National Heritage Protection Plan

Droitwich urban waterlogged deposits
Collation and synthesis

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and Keith Wilkinson
with Andrew Howard**

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Summary

Droitwich is associated with archaeologically rich waterlogged deposits and yet continues to be a focus for development and renewal, especially following the recent canal restoration. These deposits have been created through a rare combination of circumstances where an area of intense industrial activity (thick deposits) has coincided with the welling up of springs and the proximity of the river (ie wet burial conditions), and the effects of major subsidence (ie deep burial).

This project sought to address the need to protect and manage such significant remains by synthesising existing data and applying relatively new techniques for capturing information about the palaeotopography and the disposition of cultural deposits, with a particular focus on the location of buried areas of waterlogging/organic survival. Such deposits are most significant in terms of their archaeological potential, but also highly vulnerable to disturbance (whether direct or proximate). The project has, therefore, collected and collated together the available archaeological and geotechnical data, which were input into RockWorks so that interpolation could be undertaken between known points, and this was integrated with a digital terrain model derived from LiDAR data enabling three-dimensional surface plots and related cross-sections to be created. This approach was considered to have the potential to provide an advance in better understanding of these deposits, as well as possibly providing visual aids useful for their future management.

The results of the project have been positive, though at the same time many deficiencies in the process of field recording and in the project methodology have also been recognised. Where the data was densest in coverage the palaeotopography has been clearly indicated and realised for the first time in some detail. A result has been the definition of a series of micro-basins along the course of the River Salwarpe, which constitute a significant feature of the later Pleistocene/Holocene surface, and had presumably resulted from localised subsidence due to underlying salt solution. Furthermore these were also reflected in the overlying archaeological stratigraphy both in extents and thicknesses of deposits, though not in an always straightforward correlation, while the formation of organic/waterlogged deposits did seem to have a more straightforward correlation with the newly realised palaeotopography. Other aspects of the organic deposits were also revealed but not always as yet explained, and so further consideration is needed of the results beyond this immediate project. Most importantly it is felt that some confidence can be placed in these results, though clearly more data would be beneficial, especially towards the edges of deposits, and especially where the predictive use of the plots is entertained. To this end the data will be absorbed into the HER as part of the geology layer, however, it remains in question for the moment how far such information in that context can be updated and readily used.

The results also included the recognition that there were limitations with the data for much of the wider survey area, especially in terms of its quantity – this interfered with

the plotting as the software was not able to cope with this sensibly and could even create false positives in areas of no data! A core area was defined where this was minimised and the conclusions about the benefits of the project described above are mainly established through analysis of these plots. Difficulties were also encountered due to pre-set parameters in RockWorks plots as integral with the intricate process of generating the plots, which caused more drafts to be undertaken than originally intended. Paradoxically once the data was loaded, many different plots were possible, and new hypotheses could be 'easily' tested, however there was not enough time for this facility to be adequately explored.

Recommendations are made for revising recording practice so that certain key data are collected consistently for the characterisation of a site, and then made available for this type of project in future. This relates to archaeological archives in the main (as long as the information has been collected on site), but some aspects of geotechnical recording have also given rise to loss of information and confusion, and could also benefit from some guidance on better practice. Above all it is now important for the HER to continue collecting the relevant information for updating and refreshing the plots, and for this purpose it is considered that a Toolkit stage could usefully be undertaken where more attention can be given to the HER aspect and some testing carried out to ensure that this approach evolves into an effective way of managing key deposits in the future. Visual display of detailed data must be the best way to make this type of information available in an easily accessible way to a wide audience, and so other means of presenting this information should also be considered, such as TouchTable technology which is now becoming available. Above all, every effort should be made professionally to ensure that the right management decisions are made at the earliest opportunity to protect remains, and better understanding through the application of new ways of presenting the data synthetically (as represented by this project) must be a powerful way of making this possibility a more likely outcome in the future.

1 Introduction

Droitwich has long been widely known as a place of considerable archaeological interest (most obviously for Roman remains, notably a fort and a particularly early and wealthy villa). In 1964 it was designated as a 'town development area' and plans for expansion were drawn up and works commenced. Archaeological sites were affected and finally, in 1976, with the formation of the Droitwich Archaeological Committee and the appointment of an archaeologist employed by Worcestershire County Council, more systematic advice and planning became available more formally in respect of these developments. Better archaeological investigation and recording was then able to get underway and one of the corollaries of this was that by the late 1970s the great antiquity of the Droitwich salt industry had been demonstrated for the first time, as well as the great potential in some parts of the town for the exceptional survival of waterlogged remains. The especial circumstances of Droitwich (with significant deposits being affected by subsidence) have also meant the adoption, from an early date, of forms of graphic presentation not so often applied in archaeology (but more often in geology), such as fence diagrams (cf Woodiwiss 1983).

Since then many interventions have taken place, including by Worcestershire Archive & Archaeology Service (WAAS), and the present project is intended to extract as much information as possible from this fieldwork, in order, particularly, to understand more about these buried waterlogged deposits, especially in terms of their distribution and location, and also, to some extent, their depositional context, as modelled using more recently available computer software. Data relevant to this type of study have also been collected personally by the main author for many years, so that the need to access and search many individual project archives was minimised to a large extent. This was particularly important given the deficiencies in accessibility of archive data, as later referenced by this project. It is ultimately intended that the results of this study should be useful for the better curation of these very significant waterlogged remains in future.

2 Background

Waterlogged deposits, especially in an urban environment, offer the opportunity for high quality survival of archaeological eco- and artefacts (cultural) combined with a much wider than usual range of palaeoenvironmental indicators. Such deposits are, therefore, rich in potential for revealing evidence of both past activities and past living environments. They require a co-incidence of geological and other factors, such as the rapid accumulation of deposits, and more obviously a relatively high water table, to achieve and then maintain their exceptional (ie waterlogged) condition. Often this is very localised and may well be peripheral to the main settlement for obvious reasons that such places do not make suitable living areas. Only rarely do very extensive urban waterlogged deposits get formed from an intimate combination of human and natural agencies, but this has happened at Droitwich due to the geological imperative of brine springs formed in the base of the river valley, so that the salt industry was naturally drawn to the same area. Droitwich, therefore, represents a highly unusual opportunity to realise the high potential of archaeological remains as evidence of a particular industry (*viz* long term and continuous multi-period salt production of proven antiquity and proven quality based on rare inland brine springs).

The value of the waterlogged deposits in Droitwich has been enhanced by their detailed published study at some locations and there have also been many other interventions, where the information about water-table levels and the presence of archaeological remains have been recorded. Dating information about these deposits has also been consistently and systematically recorded against a framework of pottery dating put in place in the mid 1980s, which enhances the quality of information available to support the project proposed here. Excavation has, however, been limited to certain areas, and the deposits are also sometimes present at great depth where excavation has not been considered viable (see development issues below), and so the true potential of these deposits (and any associated questions) has not yet been fully established. There has, therefore, been an increasing realisation that exceptional archaeological deposits of this nature exist in the Droitwich area, most being deeply buried and, by comparison, a more belated realisation that the sequence of these deposits is not easy to interpret and so, in turn, predict in terms of presence or specific dating.

In a wider context, the realisation of extensive waterlogging brings with it other issues than just conservation, as in the cases of York where it is also now realised that protecting these deposits from decay can be compromised by off-site developments, and that deterioration can be accompanied by subsidence and, therefore, be threatening to overlying (ie built) structures (see more below).

Landscape (geology and topography)

The town of Droitwich (centred on NGR SO 894634; Fig 1a) is located on the River Salwarpe, a tributary of the Severn, and situated on the Droitwich Halite Member, part of the Mercia Mudstone Group (formerly Keuper Marl and Sandstone). The latter consists of heavy clay, which would give poor natural drainage and the use of artificial drainage is, therefore, to be expected. Within the marl there are saliferous beds deposited during the Triassic period, probably when the area was covered by a shallow sea (Northolt and Highley 1973, 4). Although the saliferous beds are not continuous from north to south, Poole and Williams (1980, 3) believed the Worcestershire salt field to be a marginal extension of the main Cheshire field. The full extent of the local saliferous beds is imperfectly known and they are expected to extend over a larger area than so far established.

At Droitwich the saliferous beds are covered by breccias formed by collapse of the surrounding rock (Poole and Williams 1980, 4). Water percolating through the beds takes up salt in solution until it forms saturated brine and is forced to the surface under artesian pressure. The resulting springs are today restricted to the lower river flood-plain in the area of the town and above the underground brine run. This may be expected to have been the main location of brine springs in the past, though salt derived from the saliferous beds has possibly had localised effects outside this area. For example, the pools identified at Upton Warren (HWCM 4151, five kilometres to the north-east of Droitwich) and dated to 42,000 years bp, were mildly brackish, which has been attributed to the saliferous beds of the area (Coope *et al* 1961, 398).

Wells, and later deep shafts, were constructed to have a good supply of the brine in earlier periods. By the 17th–18th centuries the natural brine was so plentiful that it overflowed on to the surface from a depth of 80ft, but by 1884 It was having to be pumped from a depth of 210–220ft (64–67m). The highest salt bed is at *c* 43ft (13.1m) below OD and is almost horizontal; the next bed is at 210ft (64m), the marl being at least 460ft (140.2m) thick with rock salt beds 39ft (11.9m) thick (including bands of marl).

