Cakebread, Greater London HER Manager, Historic England; Mr C Mayo, Project Manager, Pre-Construct Archaeology Ltd; Mr G Spurr, Head of Geoarchaeology, MOLA; Mr J Sygrave, Project Manager, Archaeology South-East; and Dr S Warman, Science Advisor, London, Historic England.

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SECTION 9

Deposit modelling: towards a unified approach

18. Deposit modelling: application, value, integration and archiving

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18.1. Introduction

The case studies described in this volume illustrate a variety of methodological approaches to deposit modelling that have been developed to increase our understanding of natural deposit sequences that are likely to contain cultural and environmental archaeological remains and associated evidence.

These contributions were presented initially as oral and poster papers at a project workshop held in London in June 2016. As well as the delivered papers, the event also included four break-out sessions aimed at facilitating further discussion of key generic themes that impact on deposit modelling best practice, namely: (1) *the value of deposit models and data integration*; (2) *skills and capacity*; (3) *minimum standards and outputs and*; (4) *archives and long-term data-management*.

The 50 or so invited delegates listed in Chapter 19 of this volume were divided into four rotating groups for the break-out sessions, which allowed each group to consider every theme. Discussions were guided by a group facilitator (one of the project convenors) and group recorders captured key comments relating to each; these collected insights provide the basis for this chapter, which aims to highlight common issues and challenges associated with deposit modelling.

Whilst it might be argued that this pre-invited group, composed largely of practicing geoarchaeologists or those with interests and experience of the subject matter, provides a biased outlook, the majority of those invited work within larger heritage organisations and in collaboration with colleagues who have diverse skill-sets and backgrounds, and undertake a wide variety of

projects. Therefore, it is considered that these discussions have balance and do reflect opinions shared more widely within the profession.

18.2. Break-out Theme 1: the value of deposit models and data integration

A key question the workshop sought to address was whether deposit models were seen as valuable tools by the wider archaeological community and how they are being applied within the planning and mitigation process. Discussions within all four break-out groups suggest that the application of deposit models is extremely variable across the country, with the majority of studies undertaken in south-east England.

Two major factors almost certainly explain this clustering of activity. The first is the concentration of large archaeological organisations in the region with well-established in-house geoarchaeology teams (many of whom have contributed papers to this volume); this integration of personnel ensures a generally higher profile for such methodologies within these organisations and an appreciation of their value as a mainstream tool-kit available to project managers early on in the planning and design phases of projects. Elsewhere in the country, application of deposit modelling appears to be clustered where experienced local practitioners are available to advise on such approaches to archaeological prospection. The second factor, as illustrated by a number of the case studies presented in this volume, is that the south-east has been the focus of intense economic development during the last decade; this in turn, has resulted in

the commissioning of numerous, often large-scale infrastructure projects that require innovative thinking with regard to archaeological prospection, risk analysis and best use of financial and human resources. Given this spatial bias, a key challenge for the heritage community is how to rebalance activity so that deposit modelling becomes standard mitigation practice beyond the south-east.

Emerging national infrastructure projects and other major commercial projects in the Midlands and northern England provide opportunities to apply deposit modelling tool-kits more widely. However, given the nature of competitive tendering, it is essential that if deposit modelling is considered an appropriate tool for any project, then its use must be clearly specified in the tendering process; otherwise, it may be perceived as an additional cost that will make any bid uncompetitive.

Providing curators and other historic environment managers with guidance to promote deposit modelling is critical, though this must be multi-layered to meet the needs of different end-user communities. At a national level, there needs to be the development of generic guidance, which informs heritage practitioners, managers and curators about the subject of deposit modelling and best practice; this in part, will be addressed by the publication of this volume and associated products under the auspices of Historic England. Sitting below national guidance, Regional Research Frameworks commissioned by Historic England could be expanded and/or revised to include more geoarchaeological information which, in turn, could promote deposit modelling and disseminate best practice within discrete areas. This latter initiative could certainly benefit the wider archaeological community since workshop contributors intimated that deposit models were often viewed as applicable only in alluvial landscapes, failing to recognize their potential to guide mitigation within other geological settings where thick sedimentary sequences might also be preserved: for example, aeolian, colluvial and urban contexts. Guidance should also ensure that the wider archaeological community recognizes the potential of using deposit models to inform landscape histories even where cultural remains are absent.

