SECTION 4

Modelling where dryland meets wetland
6. Grove Farm, Nottingham: modelling the alluvial sequence of the Middle Trent Valley

Chris Carey\(^1\) and David Knight\(^2\)

\(^1\)School of Environment and Technology, University of Brighton, Lewes Road, Brighton, BN2 4GJ; \(^2\)Trent & Peak Archaeology, York Archaeological Trust, 47 Aldwark, York, YO1 7BX

Abstract
A proposed wind turbine development on the floodplain of the River Trent on the western outskirts of Nottingham required the construction of a deposit model prior to further archaeological evaluation and the development of an appropriate mitigation strategy. A series of 54 purposive boreholes was drilled and recorded with the aim of creating a deposit model that would guide future archaeological investigations. Another 6 boreholes and 19 test pits were subsequently excavated for geotechnical ground investigations, permitting refinement of the initial deposit model. These surveys permitted identification of several macro-stratigraphic units across the development area, allowing archaeological potential to be defined through geomorphological zonation of the site; landform elements included one or more palaeochannels, a river terrace and an alluvial floodplain, with the Holocene sequences extending from between \(c\) 0.4 and 7m below the modern ground level (BGL). A subsequent gradiometer survey refined the zonation of the site and allowed the identification of archaeological features cut into river terraces and the upper deposits of the deep Holocene alluvial sequence. No further archaeological works were conducted after the gradiometer survey which, together with the preceding ground investigations, provided sufficient evidence for the developer, consultant and archaeological curators to determine the potential archaeological impact of the proposed construction work and the likely scale of further evaluation and mitigation work. In this respect, the project provides a model for best practice in alluvial environments impacted by construction activity.

6.1. Introduction
We focus in this paper upon a deposit model that was constructed in advance of the development by the University of Nottingham of three wind turbines on sports fields and farmland spanning the boundary between Nottingham City and Nottinghamshire (NGR: 455200 336300; Figure 6.1). The development would have involved disturbance of the contemporary floodplain of the River Trent and adjacent river terrace deposits, with unknown impacts upon subsurface deposits, leading the City and County archaeological curators to request a desk-based assessment and preliminary ground investigations prior to the granting of planning permission. The work was undertaken by Trent & Peak Archaeology and the University of Brighton, following a desk-based assessment by AECOM Ltd, with AECOM performing a consultancy role on behalf of the developer.

The initial brief from the consultant requested a gradiometer survey of the entire development area. However, given the potential depths of the alluvial sequences in the middle reaches of the Trent Valley (Bridgland \textit{et al} 2014; Knight and Howard 2004), it was recommended that targeted ground investigations should be conducted initially to clarify the subsurface stratigraphy and to assess the potential value of gradiometry as a prospection technique. The consultant was happy to revise the initial brief, and it was agreed to combine a purposive borehole survey with the geotechnical investigations accompanying development in order to establish a deposit model that would inform future archaeological investigations.

6.2. Aims and objectives
The British Geological Survey (BGS) had previously mapped the area as containing ‘Undifferentiated Alluvium’; a BGS classification that can encompass material from a host of different depositional environments. The deposit model was constructed at the assessment stage in order to enhance our understanding of the subsurface sediment stratigraphy, establish the site’s
archaeological and environmental potential, and facilitate the development of future programmes of evaluation. The process of deposit modelling was complicated by the location of much of the development area on sports fields; these had previously been ploughed and rolled flat, thereby removing any topographic expressions of surface landforms such as palaeochannels. An examinations of air photographs and plots derived from airborne lidar surveys also failed to reveal traces of buried landforms. Particular focus was placed, therefore, upon the location by ground investigations of channel deposits which might elucidate development of the riverine environment and preserve organic remains with potential for dating the channels and elucidating changes in vegetation and land-use.

6.3. Fieldwork methodology

Three stages of fieldwork were carried out with the aim of developing a robust deposit model that could provide a valuable framework for further evaluation and mitigation work.