In modern times the underground brine run has been mapped in a *c* 150m wide corridor extending to the north and south of the town, and has been associated with ground subsidence, especially from after the opening of the salt-works at Stoke Prior in *c* 1830. Apart from directly over the brine run, the ground has been expected to stabilise since their closure in 1972 – salt production in Droitwich itself had already ceased in 1922, largely due to the efforts of John Corbett to establish a spa town in preference to one dependent on industry.

Drift geology is also represented in the form of gravel terraces along the River Salwarpe. The current river course in the immediate area of the town is largely artificial having been engineered in the mid 18th century to make way for a better position for the canal.

Wider geomorphological context (by A Howard)

The solid geology of the Salwarpe Valley is overlain by a suite of Pleistocene and Holocene (superficial) deposits, which are related to the modern drainage pattern as well as earlier river systems. Despite being one of the major British rivers, the drainage of the Severn and its tributaries below the Ironbridge Gorge was formed less than half a million years ago, following the Anglian glaciation, around 450 ka BP (Marine Isotope Stage 12; Maddy *et al* 1995). Its headward expansion north of the Ironbridge Gorge and capture of rivers of the Shropshire Plain and mid Wales previously flowing to the Dee Estuary is even more recent and usually attributed to the drainage of glacial Lake Buildwas and Newport (part of a greater Lake Lapworth) at the end of the last glaciation around 15,000 years ago (see Murton and Murton 2012).

Cropping out at different altitudes within the landscape in the immediate study area are the fragmentary remains of three river terrace deposits laid down by a forerunner of the modern river. These deposits can be correlated with more extensive deposits laid down in the main River Severn and as a whole they are known as the Severn Valley Formation (Maddy 1999).

The oldest and highest of these terraces, termed the Bushley Green Member (Stratotype, Bushley Green, SO 862351), comprises around 7m of sand and gravel and is about 45m above the present river. The sediments lie beneath the Bushley Green Terrace of Wills (1938), which is also equated to the 5th Terrace of the British Geological Survey (BGS). In the Droitwich area, the unit is mapped as a remnant of sand and gravel straddling the Roman Road between the town and Wychbold. It is ascribed to the cold (glacial) climatic conditions of Marine Isotope Stage 8, around 260 ka BP. At the base of the unit, organic-rich sediments containing molluscan remains have been recorded (the Bushley Green Fossil Bed); they have been dated by amino-acid racemisation techniques to the interglacial conditions of Marine Isotope Stage 9 (noted by Bowen *et al* 1989 in Maddy *et al* 1995, to equate to the 'Hoxnian Interglacial', but now considered to represent a separate warm stage known as the 'Purfleet Interglacial' – Schreve *et al* 2002). Importantly, in terms of this project, these fossiliferous sediments demonstrate that the conditions which allow organic preservation in postglacial (Holocene) deposits also exist for remains of much greater antiquity; this point is further demonstrated by the discovery of fossiliferous remains (faunal and floral) at Strensham in the Avon Valley in deposits datable to around 200 ka BP (Marine Isotope Stage 7; de Rouffignac *et al* 1995).

The Kidderminster Station Member (Stratotype, Yate's Pit, near Kidderminster Station, SO 839763) comprises around 8m of sand and gravel around 25–30m above the present river (though the height does vary between systems). It underlies the Kidderminster Station Terrace of Wills (1938) and the 4th Terrace of the BGS and is ascribed to cold climatic conditions around 160 ka BP (Marine Isotope Stage 6; Maddy 1999). In the area of Droitwich, it crops out as large patches of material south-west of the contemporary river and town centre. The recognition of far-travelled Welsh erratic and rocks from the Wrekin reflects the input of material by ice, whose tills are recorded to the west of Birmingham around Quinton (Ridgacre Formation; Maddy *et al* 1995).

The Holt Heath Member (Stratotype, Holt Heath SO 827627) is the lowest of the three units, and comprises around 10m of sand and gravel, whose surface is around 30m above the present river. It underlies the Main Terrace of Wills (1938) and the 3rd Terrace of the BGS. Around Droitwich, it crops out as small patches of material close to the contemporary channel. The deposit contains significant quantities of erratic material from the Irish Sea Basin, which were introduced into the area during the Last Glacial Maximum (Clark *et al* 2012). Therefore, part of this deposit is certainly attributable to the Late Devensian (MIS 2). However, further upstream at Upton Warren, fossiliferous sediments of a Middle Devensian interstadial (MIS 3) dated to around 42 ka BP have been recorded (Coope *et al* 1961), although this date is probably a minimum age estimate (Bowen *et al* 1989); at Stourbridge, the remains of Hippopotamus, an indicator of the last interglacial have also been found basally (Marine Isotope Stage 5e, *c* 125 ka BP; Maddy 1999). Therefore, the Holt Heath Member is probably a composite deposit with a long history of deposition.

Whilst no other terraces are mapped around Droitwich, in the main Severn Valley, two other lower river terraces are noted: (1) the Worcester Member, which sits around 8m lower than the Holt Heath Member and is equivalent to the Worcester Terrace of Wills (1938) and the 2nd Terrace of the BGS; and (2), the Power House Member, equivalent to the Power House Terrace of Wills (1938) and the 1st Terrace of the BGS.

Below Worcester, the Power House Member is buried beneath Holocene alluvium and it seems likely that within the Salwarpe Valley, fine grained alluvium masks earlier sand and gravel deposits. Certainly, boreholes examined as part of this project demonstrate coarse sands and gravels beneath the contemporary floodplain (eg Fig 21).

In addition to the preservation within these terrace sediments of organic remains capable of providing proxy records of the environment, it should also be remembered that there is evidence from other river systems in Midland and southern Britain for human occupation during Marine Isotopes 9, 7, 3 and 2. Therefore, terrace sediments within the vicinity of Droitwich have the potential to preserve evidence of such Palaeolithic activity.

Archaeological context

Droitwich is now recognised nationally as a major prehistoric and historic centre of salt production for a period of at least 2500 years, salt in the past being a commodity of considerable economic significance. Salt was produced here until the 17th century from brine collected in surface pits/wells, and typically these were located in the very base of the River Salwarpe valley in a localised area, where the brine naturally erupted, under artesian pressure, via faults in the Triassic mudstone geology. The exploitation of the brine was, therefore, geographically very tightly focussed, and especially lay alongside the river (see Figs, 7 and 15). In later times the piping of the brine enabled salt works to be more scattered, but they still remained heavily represented in the original core area of production until the final demise of the industry.

The heavily industrial process of salt production involved the artificial heating of brine (using firewood and later coal) which created a mass of waste ash and charcoal which accumulated and was largely dumped around the production area. This great build-up of deposits ensured that earlier remains were well buried through human action, but this was enhanced by natural forces as the river flooded regularly and so alluvial deposits also contributed, sometimes greatly, as for instance in the mid Saxon period. Then about 1m of alluvial mud accumulated across the main production zone. In fact the influence of the river on the archaeological remains has been of particular importance for preservation of remains (see below), since it has increased the depth of some archaeological deposits, and sealed 5th–early 7th century and even earlier remains. This is particularly significant, since the location of the brine springs in the base of the river valley led to a great deal of earlier human activity necessarily being close to the river, as that was where production was most conveniently carried out. Archaeological deposits relating to extensive activity, therefore, have been formed under circumstances, where they were particularly prone to acquiring later protection by burial beneath alluvium. This fortuitous combination of circumstances has led to some of the nationally most significant discoveries of structural, artefactual, and environmental remains relating to salt manufacture.

Aside from the thickness of accumulated archaeological deposits in the industrial area (eg 2m of industrial dumping at medieval Upwich; Hurst 1997) with its associated waterlogging from the Iron Age right the way through to the 19th century (eg Upwich; *ibid*), preservation due to waterlogging has been encountered also on the adjacent gravel river terraces (Woodiwiss 1992), thereby affecting a wider area than might be first expected. Overall the importance of these remains has been recognised nationally, since a large area alongside the River Salwarpe as it passes through Droitwich has been scheduled as an Ancient Monument by English Heritage (see Fig 1a).