Clear guidance would have the added benefit of identifying at what stage of mitigation deposit modelling should be used; feedback from break-out groups suggested that it was generally introduced much too late in the archaeological process, either as a condition of planning or when the Written Scheme of Investigation (WSI) was being drafted. At both these stages it was considered much harder to produce realistically costed research designs or to influence evaluation/excavation strategies more generally. Appropriate guidance would allow curatorial archaeologists liaising with developers the opportunity to advise on modelling methodologies (including data collation) early on during the project process. This approach could include preliminary modelling during any

Desk-based Assessment (DBA) stage; significant sources of geoarchaeological information that could be mined include the field guides of the Quaternary Research Association (www.qra.org.uk), geotechnical records held by the National Geosciences Data Centre (<http://www.bgs.ac.uk/services/NGDC/home.html>) and developers. However, feedback from break-out groups indicated that it was essential that such tasks are undertaken by appropriately qualified personnel since leaving data collection and interpretation to staff with little or no training in geoarchaeology would invariably produce sub-standard results.

As well as the need for guidance to promote and integrate deposit modelling into the entire archaeological process and to ensure standards are adhered to, it is clear that the community of geoarchaeologists who are usually responsible for creating the models have a significant role to play in ensuring the value of such methodologies is appreciated. This issue is both an internal one to organisations (ie to convince other project managers) as well as an external one (ie to convince clients, their consultants and curatorial officers). With both these internal and external groups, the selling point of a deposit model is that it will save time, money and ultimately reduce risk of encountering unknown remains. For archaeological organisations, this is attractive since it makes tenders more cost-effective and hence competitive; for clients and consultants, reduction of risk of encountering archaeology is the key factor.

It is demonstrable by the success of the large archaeological companies who have led the way in deposit modelling in the south-east, that the methodologies are most successfully applied when geoarchaeologists are embedded within project teams. This provides the opportunity for deposit modelling to be reported as an integral component of a site narrative; presenting the results of deposit modelling as a specialist appendix at the end of a larger report should be discouraged and ideally, it should set the scene for the entire study. Ultimately, to persuade colleagues, clients and consultants to accept deposit modelling as a way forward, the community itself must use jargon-free terminology and language that can be understood by all, not a self-selecting group.

18.3. Break-out Theme 2: skills and capacity

Whilst it is desirable that the archaeological sector is able to construct deposit models, the second break-out theme considered whether staff with appropriate skills-sets were available to undertake such work and what was the nature of capacity. Each of the four groups who discussed this theme flagged the need for geoarchaeological skills. This was viewed as not just an understanding of sediment characteristics and their meaning, in order to make sense of the information available from borehole logs and other geotechnical records, but rather, the archaeological understanding and

perspective encapsulated in geoarchaeology (as opposed to practitioners trained in other earth science disciplines). Given the general shortage of geoarchaeologists, the break-out discussions suggested that a greater understanding of soils and sediments and of geoarchaeological techniques, on the part of more traditionally-trained archaeologists, should be encouraged. This might help to identify candidates for training in deposit modelling, as well as encourage a greater take-up of deposit modelling in general, owing to a wider awareness of its value amongst archaeologists.

Project and site managers regularly look at geotechnical borehole and test pit information to gain a quick approximation of made ground depths across a site. It enables calculations of the likely depth and distribution of evaluation trenches and the resources needed to excavate them. This basic appraisal, supported by a quick sketch to help visualise lateral differences in thickness, is essentially a deposit model – and it involves doing what any archaeologist would naturally do to obtain some understanding of what lies below the ground. Therefore, a conundrum has been identified; on the one hand, an argument is being made that only geoarchaeologists or those with a good level of training can construct deposit models, yet on the other hand, recognising that many archaeologists construct deposit models, albeit in a rather more sub-conscious way. If this conundrum is to be resolved, there is a need to define precisely what extra geoarchaeological skills and knowledge a deposit modeller should have and whether an ‘end user’ seeking to apply any model to archaeological questions also needs an in-depth understanding of geoarchaeology and the modelling process.

A significant hurdle to advancing knowledge and training is that geoarchaeology is not a standard component of archaeology degrees in the UK – despite all artefacts and features being integrally linked to the soils and sediments that make up any archaeological site. In the UK, fewer universities are teaching geoarchaeology at undergraduate or taught postgraduate level today than 20 years ago. However, a wide range of computer software now exists that can ostensibly create deposit models, and therefore if we have the software do we need the geoarchaeological expertise? This is a pressing question as workshop delegates were concerned that there was not always a deposit modeller available to undertake the work when required. It could be argued that there is little sense in promoting the use of deposit models if the skills and capacity to produce them does not exist.