<table>
<thead>
<tr>
<th>Deposit model location</th>
<th>Grove Farm, Nottingham, UK (NGR: 455200 336300)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depositional environment</td>
<td>Floodplain sequence of the River Trent</td>
</tr>
<tr>
<td>Size of deposit model</td>
<td>The deposit model extended across an area of c. 21 ha</td>
</tr>
<tr>
<td>Data collection strategies</td>
<td>Borehole surveys and geotechnical test pits, followed by extensive gradiometer survey</td>
</tr>
<tr>
<td>Position in the archaeological process</td>
<td>Initial ground investigations, guided by the results of desk-based assessment. Following construction of the deposit model, the developer decided not to proceed with construction work</td>
</tr>
<tr>
<td>Reason for deposit model construction</td>
<td>To model the interfaces between the key stratigraphic units, characterise the recorded Pleistocene and Holocene sediments, establish the potential for preserved archaeological and environmental remains, and establish a methodology for further evaluation and mitigation work</td>
</tr>
<tr>
<td>Archaeological questions</td>
<td>Define the depth of the Holocene sediment sequences and the likely locations of archaeological remains within these sequences</td>
</tr>
<tr>
<td>Software and modelling process</td>
<td>The data were sorted in Excel, with the surfaces of the key stratigraphic sediment units modelled in ArcGIS. A representative section was drawn in Illustrator. Gradiometer data were processed in ArcheoSurveyor software and were imported into ArcGIS</td>
</tr>
<tr>
<td>Outputs from the deposit model</td>
<td>A series of topographically modelled surfaces and representative cross sections; gradiometer map, showing geomorphological and archaeological features; and zonation of the site into different geomorphological depositional environments, with a statement of their archaeological potential</td>
</tr>
</tbody>
</table>

Stage 1: geoarchaeological borehole survey

54 purposive boreholes were drilled using a rotary corer on a regular grid (50m intervals; Figure 6.2). Site Investigation Services Ltd was contracted to undertake the boreholes under the supervision of one of the authors (CC). Detailed notes were compiled for each borehole of sediment units modelled in ArcGIS. A representative section was drawn in Illustrator. Gradiometer data were processed in ArcheoSurveyor software and were imported into ArcGIS.

Stage 2: geotechnical investigations

The locations of each of the proposed wind turbines were investigated by Castle Roc Geotech. Six cable percussion boreholes were drilled to depths of c. 8m below modern ground level (BGL) and 19 geotechnical test pits were dug by a JCB mechanical excavator equipped with a toothless bucket (Figure 6.2). This Stage 2 fieldwork was undertaken several months after completing the original deposit model, requiring it to be updated. All of these geotechnical interventions were monitored by one of the authors (CC); data were collected using the same methods as for the deposit model.
recording system that was employed during Stage 1, ensuring continuity and comparability of data.

Stage 3: gradiometer survey
Completion of the Stage 1 and 2 intrusive investigations provided the foundation for a deposit model that was refined by a gradiometer survey aimed at clarifying the subsurface topography deduced from borehole analysis and investigating whether features of archaeological interest might survive in areas not sealed by significant depths of sediment. Details of the methodology are provided in Chapter 6.5, where the results are discussed.
with reference to the geomorphic zones that were identified by analysis of the borehole data acquired during Stages 1 and 2.

6.4. Analysis of Stage 1 and Stage 2 borehole data

The borehole data obtained during Stages 1 and 2 were grouped into stratigraphic units using Excel software. Two key measurements were selected for each unit: its thickness and the depth of its upper surface below modern ground level (BGL). These data were exported into ArcGIS and modelled via a krigging function to allow a 2-dimensional reconstruction of the subsurface stratigraphy and a pseudo-3-dimensional display within ArcScene.

6.4.1. Key stratigraphic units

Five key stratigraphic units were revealed during ground investigations and are described briefly below, broadly in reverse order of date of formation.

- **Minerogenic alluvium** (Figures 6.3a&b)
  This sediment unit comprised mainly a light brown silty clay, with iron (Fe) and manganese (Mn) mottling, and formed the uppermost unit in the sediment sequence (Figure 8b). It was recorded throughout the development area, and represents the upper oxidised zone of the alluvial sequence. This unit varied significantly in depth across the application area, with a thin covering towards the west and much thicker deposits towards the east. It extended to a depth of only c. 0.4m BGL at the highest point of the river terrace sands and gravels that extended across the western part of the study area (Chapter 6.4.2: Zone 1), explaining the visibility of cropmarks and the presence of well-defined gradiometer anomalies of archaeological interest on this higher terrace landform. Towards the east of the development area it was stratified above orange-grey or orange-brown clayey sands and a dark grey sandy clay that might also be of alluvial origin (Figure 8b: deposits 12–14) but further work would be required to establish with greater confidence the origin of these lower deposits.