The high water table in the valley base is a primary factor in the exceptional preservation of archaeological deposits. An added factor is that a large part of Droitwich has been affected by subsidence (most dramatically in the modern period, though the extent of any subsidence in historic times has not been determined, and has conventionally been thought to only affect areas at a greater distance from the town). This study shows that hollows in the Holocene ground surface can now be seen to have impacted heavily on key areas of archaeological significance, ensuring their greater depth of burial and, therefore, quality of preservation, though their origins are not yet entirely clear (see below). In practice, this has tended inherently to count against their full conservation, as the deposits are then considered too deeply buried to be excavated in the normal course of events, and, the engineering preference for piling in these areas is routinely adopted, archaeological issues largely being set aside, despite the attendant issues of wider ground disturbance, and (thereafter) the unmanaged and unmanageable effects piles might be having (primarily causing dewatering and oxidisation (rotting) of deposits previously sealed (in equilibrium) in an anaerobic state. In practice English Heritage guidance on piling accepts archaeological depletion within certain parameters, while at the same time admitting that the effects of some piling are not yet understood (viz vibro-piling which has been recently used in Droitwich) (English Heritage 2007). A very limited attempt has been made to monitor deposits on one such excavation site in the town (Waitrose, WSM 35464; Patrick 2005), but the monitoring seems to have petered out after a short time, and the results, such as they were, do not seem to have been subject to any convincing professional assessment within a framework of on-going site management in the view of the principal author. Another attempt was made (this time at Street's Garage; WSM 35076) to monitor burial environments associated with a proposed development (work commissioned by WAAS from Cheetham 2006 and Wilkinson 2006). This focused on the measurement of Redox from water samples and a successful technique was developed (Woodiwiss 2007, and see Williams 2009, 21 for reference to this pioneering work). Although only a few initial readings were used in the extant report, further readings were made, but, with the onset of the recent economic recession, the development project was never completed (results remain in archive), and on-going monitoring has ceased.

Research framework

Previous assessment has confirmed the archaeological standing of Droitwich both regionally and nationally, for instance as discussed in the *Central Marches Historic Towns* (Buteux and Hurst 1996), and referred to in the *West Midlands Regional Framework for Research* (Watt 2011). Unfortunately the relevant period research assessments have only been very partially published for the west Midlands (*viz*, to date, only the earlier prehistoric period has been fully produced), and so no detailed overall up-to-date regional assessment can yet be cited for those periods most relevant to Droitwich, apart from draft papers produced ten years ago. Here reference is made to the significance of Droitwich and its salt industry, and the quality of the surviving associated archaeology (eg Hurst 2003).

Geotechnical context

Given the nature of the industry in Droitwich and its subsequent association with subsidence there has been a keen regard to borehole data being commissioned by the local authority in advance of the mid-late 20th century development of the town (*viz* housing and road schemes). Much of this work was undertaken by Johnson, Poole and Bloomer in *c* 1974, whose brief included locating the 19th century 'boreholes' (*viz* brine shafts) that had been sunk by saltmakers to win brine supplies – it was acknowledged by them that some of these historic boreholes remain unlocated. Such data included the use of piezometers to check below-ground conditions over time from at least the mid 1970s (ie Wychavon DC engineer, W L Booy, file 83/1, where two boreholes are projected in 'Chawson south' at approximately 388751 262129, and 389458 261444).

Palaeoenvironment

Study of palaeobotanical remains has taken place for several archaeological sites in Droitwich and this has revealed that particularly rich environmental remains have survived in several locations, especially along the base of the Salwarpe valley (eg Greig 1997; see above for explanation). The principal factor in their preservation has been the waterlogging of deposits in the base of the river valley. In addition exceptional circumstances prevail in the close vicinity of the brine springs themselves, and here waterlogging is combined with strongly alkaline conditions to cause the preservation of organic remains rarely recovered from elsewhere in the country (eg delicate organic materials such as hempen rope at Upwich; Crowfoot 1997). The strongly alkaline conditions of the salt springs also provide excellent preservation of calcium-based remains such as bone and shell, and so an unusually wide range of palaeoenvironmental remains are preserved here as demonstrated by the large-scale excavations of the mid 1980s (ie at Upwich), whereas elsewhere in Worcestershire such material is often in a poor state of preservation. Proxy evidence for the surrounding landscape has also been present in the form of pollen. Such a wealth of survival opens up the possibility of more techniques being available, such as the dating of shell by AAR (though with the *caveat* that in alkaline areas there can be a hard water error). Such potential might particularly suit the dating of deeper deposits which have been sampled through boreholes.

Current hydrogeology

The River Salwarpe is referred to as one of the main tributaries of the middle Severn and is regarded as an area undergoing heavy water abstraction (authorised through historic licences of Right), as the solid geology is mostly sandstone which is a very good water-bearing rock (http://www.environmentagency.gov.uk/cy/ymchwil/cynllunio/40341.aspx). The current standing is that 'there is no spare water for further groundwater abstraction' here, and indeed the groundwater is currently classified as 'over licensed' with some large public water supply abstractions taking place. More specific information on water management covering the forward strategy for 2012–18 is provided for the Salwarpe valley by the Environment Agency (2013).

Only secondary aquifers (ie existing watercourses EA map GD 03177G (2002)) are, therefore, present in the Droitwich area and these comprise both the solid and superficial geology, and they support local abstraction only (M Weston (EA), pers comm). More specifically, at Droitwich the hydrology is more complex as, not only is there the River Salwarpe (and a canal), but the water-table is also fed by natural brine springs, while subsidence is a further complicating factor. Historically brine rose to the surface under artesian pressure and strongly flowing springs were present in the Vines Park area, but today these are not so evident, as its drainage occurs into the River Salwarpe.

Development pressures

At the same time, given the position of Droitwich in the M5 corridor, Droitwich is constantly undergoing development, and, presently, due to the recent completion of the canal restoration, that development is now favouring the waterfront along the River Salwarpe where the most sensitive archaeological deposits are present, so that these are now coming under great threat. In 2002 a large area through the town and along the river was scheduled as an Ancient Monument (SAM30097), and this reflects the quality and hence national importance of the archaeological deposits proven to exist in this part of the town.

From the curatorial viewpoint here is clearly a strong case for analysis and synthesis of existing data on the waterlogged deposits given their association with high quality archaeological remains, as proven through excavation. Knowing more fully the extent of the archaeological remains and their quality would certainly be very useful for the process of managing the impacts of the ongoing development of Droitwich on buried archaeology. This synthesis (especially if combined with ongoing updating) could increasingly facilitate the prediction of both the presence and quality of archaeological deposits, specifically where waterlogged, and the more precise location and significance of those remains. The detailed communication of this type of information on the most sensitive deposits is currently particularly difficult in a planning context, and this is critical for where foundation solutions need to be designed so that the successful management of these deposits is achieved.

In addition, as modern construction continues in the vicinity, and also within the most sensitive areas, there has so far been limited opportunity to monitor the effects of this. It would be valuable for the future management of buried archaeology, and of the most sensitive deposits in particular, to be able to assess the impacts of development on the buried archaeology. A base-line study of waterlogged organic deposits (as at York; Holden *et al* 2009), therefore, would also be useful for contributing to the ability to assess/monitor change in these deposits, by providing a useful reference point of available information, as well as emphasising the quality and research potential of such unusually well preserved deposits at the beginning of the 21st century.

3 Research aims and objectives

The **aims** of this project have been:

- to assimilate and analyse all the available archaeological observations in the study area, so as to present an account of below-ground deposits focussed primarily on the waterlogged deposits, and report on results, so that there is greater recognition and appreciation of these significant deposits for the future.

Accordingly the project **objectives** were:

a) to define the locations of previous observations of waterlogged deposits (both cultural and natural) across the study area in relation to depth below ground surface (bgs) and height above natural (vertical stratigraphic sequence), against a background of the local geology, and geomorphology (drainage etc), including deeper hydrological processes eg the brine run and any modern extraction;

b) to assess their dates (by broad periods) with reference to existing artefactual and scientific dating where published, and, also, as far as reasonably possible, where in archive, as this is relevant to any interpretation of relationships between discrete points of observation;

c) to develop a digital 3-D model of these deposits against the background of their modern terrain (eg thickness, depth below the modern ground surface) – so establishing an interpretative model capable of further development where the HER period-based GIS mapping layers created from the models can be refreshed whenever new information comes to light;

d) to provide a layer in the HER that defines the extents of waterlogged deposits. (=GIS Waterlogged mapping layer based on (b-c) – .shp or lyr file as part of the Geology layer);

e) to check data conformity with the Worcestershire HER and its Environmental Index;

f) to seek to place the remains in a wider dynamic landscape accounting for the creation and preservation of such deposits as part of the process of their ongoing research and better future management, and;

g) to provide a case study for the effective integration of 3-D visualisation of waterlogged deposit data within and through HERs in their role of holding historic environment resources, and ensure this is accessible, thereby supporting the effective management and protection of such archaeological assets.

At the outset it was decided that, the provision of a mapping, assessment and presentation toolkit for use in other areas, was not to be included in this stage of the project. It was excluded because, in the event that the results were useful for that purpose, it was realised that, for the toolkit to be usefully developed, there would need to be a period of testing and liaison before an effective product could be produced. This was, therefore, set aside as a potential future project, should the present project results justify this.

3.1 Integration with research frameworks

The importance of recovering palaeoenvironmental data from organic deposits has been highlighted for the Severn valley in the West Midlands Research Frameworks for archaeology (Pearson 2011 a and b), and in the context of the Aggregates Levy Sustainability funded-assessments of archaeology and aggregates in Worcestershire (Pearson 2007; Jackson *et al* 2011). A professional curatorial strategy (Hodder 2011, 248) should include focus on deposits with environmental potential, including both off-site and on-site palaeoenvironmental work to provide a wider context for human activity.