First-hand experience of workshop delegates suggested that recruitment of new staff with appropriate geoarchaeological skills was difficult, which partly reflected the lack of university training. However, it was also suggested that the skill-set and experience needed to work as a geoarchaeologist on developer-funded projects is quite specific and is possibly best taught ‘on the job’ if the candidate has the right background. Anecdotal evidence

with respect to several jobs recently advertised (mid 2016) indicated that there had been few applicants and typically those who applied lacked suitable experience and skills. Higher research degrees in allied disciplines of earth sciences or related subjects, for example, palaeoecology, geophysics or GIS, do not offset a lack of work experience in commercial archaeology; and experienced field archaeologists with no knowledge of soils, sediments or Quaternary chronology would need significant training. A further challenge in recruiting geoarchaeologists is that opportunities for career progression are limited and specialists tend to earn less than project managers and consultants. Hence incentives for experienced geoarchaeologists to work as specialists are not great and most have to move sideways into more administrative and management roles to develop their careers. However, the shortage of skilled staff, or indeed the issue of pay and career progression, are certainly not unique to geoarchaeology, but it does suggest that if universities who are responsible for supplying undergraduate and postgraduate students with appropriate skill-sets are failing to do so, then the profession needs to consider how this skills shortage might be addressed.

Several potential avenues for increasing capacity in geoarchaeology and specifically deposit modelling were suggested during the break-out sessions. Firstly, taking opportunities to develop understanding of landscape processes, sediments and soils amongst field-staff might encourage a geoarchaeological perspective in standard archaeological approaches. Archaeologists who are already thinking along geoarchaeological lines are more likely to be receptive to deposit modelling techniques. Training might also be provided by: toolbox talks on appropriate sites; geoarchaeologists regularly working alongside the excavators; and more formal sessions, either provided internally by archaeological units or under the auspices of ClifA and Historic England. Secondly, involving archaeologists in the capture of geotechnical data and inputting stages of deposit modelling has worked on a number of projects and provides archaeologists with insights into the methodological process. In urban contexts, in particular, information on stratigraphic sequences at discrete locations is often extracted from archaeological records; this data collection could reasonably be done by archaeologists under appropriate guidance. Data inputting might also be done by non-specialists, especially if basic information and supervision is provided (such as marked-up sediment logs). However, there are always concerns when using non specialists for specialist tasks, especially when this is done for commercial reasons. In practical terms too, defining which data is input and how it is characterised, as well as interpreting the results, must be done by somebody familiar with the deposits being modelled; this is almost always likely to be a geoarchaeologist.

Simple deposit models, placing the sediment sequence and characteristics seen in a section face or borehole into

a wider context by comparison with other exposures, landforms and geology, lie at the heart of geoarchaeology. Like the archaeologist considering the characteristics of made ground across a site, however, this basic approach to understanding deposits is hardly thought of as a deposit model. Most deposit models are based on large datasets, which require the use of computer software to handle, manipulate and understand the distribution of deposits. In many cases the experts in the software (Rockworks, ArcGIS) are not the geoarchaeologists themselves and many geoarchaeologists are not overly skilled in using such software, preferring to work on paper in the first instance. However, if significant datasets are involved and software is needed, the geoarchaeologist is at a disadvantage if they cannot use modelling software to gain maximum benefit from the data.

The models presented at the workshop and illustrated as individual chapters within this volume are by their very nature aimed to be relatively simple in order to demystify the subject of deposit modelling. As the complexity of models increases, so invariably do the skills required and knowledge of soils, sediments and landscape processes that lie at the heart of geoarchaeology. Suffice to say that for the moment it is enough to concentrate on getting deposit modelling accepted as a standard archaeological process; in order to do this, the products of every deposit model must be understood by the non-specialists who want to know the archaeological relevance of the results. Therefore, a lack of archaeological awareness on the side of the modeller can undermine the value of a deposit model. For the moment at least, understanding the deposits and making their character and distribution across a site (and in the context of the wider landscape) archaeologically relevant and clear is the essential skill of an archaeological deposit modeller. Unless results are set out very clearly, simply and visually with strong links to archaeological significance, the deposit model is likely to be ignored by the potential end-user. This is damaging to the sector's perception of deposit modelling, as unintelligible work produced by one modeller can have negative repercussions for archaeological deposit modelling more widely. On the other hand, a model that clearly and simply addresses the archaeological questions in a way that can be understood with no technical knowledge required on the part of the end-user will go a long way to encourage the standard use of deposit modelling as an archaeological technique. Therefore, training and skills are an essential pre-requisite of any discussion.