- **Organic-rich palaeochannel sediments** (Figure 6.4a)
  This sediment unit was characterised by brown to blue-grey silty clays, peaty clays and blue-grey clayey sands, and incorporated several layers with moderate to good preservation of organic matter.
Figure 3: The modelled upper surface (A) and thickness (B) of the Minerogenic Alluvium (HMSO Crown Copyright, OS licence no. 100019139)
Figure 4: The modelled upper surface of the Organic-rich Palaeochannel Sediments (A) and the modelled upper surface of the Clayey Sands and Gravels (B; HMSO Crown Copyright, OS licence no. 100019139)
Figure 5: The modelled upper surface (A) and thickness (B) of the Sands and Gravels stratigraphic unit (HMSO Crown Copyright, OS licence no. 100019139)
A linear band of this deposit, indicating an infilled palaeochannel that would originally have flowed across the development area, was recorded towards the centre of the site. The age and exact orientation of this palaeochannel could not be determined during the course of fieldwork, but importantly it preserved a sequence of organic-rich fills to a depth of 5.3m BGL. A seemingly discrete deposit of similar material, interpreted as possibly further evidence for channel activity, was found towards the east of the development area.

- **Clayey sands and gravels** (Figure 6.4b)
  This deposit was found at the top of the sands and gravels in the west of the development area. It extended typically to a maximum depth of c. 1.5m BGL and comprised a stiff clay matrix with small pea gravel and sand. This deposit is distinct from the underlying sands and gravels, and could represent fluvial reworking of the underlying terrace surface or the impact of contemporary weathering processes.

- **Sands and gravels** (Figure 6.5a&b)
  These consisted of rounded to sub-angular gravel clasts, with a considerable component of orange-brown, fine to medium sand. This sand and gravel was often matrix-supported. Intermittent sandy deposits, interpreted as bar top sediments, were recorded overlying this unit. This material formed a thick terrace deposit in the western half of the development area. In contrast, the eastern side of the area was characterised by notably thinner sand and gravel deposits, indicating erosion of the terrace across that part of the site.

- **Mercia Mudstone bedrock** (Figure 6.6)
  This lithological unit represents the top of the underlying Triassic mudstone bedrock. Its surface represents a late Pleistocene planation surface, and could potentially be associated with Middle or Upper Palaeolithic archaeological remains on its surface. An area of deeper incision was preserved in the bedrock in the middle of the development area, corresponding with the course of the major palaeochannel that has been described above.

6.4.2. Geomorphic zones deduced from borehole data
From the description and mapping of the macrostratigraphic sediment units described above, four
Grove Farm, Nottingham: modelling the alluvial sequence of the Middle Trent Valley

75

geomorphic zones with variable archaeological and palaeoenvironmental potential were defined. All were sealed by variable depths of light brown silty clay alluvium that on the higher river terrace and along the edge of the floodplain merged into an upper ploughed horizon of brown-grey silty clay (Figure 8: deposits 1 and 2). The distribution of these geomorphic zones is shown in Figure 6.7, while their sediment stratigraphy and architecture is illustrated in a representative south-west to north-east cross-section across the site (Figure 6.8).

Zone 1 (river terrace sands and gravels): area of river terrace sands and gravels, extending to a maximum depth of c. 8m BGL and masked by shallow minerogenic alluvium with a ploughed A horizon (to a maximum depth of c. 1m BGL). This elevated topographic zone was attributed tentatively to the late Pleistocene Holme Pierrepont Sand and Gravel (Bridgland et al. 2014, 26–32); it was suggested that the overlying clayey sands and gravels described in Chapter 6.4.1 could signify reworking of the late Pleistocene terrace surface or perhaps just coeval weathering processes.