This study represents the first opportunity to synthesis data relating to such valuable, yet sensitive and vulnerable deposits, and is undertaken in accordance with the regional research framework for the West Midlands (eg Hurst 2011, 119; Hooke 2011, 166, including the definition of where such deposits are located ie especially alluviated river valleys *ibid* 167). Nationally, the study contributes generally towards aspects of the NHPP Action Plan of the National Heritage Protection Plan (EH NHPP 2011), as follows:

by developing:

Foresight - NHPP Activity topic 1B ie Identifying threats to, and opportunities for the historic environment and assets

Foresight - NHPP Activity topic 1D ie by providing mechanisms to identify flexible/timely responses to changing circumstances and to review effectiveness of outcomes

by providing:

Strategic threat assessment and response - NHPP Activity topic 2A ie 'Development-based threats'

Understanding - NHPP Measure 4 'Assessment of significance', in terms of predicting significance of deposits;

and (potentially) improving:

Response - NHPP Measure 5 'Protection', by synthesising data for input to the HER and potentially developing mechanisms for better combining and presenting data.

The study explicitly forms a component of:

NHPP Measure 3, **Identification of potential**, and NHPP Activity Topic 3A 'Identification of heritage assets and their significance', **specifically 3A5 'Identification of wetland/waterlogged sites**'.

4 Project scope

The project specifically includes:

- the modelling of buried deposits, specifically all available data relating to waterlogged deposits in Droitwich, regardless of whether associated with salt production or not **ie all waterlogged deposits in the study area**, and;

- the creation of the means of effectively disseminating these data to best advantage for ensuring that there is appreciation of the resource and facilitating its management for the future.

The project has specifically **excluded**:

- overlap with the Worcestershire Wetlands project (EH project ref 6244);

- detailed data compilation in regard to other (ie non-waterlogged) archaeological deposits, except in so far as these may be relevant to an understanding of the archaeological characteristics of the waterlogged deposits;

- most detailed lithological data, especially where derived from boreholes, except where the latter are useful to establish the top of solid geology, water-table level, and top/bottom of bulk glacio-fluvial (terrace) deposits, and made-ground (ie interpreted bulk deposits);

- the formal creation of an overall dynamic geomorphological valley model in explanation of data, though allusion may be made to formation processes, as appropriate, and;

- any field validation ('ground-truthing') of the resulting deposit modelling, as the extents and methods appropriate to such an exercise cannot yet be specified, nor is the desirability of such a course established.

5 Interfaces

The project interfaces with a number of past, on-going or forthcoming projects, and archaeological policies as follows:

- Central Marches Historic Towns (Buteux and Hurst 1996)

- West Midlands regional framework for research (Watt 2011)

- Mapping of organic deposits in Worcestershire (Pearson forthcoming)

and the following wider planning/policy frameworks looking forward:

- Wychavon District Local Plan (adopted June 2006) (http://www.wychavon.gov.uk/cms/pdf/wdc-planning-lp-plan-local_plan2-_for-web_.pdf) where the planning policy on 'Sites of archaeological significance' (ENV 10) is stated as follows: that 'remains … vary in terms of … their present state of preservation', and stipulates 'preservation' or, in appropriate circumstances, mitigation in the event of the removal of archaeological remains.

- Current review of flood risk and as yet unspecified local responses as represented by the initiative *Flood Risk Management in England* (National Audit Office 2011), published as policy by Department for Environment, Food and Rural Affairs and Environment Agency in October 2011 (available at http://www.nao.org.uk/publications/1012/flood_management.aspx).

  Though flood risk my not pose direct risks to the deeply buried archaeological deposits forming the subject of this report, there may be ancillary works (ie flood defences and other related structures ie balancing ponds) that would pose a very real (either immediate or longer term) threat to these remains. At a time when greater responsibility and discretion has been devolved to local authorities to identify flood risk, and in the present economic circumstances it remains uncertain how much of a current risk this represents to buried archaeology (ie internal WCC communication needed on this subject).

- 2012–18 programme for water abstraction for the middle Severn catchment (see http://www.environment-agency.gov.uk/static/documents/Research/worcs_cams_1872801.pdf as part of the *Catchment Abstraction Management Strategy* or CAMS), where the River Salwarpe is recorded as 'over-abstracted' over most of its length, '… causing unacceptable damage to the environment at low flows' with on-going monitoring of the River Salwarpe by the Environment Agency re water levels (gauging station at Harford Mill, downstream of Droitwich at 19.15 AOD (see http://www.environment-agency.gov.uk/homeandleisure/floods/riverlevels/120744.aspx?stationId=2007).

The primary users of the project products are expected to be:

- archaeological practitioners, developers, researchers and members of the public who consult the HER (facilitating the latter in line with their potential greater involvement in public engagement - see http://hc.english-heritage.org.uk) – and particularly the Worcestershire HER and Planning Advisory Service (both of whom were consulted in the preparation of this proposal), and;

- a wide range of other professional bodies and organisations, especially those, such as the Environment Agency, engaged in general planning policy formulation and implementation. It should also not be underestimated, given the widely known significance of Droitwich archaeological deposits, that members of the (informal) local heritage network are also likely to find the study of particular interest, especially in the context of developing policy links between localism and heritage - it is accordingly envisaged that the local community could find the presentation of archaeological data easier via a 3-D interpretation (with appropriate caveats) and, therefore, this project could facilitate the aims of the Localism Bill which aims for communities to be more involved in decisions that affect them (ie by making the data from site archives more widely available).

6 Methods

The project follows the format and procedures described in *Management of research projects in the historic environment: the MoRPHE project manager's guide* (English Heritage 2006).

Where possible, standard terminology will be used for period and deposit description (HMRC period list and MDA thesaurus respectively). It was found necessary to also pay attention to the variable terminology encountered in borehole logs and archaeological recording to make this consistent. To provide more complete data some assumptions were also made (eg that alluvium was Holocene in date).

Study area

The main study area is shown in Figure 1a and has been defined in order to include:

a) the known areas of waterlogged urban archaeological deposits based on existing field data, as being the principal focus of the project;

b) the main river system and its tributaries within the modern urban area of Droitwich, as the wider urban and hydrological context, and;

c) a rural remnant on the edge of the built-up area at either end of the selected river course where natural character of the river valley is evident, as an area potentially under threat from major development.

This study area, therefore, encompasses sufficient area to provide a context taking into account geological and geomorphological aspects (notably brine run and river valley) and their contribution to the extents and character of archaeological deposits across the town.

Stage 2 – LiDAR/Rockworks and GIS layer design, and data collection (desk-based survey)

Following completion of a formal project design (Stage 1) consultation was firstly carried out in close consultation with Keith Wilkinson and with the HER to specify the particular data fields which should be populated during data collection, so that the required analysis was within the capability of the project data.

LiDAR data

LiDAR data covering most of the proposed study area was acquired from Geomatics Group (Environment Agency) and used to create an overall digital terrain model (DTM) for the study area. These data included coverage of extensive built-up areas, where data processing had removed features obscuring the existing land surface, thereby revealing the underlying topography. DTM 1m LiDAR ASCII data (including elevation) at 1m resolution was available for the entire study area shown in Figure 1a (total of 11km^2); except for its extreme south-east corner. The data was described as accurate to '+/-15cm RMSE in Z (root mean square estimates of the elevation estimates)'.

The initial creation of the ground-surface model was a critical step, since the archaeological data (based on its original associated locational data) could then be suspended beneath this surface, thus enabling true 3-D plotting of individual points and, thereby the full spatial plotting of the archaeological observations. This process was then used to produce an atlas of that data, and, therefore, of the buried deposits. The DTM view also allowed for the identification of surface palaeochannels due to the fine resolution available in this data-set.

The LiDAR data was purchased on the basis of internal use (ie non-commercial) and this required that any results displayed using the data must ensure that the raw data cannot be reverse engineered and, where published, are made available free-to-access.

Development of GIS layer

All deposits (ie both archaeological and where naturally derived) identified as having potential for organic preservation, after initially plotting within Rockworks, were intended to be exported into a GIS (with ArcMap Version 10). A contour and watercourses layer from the HER GIS was incorporated as a separate file to supplement the map background available to Keith Wilkinson, and to aid incorporating the generated models within the HER.

Sources of the data - archaeology

Project records in the county archaeological archive were searched for relevant data. **Existing** observations (eg archaeological observations on **all waterlogged deposits**) were collected, collated and assessed from (un)published project archives. There were two main collections consulted:

a) 'Grey literature' reports as published via http://www.worcestershire.gov.uk/cms/archive-and-archaeology/search-our-records/online-archaeology-library.aspx;

b) Project archives - often the place where the most relevant data for this study still resided (as currently held in the Worcestershire Archaeology office at The Hive);

An HER search was also requested on environmental remains (which includes waterlogged), but the latter data were not straightforward to extract due to the current specification for assimilating this type of site data. The HER, with its GIS basis, was, however, particularly useful for resolving any issues relating to the following criteria:

a) site location, especially where, in some cases, several observation points were to be recorded within the same site (ie for larger excavation areas), and so accuracy was required to the nearest metre, though, generally, grid references were recorded to within 10m. One of the most common issues was missing/limited NGR data and this was also resolved by recourse to the HER and laboriously pinpointing each observation point with reference to available map resources, and;

b) site name/address.