18.4. Break-out Theme 3: minimum standards and outputs

To discuss the minimum standards required by a deposit model, in the first instance a general consensus must be achieved regarding what a deposit model is and what the deposit model is used for. Whilst an obvious statement is deposit models investigate subsurface stratigraphy, how

they actually do this and what results are generated from these investigations is much more variable.

During roundtable discussions there was general agreement that a deposit model was constructed from 'more than one borehole', as this requires interpolation between data points to understand the nature of and interpret subsurface stratigraphy. It was also considered that a deposit model must make a statement of 'archaeological potential' and be used for managing archaeological risk within the planning process.

It was also noted that a variety of terms are used to describe deposit models: for example, predictive models, geoarchaeological potential models and geological models, with each term having a slightly different meaning, dependent on the user group. Going forward, there is a need to standardize terminology and practices relating to this subject.

A range of views were presented as to what could and should be expected from a deposit model. It was felt generally that both the inputs to, and outputs from, deposit models were rarely specified, and that this reflected limited use by curators and other planning archaeologists. Often, there is the sense that it is the contractors who suggest the provision of a deposit model to aid site understanding, and therefore the outputs and standards are shaped by the specialist rather than the curatorial/planning archaeologist who may lack the knowledge and confidence to specify deposit models during the drafting of archaeological briefs. This creates an interesting driver to deposit modelling within the UK and also raises significant questions regarding what are essential data inputs and outputs given the competitive nature of tendering and the need for organisations to invariably 'cut their cloth' to secure work. If care is not taken, this could lead to a 'colouring by numbers' approach to deposit modelling rather than tailoring both the inputs and outputs to the specific requirements of any given project.

In the context of roundtable discussions, a number of minimum outputs were suggested. All deposit models should identify significant sedimentary units, model 'key' upper and/or lower bounding surfaces, and reconstruct at least one representative cross-section. An accompanying report must include a description of the inputted data, the precise method of model construction (software, interpolation functions etc), a consideration of archaeological risk, a statement of archaeological potential and a non-technical summary.

Deposit modellers must also be explicit about the level of confidence that can be placed on individual models and the data used to construct it; where there are concerns with respect to the integrity of data, these should be clearly expressed. For example, when using geophysical data, such as that collected through electrical resistivity survey, the interface between sediment units is interpreted in two stages. Firstly, the proxy data such as the resistivity values are measured and interpreted; secondly, these values are used to identify variations in sediment

structure and texture, which are related back to formation process and environment of deposition. The interpreted geophysical dataset can then be compared with borehole data where changes in sediment type are logged directly. This difference in using data to achieve the same end point (ie the interpretation of a sedimentary sequence) needs to be clearly identified in a deposit modellers' report. This openness is essential so that secondary users of deposit models do not misinterpret outputs and in so doing, make unsound archaeological inferences from the model.

As a general rule, it was considered that geophysical data should not be used in isolation and for deposit modelling, it must always be supplemented by ground-truthing from borehole data or hand augering to securely interpret trends in the geophysical data. Any primary geotechnical data used for constructing a deposit model should also form an appendix to the associated report, although it is recognised that issues of confidentiality may come into play here, especially if deposit models are to be archived with a HER and/or the ADS.

Therefore, deposit models must contain a clear distinction between data and interpretation, and as well as clear definition of the data, there also needs to be a clear definition of what is being interpreted from the data. Is the deposit model seeking to define archaeological contexts, sedimentary units, broader depositional environments, palaeolandscapes, or all of the above? Each of these terms requires definition and clarity when used by deposit modellers, especially when they are translated for the end-users, who might include the field archaeologist, the curator and/or the developer. A further standardisation that should be applied to each deposit model is a clear definition of what the key sediment units are and why they are important. Further statements should accompany this on the difference (or similarity) between key sediment units and distinct archaeological contexts.

With regards to what is being interpreted and inferred from the deposit models, a clear distinction was emphasised between archaeological potential and preservation potential, with this theme picked up, for example, in the individual chapters of both Malim (Chapter 15) and Hunter-Mann and Oxley (Chapter 16). Advanced deposit models can capture data relating to groundwater and geochemical conditions (eg perched watertables, redox, pH etc) that can aid assessment of archaeological potential and survival.