The terrace deposit has a very high potential for the preservation of archaeological features cut into the terrace and/or preserved beneath alluvium, as demonstrated by the available air photographic evidence. This reveals cropmarks indicative of archaeological features across the terrace, including an enclosure complex at the highest point of the landform. This cropmark complex invites close comparison on typological grounds with Iron Age and Romano-British occupation foci along the Trent Valley, suggesting that as elsewhere in the Valley the river terrace may have provided an attractive focus for settlement during these periods (Knight and Howard 2004, 79–151).

Zone 2 (central palaeochannel sequence): major palaeochannel complex, characterised by a band of deeper minerogenic alluvial deposits above the sands and gravels (to c. 4.5m BGL), with areas of significant organic preservation and high palaeoenvironmental potential. The underlying sand and gravel deposits are significantly thinner, ranging in depth from c. 4.5–7m BGL. Zone 2 is topographically lower than Zone 1, and coincides with the location of one or more palaeochannels that have incised into the underlying sands and gravels. The channel deposits preserve organic-rich sediments with significant potential for elucidating changes in the valley environment. The cross-section (Fig.6.8b) could signify two palaeochannels, coinciding respectively with boreholes CC31 and
Figure 8: West-east cross-section of the development area, showing the four geomorphic zones and the locations of borehole (BH), test-pit (TP) and rotary core (CC) records used to construct the cross-section (CPT, cone penetration test; SCPT: seismic cone penetration test; HMSO Crown Copyright, OS licence no. 100019139)
### Table 6.1: Summary of archaeological and palaeoenvironmental potential of the geomorphic zones deduced from analysis of the borehole data

<table>
<thead>
<tr>
<th>Geomorphic zone</th>
<th>Key stratigraphic unit</th>
<th>Main lithology</th>
<th>Archaeological potential and indicative date</th>
<th>Palaeoenvironmental potential</th>
<th>Indicative depth below ground level (BGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 River terrace sands and gravels</td>
<td>Minerogenic alluvium</td>
<td>Brown-grey silty clay with Fe and Mn mottling</td>
<td>Low Holocene</td>
<td>Low</td>
<td>0 – 0.4m BGL</td>
</tr>
<tr>
<td></td>
<td>Clayey sands and gravels</td>
<td>Brown-grey, stiff and concreted clayey sand with small gravel clasts</td>
<td>High: multiperiod archaeological remains cut into/above the surface Late Pleistocene to Early/Mid Holocene</td>
<td>Low</td>
<td>0.4 – 1.3m BGL</td>
</tr>
<tr>
<td></td>
<td>Sands and gravels</td>
<td>Rounded to sub-angular clasts in orange to grey, fine to medium sand</td>
<td>High: multiperiod archaeological remains cut into/above the surface Late Pleistocene (Holme Pierrepont Member)</td>
<td>Low to moderate</td>
<td>1.3 – 7.0m BGL</td>
</tr>
<tr>
<td>2 Central palaeo-channel sequence</td>
<td>Minerogenic alluvium</td>
<td>Brown-grey silty clay with Fe and Mn mottling</td>
<td>Low Holocene</td>
<td>Low</td>
<td>0 – 1.0m BGL</td>
</tr>
<tr>
<td></td>
<td>Organic-rich palaeochannel sediments</td>
<td>Blue to grey silty clay and clayey sand, often with visible organic remains</td>
<td>High: multiperiod archaeological remains stratified in sediment matrix (eg fishweirs, logboats, bridges &amp; trackways) Holocene</td>
<td>High</td>
<td>1.0 – 5.3m BGL</td>
</tr>
<tr>
<td></td>
<td>Sands and gravels</td>
<td>Rounded to sub-angular clasts in orange to grey, fine to medium sand</td>
<td>Moderate: multiperiod archaeological remains; character dependent on date of gravel Late Pleistocene (Holme Pierrepont Member)</td>
<td>Low to moderate</td>
<td>5.3 – 7.0m BGL</td>
</tr>
<tr>
<td>3 Alluvial floodplain</td>
<td>Minerogenic alluvium</td>
<td>Brown grey silty clay with Fe and Mn mottling</td>
<td>Low Holocene</td>
<td>Low</td>
<td>0 – 0.2m BGL</td>
</tr>
<tr>
<td></td>
<td>Minerogenic alluvium</td>
<td>Light brown to grey sand silt, with clay</td>
<td>Unknown Holocene</td>
<td>Low</td>
<td>0.2 – 1.0m BGL</td>
</tr>
<tr>
<td></td>
<td>Sands and gravels</td>
<td>Rounded to sub-angular clasts in orange to grey, fine to medium sand</td>
<td>Moderate: sands and gravels tentatively dated to the Holocene Holocene?</td>
<td>Low to moderate</td>
<td>1.0 – 6.0m BGL</td>
</tr>
<tr>
<td>4 Possible eastern palaeo-channel sequence</td>
<td>Minerogenic alluvium</td>
<td>Brown grey silty clay with Fe and Mn mottling</td>
<td>Low Holocene</td>
<td>Low</td>
<td>0 – 0.1m BGL</td>
</tr>
<tr>
<td></td>
<td>Minerogenic alluvium</td>
<td>Light brown to grey clay silt with sand</td>
<td>Unknown Holocene</td>
<td>Low</td>
<td>0.1 – 2.0 m BGL</td>
</tr>
<tr>
<td></td>
<td>Sands and gravels</td>
<td>Rounded to sub-angular clasts in orange to grey, fine to medium sand; associated organic remains</td>
<td>Moderate: sands and gravels tentatively dated to the Holocene Holocene?</td>
<td>Low to moderate</td>
<td>2.0 – 7.0m BGL</td>
</tr>
</tbody>
</table>
 of archaeological features should be interpreted with caution.