On larger excavation areas it was intended to extract the relevant information for at least two opposite points on the site – site labelling, for project purposes, was adapted to reflect this.

Specific data from archaeological archives were collected as follows (**NB this information was generally not available from the uploaded site data already held within the HER**):

a) waterlogged **layers** recorded during archaeological works. Both cultural (identified to period), and natural (eg alluvial) deposits represent key data (especially where well-dated top and bottom levels area known) – this excludes waterlogging in specific features, as these sometimes comprised localised burial environments with waterlogging, for instance in the case of the clay-lined tanks typical of the pre-medieval salt industry (Woodiwiss 1992, 10–13);

b) presence and nature of water-tables, where available (usually incidental references in (a));

c) location of contemporary wetland deposits, as these are known to be potentially of considerable archaeological significance (cf Impney; Williams *et al* 2005), including areas of current and former wetland as mapped by the *Worcestershire Historic Landscape Characterisation Project* (http://www.worcestershire.gov.uk/cms/archive-and-archaeology/information-and-advice/projects/historic-landscapes.aspx), and;

d) indications of wet deposits in the recent past as recorded on larger-scale historical mapping (particularly on the 1st edition OS of the later 19th century).

Sources of the data – borehole logs

A considerable amount of borehole data was available on the BGS website (http://www.bgs.ac.uk/data/boreholescans/ - this category of data was virtually entirely from this one source, apart from a few borehole observations taken for archaeological purposes. As much archaeological and geomorphological data as possible (both aspects often involving interpretation) was extracted here, while also sifting out the purely lithological data. Relevant data from all the available boreholes logs was included and, fortunately, the majority of logs were freely available as scans on the BGS website. However, some were only available for a fee and these were not used (two areas in particular were left blank as a result of this: *viz* centred on SO 9050 6340 and 8835 6330). Where additional, mainly lithological data, was captured, this was retained as potentially of future use. For instance, by implicitly recording energy, this could provide some idea of the environmental potential of deposits, such as during the onset of an interstadial (A Howard, pers comm).

Data collection

The archaeological data was compiled on a *pro forma* sheet. This reflects the nature of the archaeological data where the relevant quantitative and qualitative data had to be reconstructed from the site archive, and/or incidental comments in the report. Once available the information was often, especially for larger sites, schematised in order to produce data that could be expressed as a spot observation, so that this could be plotted.

Data management

A spreadsheet in Excel format was exported from the ARCA (Department of Archaeology consultancy, University of Winchester) RockWorks borehole database and was used as a template. The data were then managed and manipulated using the RockWorks 15 geological utilities software (RockWare Inc 2013), which utilises a Microsoft Access engine to store data in a series of inter-related tables each recording a different property, as follows:

a) location: the Ordnance Survey National Grid Reference (NGR), Ordnance Datum (OD) elevation and total length (depth) of the observation;

b) stratigraphy: an interpretive category grouping strata (whether lithological or archaeological) into formal geological/archaeological sub-divisions.

Broadly the data were grouped into a number of (non-formal) stratigraphic categories, as below:

Topsoil
Cultural deposit
or Organic Cultural deposit
or Redeposited Marl

Holocene Alluvium
Holocene Organic Alluvium
Lower Alluvium
Pleistocene Terrace**
or Kidderminster Station Member

Droitwich Halite Member
Mercia Mudstone Group
**undifferentiated terrace member including Kidderminster Station Member (4th Severn Terrace)

Distinctions were sometimes on a pragmatic working basis rather than defined in any precise way (eg peat *versus* organic alluvium). RockWorks also required all stratigraphic units to follow a consistent pattern of inter-relationship – while this was clearly no issue for simple period designations, it did cause an issue where another attribute was attached (eg 'waterlogged/medieval', as that could be both above and/or below 'medieval'). This meant that waterlogged archaeological deposits could only be modelled by reference to separate labels which were non-period specific (ie 'organic cultural deposit'). Though 'Holocene organic alluvium' usually worked in the same way there were occasions when stratigraphically its position caused RockWorks a problem and so 'Lower Holocene alluvium' had also to be introduced, though effectively the same material. Therefore, some temporary adapting of the data labels for organic alluvium ended up being necessary to display the data – in presentation this could be made seamless by using the same conventions for both units. The Excel spreadsheet was finally imported into separate RockWorks projects resulting in databases containing stratigraphic data by formation and by archaeological period.

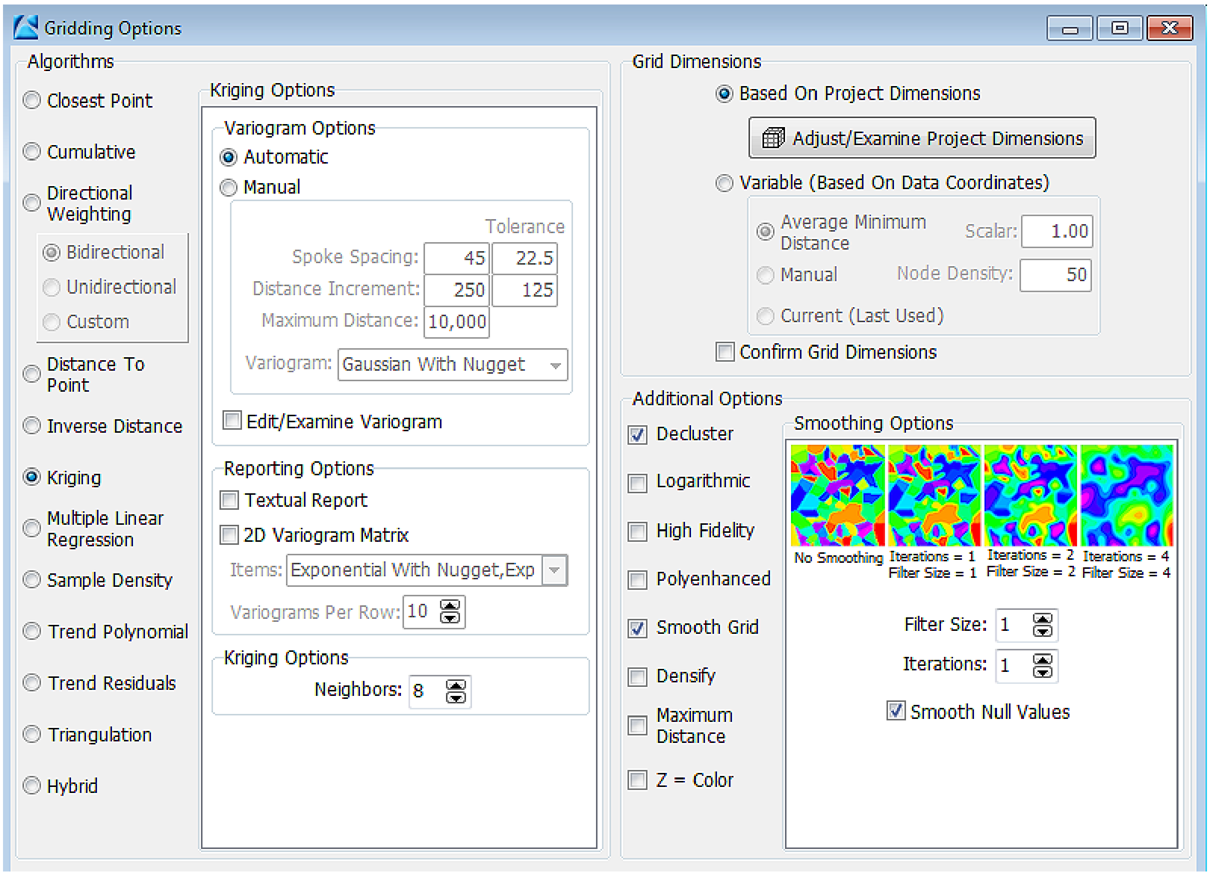
Where uncertainty existed about the accuracy of data this was indicated by colour-coding the data (amber = slightly uncertain; red = doubtful), but this property of the data was ignored by RockWorks during any plotting. Unfortunately it was not possible to discount in plot outputs those areas where data was inadequate.

Where heights above OD were missing from the record it was possible for these to be independently inserted from the LiDAR data.

Stage 3 – Data input, collation and analysis

Data modelling

Models were made of the stratigraphic data on the basis of the stratigraphy categories of the two databases and using the two-dimensional 'Structural elevation' and 'Stratigraphic thickness' routines of RockWorks 15 (= 'Combined stratigraphy' table). Given that the geographic locations of the data points (ie boreholes and stratigraphic records) were not evenly spread out across the study area, a Kriging algorithm was applied, the models being run a number of times with different number of 'neighbours' (ie surrounding records of deposit elevation or thickness), and '8' was a compromise used to generate the final models. The filter size and iteration values were adjusted to their maximum ('4' in both cases), but '1' was settled on, since, although the smoothed model that resulted looked visually more attractive, it gave rather a false impression of accuracy. Therefore, minimum declustering and smoothing setting was used so that the modelled data took the greatest possible account of the variation in the original data.



A series of composite cross-sections was generated from the databases by employing the Striplog function of RockWorks. The purpose of these cross-sections was to explore changes in stratigraphic properties along axes perpendicular to the river channels and also to explain variations seen in the structural elevation and deposit thickness models.