18.4.1. Baseline information and data sources

The question of what actually constitute baseline data and techniques for deposit modelling provided fluid debate but ended with little clarification of the issues due to the variable nature of deposit modelling and the fact that each model is unique. Nearly all deposit models will consult pre-existing geotechnical data and this is considered a key requirement. However, accessing previously collected geotechnical data for individual sites is far from straightforward, especially if confidential. It was

considered that the commissioning of purposive boreholes was desirable, but this was not always practical, especially if budgets are limited. Using general geotechnical records have the added problem that when described by geotechnical engineers, they lack sufficient descriptive detail for geoarchaeologists; for example, the term 'made ground' can cover a variety of deposit types but also include archaeologically-significant sediments, including structures.

18.4.2. How can deposit models be presented more clearly?

Deposit models are usually produced in colour format and many colour schemes used are intuitive; for example, rivers or potential palaeochannels shaded in blue, organic areas depicted by black. To provide extra clarity, deposit models should include additional information that allows the end-user to orientate themselves, for example, in relation to local landmarks, Ordnance Survey maps and field numbers. Time invested in producing high-quality graphics and tools for visualisation was considered as being a priority to help explain deposit model outputs. Two-dimensional topographic surfaces and cross-sections were considered essential outputs from deposit models with three-dimensional rotational visualisations seen as desirable. Whilst illustrations might be complex in terms of what they convey, they must be interpretable by a more generalised readership and where annotated, they must be free of jargon. This is critical since the data does not speak for itself and it is important that the specialist guides the generalist through the relevance of the outputs.

Once created, deposit models should be more closely integrated with the ground-truthing of the archaeological remains, gleaned through the process of evaluation and excavation. Part of this process, tying together the recovery of archaeology and the initial deposit model, will have to occur as part of a post-excavation process, but beginning this process early on was considered a valuable step in assessing how successful a deposit model has been in identifying archaeology.

However, what this testing would consist of was not agreed on, ranging from qualitative assessments through to the use of statistics. From both a modellers' and curatorial perspective if deposit models are going to be prescribed as part of the development process, confidence has to be demonstrated in the modelling process. As well as reflecting on the usefulness of deposit models on individual sites, it was also considered desirable that some models are compared using different data sources, different software and by different groups to compare outputs when the archaeological reality of a location was known. Such tests need to be disseminated to the wider deposit modelling community with clarity of the level of success as well as the limitations of models. It was considered worthwhile to provide future forums to discuss the success and failures of deposit models

against emergent archaeological realities. There was an acknowledgement of the low level of publication of deposit models in general, and very few that compare the results of deposit models to subsequent excavation data.

18.5. Break-out Theme 4: archives and long-term data-management

The final break-out identified a number of key themes.

18.5.1. Archive contents

There was extensive discussion on the subject of the geoarchaeological, locational and other data that should be incorporated in project archives and the format of these data. It was emphasised that although the derived models provided important insights into landscape development and anthropogenic impact, the key priority was the preservation of primary data in robust formats that could be accessed easily by future researchers. Only if this were achieved, it was argued, would it be possible for future workers to review and reinterpret the data upon which models had been developed and to test the conclusions that had been drawn previously.

To achieve this result, it was recommended that Written Schemes of Investigation in advance of development include the requirement that contractors submit the primary data, derived model and report to an accredited archive. This guidance would empower the curator to insist upon the definition of an archive strategy at the outset of deposit modelling projects and thus expedite storage in an appropriate format of the primary data acquired during field investigations. It was argued that this requirement should be extended to University-based and other researchers conducting ground investigations outside of the development process, including community groups engaged in geoarchaeological investigations (as at Farndon Fields, Nottinghamshire: Garton *et al* 2015).

18.5.2. Archive stores and data formats

It was recommended that an accredited digital archive such as that maintained by the British Geological Survey or the Archaeology Data Service should be identified for data generated during the deposit modelling process. It was proposed that digital data should also be integrated with the appropriate regional Historic Environment Record. It is therefore critical that investigators liaise on GIS and other software packages with Historic Environment Records (HER) staff at the project development stage. This, it was felt, would enable the effective integration of project data into the HER and would assist the development of programmes of investigation and analysis that addressed directly regional research and management priorities.

To ensure maximum access to preserved archives, it was recommended that digital data be stored in simple formats that would ensure accessibility to future researchers (eg as csv files). The advantages of ensuring

deposition of paper as well as scanned records of documentary archive material (relating for example to borehole descriptions) were also emphasised, although it was recognised that the feasibility of this would depend upon the availability of adequate storage space in an appropriate regional museum.