<table>
<thead>
<tr>
<th>Zone</th>
<th>Rationale for gradiometer survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Define archaeological remains on the terrace (could be cut into clayey sands and gravels from c 0.4m BGL) and at the interface between Zone 1 (terrace) and Zone 2 (palaeochannel)</td>
</tr>
<tr>
<td>2</td>
<td>Define the area of Zone 2 palaeochannel and its interfaces with Zones 1 and 3</td>
</tr>
<tr>
<td>3</td>
<td>Prospect for archaeological features cut into the surface of the gravels (recorded at a level of c 1.0m BGL) and define this zone more precisely</td>
</tr>
<tr>
<td>4</td>
<td>Define more closely the spatial extent of this zone</td>
</tr>
</tbody>
</table>

The gradiometer survey defined successfully multiple groups of potential archaeological features within areas characterised by shallow alluvial cover, adding significantly thereby to our understanding of the archaeological resource (Figures 6.9 and 6.10). The late prehistoric/Romano-British enclosure complex on the gravel terrace of Zone 1, with its traces of possible roundhouses and field boundaries, is particularly noteworthy, together with traces of another small palaeochannel that could be shown cutting into Zone 1 and possible building debris at the edge of the former channel. A possible trackway was shown traversing the lower floodplain in Zone 3. In addition, the interface between Zones 1 and 2 was defined more closely by the gradiometer data; the plot of magnetic anomalies reveals the same general trend as indicated by the borehole data, but locates the edge of the interface more precisely, slightly farther to the east of the boundary that was postulated from the borehole survey (Figure 6.10). The deposit model was refined after completion of the gradiometer survey, with the definition of another palaeochannel zone (termed Zone 5) in the northern part of the study area and the merging of Zones 3 and 4 into a single zone (renamed Zone 3). The gradiometer survey identified in the L-shaped northern extension of the development area a linear zone that was magnetically much quieter than the Zone 1 terrace, suggesting that the higher terrace landform might have been edged on its northern side by another palaeochannel zone (Figure 6.10: termed Zone 5). In addition, it was concluded after the gradiometer survey that Zones 3 and 4 were not sufficiently distinct to be
Figure 9: The gradiometer survey across the development area, shown as semi-transparent where it overlies the plotted upper surface of the Sands and Gravels (A) and with interpretation of the gradiometer data, showing the wealth of geomorphological and archaeological anomalies (B; HMSO Crown Copyright, OS licence no. 100019139)
identified as different zones and were better interpreted as constituents of a Holocene floodplain landform (Zone 3). The gradiometry survey was successful, therefore, in refining our understanding of the archaeological and geoarchaeological resource and emphasises the value of detailed geophysical survey as a tool for the deposit modeller.