A trial run at plotting based on the first draft of the data-set revealed that, on average, there were too few points of observation across a large part of the survey area. This suggested that it would be advisable to define an inner area where the most information was available. The plotting of results by period was affected by the same deficiency of information which reduced the efficacy of any period plots. Where all the data (boreholes and archaeology) were combined, however, certain aspects of the buried deposits (top of solid geology, and extent of alluvium, cultural remains, and general waterlogging) could be drawn out with some greater certainty that reflected actuality. This was especially the case for the central area of archaeology where all points of observation were used (ie Fig 8).

Contextualisation of the study

A brief specialist review of the general geomorphological context was also undertaken (by A Howard), mainly using BGS mapping, so that the defined urban waterlogged deposits had some wider context as to their setting. This context was quite limited in extent and was derived primarily from about 1km beyond the main survey area (ie where just beyond the sub-/urbanised zone).

Stage 4 Results - report production and dissemination

Data output

Plots of the data constituted one of the main outputs of the project. The structural elevation and deposit thickness models generated in RockWorks were exported as Shape files and then read into ESRI ArcGIS 10.1. Once a scale, north arrow and a key had been added, the resultant maps were exported. For the plots 'AI', 'TIF' and 'JPG' images were produced, the first two being the at full 600dpi resolution for use in the report ('JPG' images being produced at 300dpi resolution for general use). Some further editing was necessary in Illustrator to create the final figures to the required standard (eg adding joining lines between the individual locations across the cross-sections, such as Fig 17), but this was limited to further facilitating data display rather than more cosmetic issues such as scales and keys. A 'GIS' directory contained Shape files for all of the models and was intended for the HER (where a separate mapping layer based on a .shp or lyr file was created as part of the Geology layer; Oliver Russell, pers comm).

A brief report summarising results (including models generated in RockWorks, where appropriate) and evaluating the project was prepared at the conclusion of the project and, as part of archiving the project, data (Excel format; any LiDAR data omitted), is intended to be submitted to the ADS.

In the light of the project experience the following would also be capable of being considered in terms of follow-up after the final reporting:

a) the possibility that the project could constitute a pilot study for wider application in similar circumstances (the 'toolkit'/ guidance), and so be of wider professional interest. Though it was appreciated that this would require further development beyond this project in order to ensure a good fit with HERs and the historic environment process generally (but it would also be dependent on the results of other similar projects being undertaken in parallel; J Heathcote, pers comm. - January 2013), and;

b) whether the results were capable of wider dissemination applying new presentation technology. For instance, a larger interactive system, TouchTable (http://www.touchtable.com/products-tt45.php) at the new library and history centre development in Worcester (*The Hive*) may be a way of providing a more interactive and engaging means of publicly presenting the data - though not formally included as a product of this project, this specific outcome is considered highly desirable for disseminating the results to a wide public audience.

An article is also intended to be produced for inclusion in the journal *The Historic Environment. Policy and Practice* to highlight the approaches used and potential of such mapping to the archaeological profession. This will include what was tried and how/why it didn't work, in order that others can assess the likelihood of success with similar standards of data. However, it is possible that this might be best undertaken as part of a stage developing the toolkit, as then a more definite vision could be given of the product and how it would be achieved.

7 Results

Data was collected for the purposes of this project from the following sources, and plotted three-dimensionally on the LiDAR-derived DTM (Figs 2–3):

i. Archaeological sites: in all 85 archaeological observation-points were included based on 68 project reports/archives which were checked for relevant data, and of which 41 produced useful relevant information. For the larger sites multiple observation points were normally selected to cover the extents of the site, usually relying on the main recorded sections. The 27 sites omitted qualified for this treatment on various grounds, including having no section record or otherwise insufficient records, or sometimes due to an inadequate archaeological response to the archaeological threat in the first place (eg Middlewich brine pit salvage work which predated PPG-16).

ii. Geotechnical sites: a total of 385 boreholes were included in this data survey. In many cases deposit description treated all archaeology as made-ground so there was no possibility of period differentiation, nor of any interpretation of these deposits given the many different types of 'artificial' ground (Price *et al* 2011). As with archaeology data the recording of waterlogged conditions was not always specific in the logs, and had to be inferred from the terminology used (eg the use of terms such as 'wet' or 'damp', combined with the recording of water-strike data). The borehole lithological data were not subject to so much variation and were collected as seen (ie without the need to manipulate and adapt data to make for consistent data entry).

Modelling the data

Each figure (Figs 1–24) is described in an extended caption. In each case plots have been modelled using RockWorks by extrapolating from all available observation points within the extents of that figure. Thickness of waterlogged cultural deposits is only plotted for the core study area (ie Fig 14), as data is lacking for the wider study area, and this presents difficulties for general plotting (see more below). These data have been used to create both thematic plan models (Figs 4–15) and cross-sections (Figs 16–24).

8 Discussion

It has been possible to closely integrate the archaeological and geotechnical data, though in the latter case considerable interpretation was necessary. It was noted that the geology of the area lends itself particularly to this approach, as the deposits are often quite unequivocal, even when different descriptions were used. Overall, the interpolated plots were produced at two different scales: firstly at the level of the whole survey area (eg Fig 4), and secondly for a core area defined as the key archaeological area (eg Fig 8; including the historic salt-making centres of Upwich, Middlewich and Netherwich, for the locations of which see Fig 15), as well as being that area with the densest archaeological/geotechnical data.

The 3D-modelling approach has allowed looking at the archaeology of Droitwich in a different way than usual (eg at a different scale), and one of the main conclusions is that there is a case to be made for a correlation between the quality of archaeological deposits and the underlying palaeotopography as represented by the geology. In particular, it can now be seen by using 3D analysis that the Pleistocene/Holocene/archaeological deposits are, in fact, (to a large extent) fills within micro basins at the top of the solid geology. Modelling the data has, therefore, allowed these basins (possibly including ?later subsidence hollows - though the current explanation of subsidence on its own cannot be used to explain these hollows, as they do not all overlie the brine run) to emerge. The concomitant plotting of the cross-sections has revealed this most clearly for the Upwich area (historically the principal salt production centre), though deepening to its east (Figs 4 and 8; for location of Upwich see Figs 7 and 15). Possibly solution of other salt deposits west of the main brine run (ie situated over the wet rock head) as mapped by Poole and Williams (1980), near the surface and, therefore, prone to groundwater (especially by the river), could account for this pattern of lesser and more localised discrete subsidence hollows (cf Cooper 2002, 510). Though other factors such as scouring by the river may have formed/augmented these features (A Howard, pers comm).

The identification of these hollows in the surface of the solid geology is particularly significant since, due to their infilling, they are no longer visible in the present topography (see eg Figs 20 and 22). This information should now significantly enable archaeologists to suggest new reasons for why archaeological deposits are present and for their composition, and so potentially explain more systematically some of the variation in the quality of these deposits, as well as aiding the prediction of areas where preservation will be likely. The latter is borne out by the correspondence of the thickest area of known waterlogging corresponding with the buried basins (cf Figs 4, 6, 8 and 15). There was also a reasonable correspondence here with mapping of flood-risk areas by the Environment Agency, where such surface effect was still apparent from these underlying basins in the Holocene/Mercia Mudstone surface (http://maps.environment-agency.gov.uk/).

It is considered that the models of the greatest reliability are those where deposits occur in many records, and this particularly applies to Mercia Mudstone, Pleistocene gravel and alluvium. In which case these geological deposits can now be modelled with reasonable confidence (including with the HER where it has 3-D capability) and so provide the detailed palaeotopography within which archaeological deposits were formed, at least where these records are most dense – hence the confidence in the existence of the micro basins. From the geomorphological viewpoint these models show some more potentially interesting patterns, including the following possibilities:

> Pleistocene gravel is found on the valley sides (from a purely geological point of view it would be interesting to look at the elevation of the gravel outcrops and to see whether there are multiple terraces), and not in the valley base, i.e. there is

> no floodplain terrace. These data might be consistent with a subsidence hypothesis as most river systems in central and southern England do have a floodplain terrace, ie Holocene alluvium adjacent to present river channels sitting on top of Pleistocene gravel. Another argument suggesting that subsidence might be of importance in the Holocene is the fact that Holocene alluvium outcrops on the valley sides (where it does overlie Pleistocene alluvium). It would be interesting to look at the elevation it reaches, compare it with that in the valley centre and this might give some indication of the subsidence. Ideally one would drill the alluvium in these different locations and date it to determine whether subsidence was uniform or only related to certain periods in the Holocene. (Keith Wilkinson)

Given the rather limited options there have been during the course of the project for checking and re-running the plots in various different ways, as well as experimenting with different cross-sections, it is important to acknowledge that the plots presented in the report should be regarded as samples, with various alternative models being possible (depending on software settings etc) rather than there being one definitive model. This was also complicated by the variability of plot presentation style, which added a necessary stage of experimentation, though not formally part of the project. The complex procedure for generating the plots especially prevented convenient selection of the best presentation option in each case, despite the arduous efforts made in this direction. However, many hypotheses can now be generated from the models now that the data has been input (ie the plots included in this report do not constitute all the possibilities), and then tested by re-running the data. For instance, new cross-sections from the records in the stratigraphic database could now be used to test new interpretations. However, it should be borne in mind that the models cannot be taken at face value for many parts of the study area (most especially where data is sparse), and so should only be seen as providing, most particularly in these cases, just broad guidance.

