8. An archaeological deposit model of Site A, London Gateway Port development

Chris Carey

School of Environment and Technology, University of Brighton, Lewes Road, Brighton, BN2 4GJ

Abstract

During 2008 an ecological compensation scheme as part of the DP World London Gateway Port development, adjacent to the Thames estuary near Stanford-le-Hope, Essex, required the creation of an intertidal habitat, through a reduction of the land surface by approximately 1m and re-alignment and breach of the existing sea wall in an area of historically reclaimed salt marsh. This compensation area was referred to as Site A and later renamed Stanford Wharf Nature Reserve. Deposit modelling was undertaken across Site A, using gouge coring and resistivity transects to define the interface of the Holocene-Pleistocene deposits and to characterise the sedimentary architecture of the postglacial sequence. A gradiometer survey was also undertaken as part of the deposit modelling programme to identify archaeological remains within the upper 1m of the sediment sequence, which was the limit of the impact depth from ground reduction. The deposit model allowed a geoarchaeological zonation of the site, with Zone 1 interpreted as a buried river terrace containing the potential for deeply stratified and well-preserved archaeological remains. Evaluation trenching targeted key archaeological features across the site to characterise the depths and potential of any recorded archaeological and palaeoenvironmental remains. This approach of targeted evaluation, informed by deposit modelling, allowed for a reduced trenching strategy compared to a standard blanket evaluation.

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Figure 8.1: The location of Site A on the north bank of the Lower Thames Estuary
process of an agreed percentage area. In turn, this allowed the archaeological process to proceed quickly from evaluation into excavation mitigation and facilitated post-excavation analysis of the sequences, providing a rich archaeological narrative.

8.1. Introduction

The development of DP World London Gateway Port development, adjacent to the Thames Estuary near Stanford-le-Hope, Essex, was a major infrastructure project requiring a complex package of mitigation responses for historic environment assets, including palaeoenvironmental remains. The development was spread across several sites within the locality, with the archaeological mitigation for each site undertaken within a larger, overarching framework. One of the most important components in the overarching framework was the development of a site-wide deposit model (Bates et al. 2012), which provided the context for further stages of work. The archaeological project was run by Oxford Archaeology, who embedded a geoarchaeologist within the site team to oversee the archaeological programme across a number of sites, many of which (such as Site A) had deep intertidal sediment sequences.

The development required the designation of a parcel of land within the lower Thames Estuary to be used as ecological compensation for the loss of intertidal habitat within the wider scheme. Site A (Figure 8.1; NGR 569900, 181100) was selected for this purpose: an area of previously reclaimed intertidal habitat used as arable farmland. The ecological compensation scheme proposed breaching a sea wall and lowering the contemporary ground surface by approximately 1m in order to return this area to saltmarsh. As Site A lay outside of the boundary of the original deposit model (Bates et al. 2012) it was proposed to construct a small-scale model, principally to understand the character of the interface between the Pleistocene sands and gravels and the finer-grained postglacial (Holocene) sedimentary sequence at Site A. Prior to undertaking field investigations, British Geological Survey (BGS) mapping suggested that Site A was blanketed by a deep sequence of fine-grained alluvium (undifferentiated). Therefore, it was assumed that the approximate 1m reduction in land surface would only impact upon relatively recent intertidal silts and clays with low archaeological potential. Deposit modelling was undertaken in November 2008 followed by archaeological evaluation and mitigation in 2009.

Figure 8.2: Existing lidar data and geotechnical test pits
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). 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
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).
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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.

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)
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-east 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 sand 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)
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:
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- 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)](image-url)
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 geoaarchaeological 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 1. 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 geoaarchaeological 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-exavation 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.
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.

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References
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 preexisting 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