6.6. Conclusions: combining borehole data and gradiometry

The borehole and gradiometry surveys provided crucial data for understanding the subsurface topography and stratigraphy of the proposed windfarm development and enabled the developer and consultant to assess clearly, in consultation with the regional archaeological curators, the required scale of further evaluation and mitigation work. It was decided, in view of the results of these investigations, not to proceed further with the development, and no additional work has been conducted in this area since completion of the gradiometry survey in 2011. Many questions remain regarding the development of this landscape and its exploitation by human communities, but the procedures adopted have emphasised the value of a staged approach to the development of a deposit model that could then inform future action. Without this model, the risks of development could not have been quantified and a reasoned decision on how best to proceed could not have been made. In this respect, the approach can be seen as an exemplar for establishing optimum evaluation and mitigation strategies, providing a methodology on how to proceed with site investigations in advance of development in alluvial environments whose archaeological and palaeoenvironmental potential are hidden firmly from view.

The primary data and reports generated by this project have been deposited in Nottingham City Museum (accession No. NCMG 2011-44). Copies of the project reports may also be consulted by application to the Nottinghamshire County Council Historic Environment Record and are available in digital format from the Archaeology Data Service (Carey and Knight 2011 a, b and c).

Acknowledgements

Thanks are extended to the University of Nottingham for funding this work and to Richard Wigginton and his
colleagues in the Estates Office for providing access to University land and for expediting work on site. We would also like to thank Matthew Parker Wooding, then of AECOM Ltd, for his help in setting up the project and for advising as consultant during its execution. AECOM kindly provided Ordnance Survey mapping under OS licence number 100019139. Thanks are due also to William Donger for expediting access to farmland in the western portion of the proposed development area. James Rackham provided valuable advice on the environmental sampling strategy and the choice of borehole rig. The Stage 1 borehole survey was carried out by Site Investigation Services Ltd and the Stage 2 geotechnical survey by Castle Roc Geotech. Curatorial advice was provided by Ursilla Spence (Nottinghamshire County Council) and the late Gordon Young (Nottingham City Council). Trent & Peak Archaeology staff Laura Binns, Julia Walker and Peter Webb assisted with surveying and sediment recording. The magnetometry survey was conducted with the assistance of Olaf Bayer.

References

Carey, C and Knight, D 2011a ‘Grove Farm, Nottingham: geoarchaeological assessment of sediment sequences and description of archaeological and palaeoenvironmental potential’. Nottingham: Trent & Peak Archaeology (unpublished report, May 2011; deposited with Archaeology Data Service)
Carey, C and Knight, D 2011b ‘Grove Farm, Nottingham: archaeological monitoring of geotechnical investigations and development of updated deposit model’. Nottingham: Trent & Peak Archaeology (unpublished report, Oct 2011; deposited with Archaeology Data Service)
Carey, C and Knight, D 2011c ‘Grove Farm, Nottingham: archaeological gradiometer survey’. Nottingham: Trent & Peak Archaeology (unpublished report, Nov 2011; deposited with Archaeology Data Service)
Knight, D and Howard, A J 2014. Trent Valley Landscapes. Kings Lynn: Heritage Marketing and Publications Ltd
Constructing a geoarchaeological deposit model: Grove Farm, Nottingham

Assess pre-existing data
- British Geological Survey mapping
- Aerial photographs
- Lidar data: not available to project at the time of survey

Develop rationale for model construction and key aims/objectives
- Understand Holocene sediment sequences
- Define archaeological potential
- Recognise different depositional environments

Can the deposit model be constructed using pre-existing data?
No

Commission further ground investigations, including:
- Additional purposive boreholes and recording of geotechnical boreholes and test pits

Construct deposit model comprising one or more of the following:
- Interpolation of key macro-stratigraphic sediment units’ upper surfaces
- Interpolation of key macro-stratigraphic sediment units’ thicknesses
- Representative cross-section across the application area

Ground truth deposit model through fieldwork and relate back to rationale of project aims and objectives
- Gradiometer survey used to define archaeological features and refine deposit model.

Revise final product
Deposit model updated with the gradiometer data and a further report issued.

Archive and re-use
Data and reports archived with Nottingham City Council, Nottinghamshire HER and the Archaeology Data Service