The project has pursued the wider context in an effort to better understand the phenomenon of waterlogging in the specific context of Droitwich, and to have focussed overmuch on just the waterlogged deposits would have only ended up with up to four models, all of which would have been unreliable and, therefore, would have been of little inherent use. In that case, in terms of mapping, by far the best approach, given the relatively few records of waterlogged deposits, would have been simply to plot these occurrences as graduated symbols (ie larger symbols for greater thicknesses). But, by going beyond the letter of the brief (in accordance with the proposal; Hurst 2012), some very interesting data have now been generated, including a greater possibility of understanding the extents and survival of the waterlogged deposits within a wider physical context (ie see above).

In most respects the emerging picture should still be regarded as impressionistic, until further data has accumulated and then more testing been carried out. Importantly, the current impressionistic results are now capable of refinement as more data becomes available, **as long as the dataset is added to and the plots regenerated**. As well as finding where new waterlogged deposits are most likely to occur, additional results have been to identify where period deposits are apparently absent or truncated, and where data are inadequate, such information being latent in the figures already produced. Further focussing in on the very specific areas where the data is at its maximum would also be worth doing, if development was due to affect these areas (ie this would enhance parts of the existing plots).

Apart from the palaeotopographical features referred above, the plots do seem to indicate several other salient aspects, such as:

a) the relocation of activities over time, at least measured in terms of the deposits left behind. Though these do not represent new information there is now the possibility to more readily assess the thickness of cultural deposits across the town (with the caveats cited above) and their potential for being waterlogged;

b) the abrupt variation in the top levels of the Mercia Mudstone which is probably the best indication of subsidence (eg Fig 22). And where this is observed, it seems to occur on one side only, as if the ground has fractured unevenly across the drop zone rather than being a whole area evenly subsided. Though the possibility of scouring by the river should also be considered in this context (A Howard, pers comm). Some consideration might, therefore, now be given to the mechanism giving rise to this effect.

Other apparent anomalies, however, may point to new aspects of interest, for instance as follows:

a) in the distribution of the occupation debris, when viewed against the palaeo-topographical bias now revealed in the landscape, though this is probably explained by the need to site certain activities next to the best sources of brine (see Fig 14) and for habitation to avoid the areas most prone to flooding;

b) the surprisingly high absolute elevation of the top of the waterlogged cultural deposits, presumably where these deposits are at their greatest extent (Fig 15).

Some quite positive results seem, therefore, to have been achieved in a project using software still relatively unfamiliar in archaeological applications, and reliant on data of a kind not easily extracted from archaeological archives (the latter in particular suggests issues that really must be addressed for the future – see more below). Whereas, at the same time, considerable limitations have also been encountered, and by no means always overcome.

Limitations

Some limitations were due to lack of familiarity with the RockWorks software by the principal author, as it has very specific requirements for the form of the data and the way it is output is also circumscribed and rather complex given the demands on the data needed and the range of modelling options available (see more below). Greater familiarity would have enabled more proficiency to overcome some of the drawbacks listed below but by no means all.

The impacts of the limitations and drawbacks described below were only fully realised once the project was already under way - where possible their effects were minimised as far as possible, but in many cases their negative impacts remain embedded in the plots as they relate to the quality of the data being used, and the ability of the software to use that data for creating the models, each time subject to pre-sets which might need adjustment to optimise the individual outputs and/or create a more aesthetically pleasing series.

On a positive note the issues of file size that were initially expected to obstruct data transfer by email in practice failed to materialise, and so the Dropbox facility that was put in place for this purpose, was ultimately not needed.

Manipulation of data

There were several instances where visual parameters of the outputs were pre-set by RockWorks, which was not really at all ideal for such a project where analysis required flexibility in data manipulation. For instance, the vertical interval for the cross-section diagrams was pre-set at 2m, and thicknesses of deposits could only be plotted down to a minimum of 0.2m, both of which could result in the loss of more subtle effects.

Rockworks also only modelled one category of data at a time which prevents more sophisticated analysis on screen of where one variable might be affecting another, and, instead, multiple print-outs have to be compared.

Presentation of the data

The practicalities of the routine of exporting the RockWorks plots and cross-sections was really quite involved, and this even meant intense and lengthy sessions when finalising the appearance of the figures (apart from any more cosmetic work that was done in Illustrator on individual figures). The strictly time-limited sessions available meant that other plots and cross-sections suggested during the course of the analysis stage, could not be fully pursued, so that, for instance, once the micro-basins were identified in plan, a cross-section along the base of the main valley was not possible within the confines of the project.

In practice it was also found that there were some minor limitations experienced with outputting the plots where there was a limited colour palette for shading variation – this explains why so many of the plots use red as a principal colour as the human eye seemed more attuned to variations in shading in this colour. The strict sequential issue mentioned above (in Methods: data management) for how stratigraphic units were labelled also had a minor impact that some cross-sections had to be subsequently slightly adapted in Illustrator to create the finalised figure (eg Fig 21). It was also difficult in some cases to ensure the specified stratigraphic units were always consistent in their relationships to each other, most obviously where alluvium could intervene at any point. In retrospect more thought should have been paid to this, as some of the re-running of the data resulted from not getting this right from the start. RockWorks for similar reasons did not readily lend itself to tracking waterlogged deposits as this was focussing on a variable attribute rather than a single chronologically based unit. To render the waterlogging and yet retain period detail, it was sometimes necessary to manually adapt the figure to show the waterlogging (eg Fig 21), while in 3-D modelling period information about waterlogging was supplanted by 'organic cultural deposit' as appropriate (Figs 17–24). Another issue was the tendency of RockWorks to fill the whole area of a plot with whichever category of data is being modelled regardless of how sparse or uneven the data - there were cases where this seemed to generate false positives where were particularly unhelpful (eg Fig 15).

Paradoxically the great range of possibilities for output styles (both black and white and colour – but see below) made fixing on a preferred style problematic given the limited time available to determine the final appearance on the plots (ie just two joint team consultations).

Given the imperfections of the data (irregularly spaced and often insufficient) and also of the software output (see above), the drawing of boundary lines on the map plots was not considered feasible – indeed the plots have to be read largely as indications of confidence where greater presence (most often thickness) equates to a greater certainty of presence of any given quality and vice versa. The map plots (Figs 4–15), therefore, cannot be taken at face value and have to be carefully interpreted along these lines.

9 Conclusions

This project represents an attempt to plot archaeologically rich (ie waterlogged) deposits in such a way that useful information might be made available more easily for their future management, especially in an urban area where there is considerable development pressure. As such it is a continuation of an endeavour that was initiated in the 1960s/70s when the accumulation of urban archaeological data was envisaged as a way of seeing 'what types of deposits survive, where and to what degree … [leading to] strategies for preservation' (EH Brief for Urban Survey Documents). This falls under the rather innocuous phrase 'identification of the archaeological resource'. Though the theory was conceptually fairly straightforward, the implementation was largely a different matter, due to variability in the quality of the archaeological data needed for this purpose, and real success was probably only achieved most arguably in the rare instances where a resident unit had operated over a long period (eg York). At this time the concern was largely focussed on preservation, and so locating period deposits was considered essential if their value was to be assessable against research priorities, so establishing the case for preservation was essential for this process – any surprises late on in the field project were unlikely to be accommodated in any such scheme. Though this is not the place to critique this approach, the changing fashion in research priorities is certainly one area of weakness in such a strategy; and the practical difficulties encountered in mapping and displaying the data remained an obstacle (ie preferably with the option for readily redisplaying the data, as more information was accumulated), until the introduction of computers which allowed complex spatial analysis for the first time, and ease of re-iteration with supplementary data. Though, even then the variable availability of the key archaeological data has remained an issue, perhaps now even exacerbated by the fragmentation of archaeological provision by its delivery by a range of different organisations, increasingly the case since the mid 1990s. By 2006 it was finally being reported by BGS that with increased computing power and the new availability of digital terrain models that a new survey product (a systematic 3-D model) was possible.

Deposit modelling

Remote sensing of archaeological remains has a long history, much of which being when aerial archaeology led the way in site discovery. Now other possibilities are emerging, which are suited to use especially in alluvial environments by modelling drainage patterns (eg Challis and Howard 2006), and there has developed also an interest in three-dimensionally modelling buried deposits as more information has been accumulated from fieldwork. In some cases, both these strands of investigation have been brought together. Whereas this is not the place to expatiate about the history of this new endeavour of archaeology, there have been several attempts in recent years to address this sort of issue, of which examples are: Great Yarmouth (Hamilton 2006; most relevantly to this project in terms of general methodology, though not so relevant geomorphologically since it is on a marine plain), Nantwich (SLR 2007), Hereford (Baker and Preece 2010), and Lea valley, London (Corcoran *et at* 2011). In addition the general subject of waterlogged preservation has also been investigated more thoroughly, including the physical circumstances in which it can occur and the attendant (largely chemical) processes (Holden *et al* 2006, and the PARIS papers in Corfield *et al* 1998, Gregory 2012, Kars and Heeringen 2008, and Nixon 2004), while the physical impact of anthropogenic activity in the form of urban environments has also formed the subject of major study (London where archaeology was subsumed under 'soils' for the URGENT (Urban Regeneration and the Environment) project).