18.5.3. Evolution of deposit models

It was recommended that investigators consult wherever possible the results of previous exercises of deposit modelling on or close to the study area, as this would permit the development of more targeted and cost-effective investigation strategies. It was felt that knowledge of data acquired during earlier investigations on or close to the site would also facilitate interpretation of results gained during borehole surveys and other ground investigations. Plotting of palaeochannel deposits within proposed quarry extraction zones, for example, would be expedited if these could be assessed within wider interpretative frameworks such as that developed for the Trent catchment (Baker 2006; Stein *et al* 2017).

It was recommended that reports on work conducted should include a review of previous deposit models developed within or close to the study area. This would provide the opportunity to consider how the most recent phase of investigations has enhanced or challenged established deposit models, thereby enhancing understanding of regional landscape development.

18.5.4. Integration of results of multiple projects

It was noted that several recently completed 'Big Data' projects, such as that focused upon archaeological investigations in advance of aggregates extraction in the Upper Thames (Morrison *et al* 2014), had flagged the problems of interpreting landscape change on the basis of multiple interventions by different contractors over protracted time periods. It was recognised that problems of software compatibility may complicate attempts to integrate multiple surveys. However, modes of achieving this should be considered during the project development stage in liaison with the regional historic environment curator, and deposit modellers should be encouraged to share their data in the interest of developing a wider understanding of the landscape.

It was recognised that the integration of past datasets in intensively studied areas such as the Thames or Trent Valleys would be well beyond the scope of developer-funded investigations. For that reason, it was recommended that priority be given to the development of initiatives outside the development process that might facilitate the integration of current datasets. This would release the untapped potential of the data accumulated during past developer-funded investigations, as well as providing a firmer foundation for the development of subsequent schemes of investigation.

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19. Concluding remarks

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By way of a series of technical case studies and overview chapters, this volume has sought to describe how deposit modelling can be used to investigate archaeological sites and landscapes in a wide variety of environments, from terrestrial to perimarine, urban to rural. The selected case studies described herein aim to provide examples of good practice and are underpinned by detailed technical information that considers: the *raison d'être* for modelling; the data and methodologies used; as well as approaches to project archiving and data storage.

By using a largely standardized template, it is intended that the user of this volume, with relative ease, can compare and contrast the approaches taken to deposit modelling and assess the additional information and therefore insights that it can deliver for archaeological projects. Whilst the case studies outlined here are considered examples of good practice, it must be stressed that the methodologies described are not considered fixed or rigid, and no one approach will provide a 'one fits all' solution for a particular environment or site type. Rather, with a range of knowledge to hand, the user may tailor methodologies for their site, perhaps mixing and matching a number of technical elements described here.

It must be emphasised that deposit modelling as a sub-discipline of geoarchaeology is still very much in its infancy. Chapter 18 has been written largely on the basis of thoughts and opinions captured during a workshop of practitioners and stakeholders held in London (June 2016), prior to the editing of this volume. The chapter demonstrates that there are still many issues to be considered and challenges to be overcome, especially with respect to data standards, archiving, training and skills capacity. This volume does not claim to provide solutions to many of the issues discussed; however, it is hoped that it goes some considerable way to advancing common themes and goals, and will provide a foundational platform for further discussion and methodological development.

Perhaps most importantly of all, together with the Historic England Guidance Document *Deposit Modelling for Archaeological Projects* that is currently in preparation, it is hoped that this volume will provide a wide-ranging group of heritage practitioners, not just geoarchaeologists and environmental archaeologists, with the knowledge and therefore confidence to use deposit modelling as part of the wider tool-kit for archaeological investigation.

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Acknowledgements

The editors would like to express thanks to Historic England for funding this project (Number 7257) and to the many individuals within the organisation who provided support and advice throughout the process; special thanks must go to Hannah Fluck and Jane Sidell who spent much time and effort reviewing the entirety of this volume and delivering constructive feedback. The production of this volume would not have been possible without the enthusiasm, help and support of all the individuals

who attended the workshop, which provided a platform for debate and discussion; the authors of the subsequent chapters merit further thanks for submitting papers in a timely manner and putting up with our editorial requests for revisions to original manuscripts and illustrations. Last but not least, thanks are due to the University of Brighton for their administration and encouragement of this research and Paul Luffman of Short Run Press Ltd for support during the final publication of this volume.