Where these projects are particularly focussed on waterlogged remains, each has employed a different methodology indicating that archaeologists are also currently exploring the possibilities offered by new technology, at a time when accumulated data from many interventions is persuading many that modelling should be capable of providing some pre-emptive gain, notably where decision-making is necessary about mitigating the results of development. In some cases methods used from other fields have been redeployed in archaeology such as RockWorks, which, more conventionally, was initially used to study the form of geological deposits, for instance at Bristol (Wilkinson 2003).

At Great Yarmouth 114 boreholes were sunk specifically to gather information in an urban archaeological context where relatively little information was available, and were supported by a programme of analysis and dating. The data was interpreted via RockWorks, and was then used to inform development work by providing a palaeotopographical context for the whole town (Hamilton 2006). The advantages of the resultant diagrams for the purposes of public presentation and outreach and applicability to the planning process were pointed out as a part of the delivery of this project with both geological and archaeological phases being revealed.

Recent assessment of waterlogged deposits at Nantwich (Cheshire; SLR 2007) where the same industrial associations were present, and here, as at Great Yarmouth, additional fieldwork was undertaken as an integral part of the project, most especially to fill in gaps in coverage. Here the data comprised 43 archaeological observation points (of which only 7 have comprehensive data on levels of waterlogged deposits and where the majority of sites have only an approximated surface AOD) and 109 boreholes. Here great attention was paid to surface aquifers, and one of the main factors in the waterlogging was concluded to be the historic change in the river (SLR 2007, 18).

For the Hereford project already existing data was used, and here it was concluded that information was too sparse to allow useful results for mapping archaeological deposits; only 6.5% (25) of all interventions provided useful information, and a similar approach based on the use of DTM LiDAR was applied, though without any interpolated modelling (Baker and Preece 2010). This contrasted with 60% (41) of sampled Droitwich archaeological observations providing useful data, even apart from the substantial additional information gleaned from numerous borehole records. However, the gain in visual presentation of subtle effects within Hereford urban topography was amply demonstrated in the LiDAR data itself.

In London the Lea valley has recently been investigated via modern geotechnical boreholes for the purposes of recreating larger tracts of past landscapes and the predictive modelling of human activity (Corcoran *et al* 2011), and this, in its broad framework, has some similarities with of the Droitwich project in terms of a heavy reliance on borehole data for some parts of the study area, especially where little archaeological recording has been done.

Other projects associated with waterlogged deposits have sometimes had an equally important but different focus. As at York, where in the 1990s a spectacular example of decay of waterlogged deposits was demonstrated to have occurred post 1960–1994, apparently affecting the upper 2m of archaeological deposits; but here the focus has been on monitoring burial conditions rather than modelling the deposits (Kenward and Hall 2000; Davis *et al* 2002). Due to the dawning awareness of the possibility of damaging waterlogged deposits, even when they were not directly impacted on by a development, other related projects have been subsequently initiated. These have had the effect of encouraging the collection of data sometimes, or perhaps most usually, in situations where deterioration was expected due to recent development (ie the monitoring being installed as part of that development). This stemmed from a professional focus on gathering data for the better predictability of changes in buried environments depending on impacts from modern development, so that eventually greater effort could be made to protect these deposits in advance. However, professionally this must be seen as largely a second-tier response to the more important task of being able to confidently predict where waterlogged deposits might be located in the first place.

As can be seen from the above, there are currently both practical and methodological uncertainties facing the management of what is acknowledged to be the most valuable archaeological deposits, where waterlogging has occurred. This project engages with this debate on the best way forward on this front

Droitwich

Natural organic deposits have first come to light during archaeological works (Mann 2007) and others have been recorded in the past (eg peaty alluvium at nearby Huntingtrap common; Mitchell *et al* 1961). The combination of both widespread natural organic deposits as well as high quality waterlogged anthropogenic remains at Droitwich suggests that this is a general area where remains should be expected along the lower part of the river valley rather than viewed as an exception. However obvious these have been made by archaeological work in the field, it has still been possible for severe damage to occur quite recently, as at Impney (just east of Droitwich), where Mesolithic deposits were machined away as part of a development in *c* 2005.

Though unclear as to its impact, the current EA assessment of the water landscape for this area also indicates that water is currently fully utilised to its full quota for farming and industry in the Droitwich area (ie only restricted water available from aquifers (Environmental Agency 2013, 13, map 3). Surface water is also subject to restriction, with for much of the year more groundwater already being abstracted than 'available' (*ibid*, 11). Such an assessment may suggest active decay and so diminishing longer term viability of any organic deposits in the Salwarpe valley. This situation has already prevailed for some while as the River Salwarpe and it tributaries were being designated as being 'over-abstracted' in 2006 (Environment Agency 2006, 16). The effects of this on buried archaeology are presently unknown, though the additional presence of brine springs in the town area may mitigate any shortage of ground/surface water.

The above indicates the need for a more proficient way of determining the likely presence of waterlogged deposits rather than the continuing tendency to underestimate their extent, especially where the process is led by consultancy without any detailed knowledge or experience of such sites with their heavy requirements (and therefore) costs for analysis and reporting.

For Droitwich this first attempt at 3D-modelling the data can be considered to have had some beneficial results as follows, though with the acknowledgement that more data is always needed, and that there are considerable drawbacks in working with RockWorks in this way and weaknesses in the resulting outputs:

a) initial results suggest that the modelling has worked in terms of suggesting fresh interpretations (and even new discoveries) based on existing data, while the limitations of the methodology have also been pinpointed for future reference;

b) a lot of available data has now been combined in a single data-set which is now available and which can now be supplemented in the future to enable more refined plot to be produced, or reworked to test alternative hypotheses. As data continues to accumulate it will be increasingly possible to model the underlying Holocene ground surface – other features may also be identified such as levees associated with the historical alluviation, and such features may well be very important for understanding more localised waterlogging.

This Droitwich project perhaps brings us closer to the situation with wetlands on the land surface where the plotting of surviving wetland is a basic step towards protection, given that it now forms an important focus for preservation for reasons of biodiversity (eg Visions for the future; http://www.wetlandvision.org.uk/visions.aspx). Having a detailed plot of surface drainage from the LiDAR data is a first big step as well, as that is likely to have contributed to survival of waterlogged deposits. And since it is now acknowledged that the blunt use of LiDAR data as a means of identifying waterlogged deposits does not work (Carey *et al* 2008), clearly another approach, such as that demonstrated here, is needed to locate and present such deposits. The project may also demonstrate the value of amassed data where it is possible to join together both the archaeological and geoarchaeological data.

However, a major outcome of the project is to realise the deficiencies of archaeological archives (and to some extent of the geotechnical sources as well) for the purposes of such a study. Strikingly the problems relating to the collection of data seem to stretch even to current practice. As an example of that, site publication generally would not include the sort of data basic to this project. Indeed few sections are generally published (and, even where published, no indication of original ground surface level or absolute levels may be given). Then delving more deeply, in many cases even the fieldwork record/archive, also omits key data as defined by this project, both in the case of projects carried out currently (eg levels relating to a full geological or at least Holocene sequence, and levels of the water-table) and in the past. This deficiency inevitably then extends to the HER. However, even if the data had existed, it is hardly likely an HER would have stored it in a way that it could have been easily extracted. Hence the archaeological archive is paramount for this type of project, and of course that is one of the least invested-in and reliably consistent and available elements of the British archaeology landscape.

Wider fluvial context and valley floor development (by A Howard)

LiDAR imagery demonstrates that the post-glacial (Holocene) valley floor is incised through the Pleistocene river terrace deposits and borehole records provide some evidence for basal sands and gravels cropping out beneath the postglacial alluvium (as seen in the main valley floor of the Severn). However, the climatic amelioration of the post-glacial allowed the Salwarpe to develop primarily through vertical accretion of fine grained sediments (alluvium).

Borehole records indicate significant organic preservation in a number of areas of the valley floor, which suggests that the river has remained relatively stable over the last 10,000 years, allowing peats and other proxy-rich materials to accumulate to significant depths in the floodplain. Other boreholes indicate isolated areas of organic preservation, which perhaps relate to discrete palaeochannels, rather than more extensive backswamp areas. Whether the valley floor comprised a single channel, or perhaps more, likely, consisted of several channels flowing contemporaneously (an anastomosing system) cannot be determined from lithostratigraphic records alone and would require radiometric dating of multiple organic sequences. However, fine grained alluviation in anastomosed systems is not uncommon in lowland contexts such as the Salwarpe prior to major channelization (see Howard and Macklin 1999).

The fine grained alluviation, which probably commenced in later prehistory (eg Shotton 1978; Brown *et al* 2013) has blanketed the later floodplain, and has the potential to mask earlier archaeological features, as well as subdue landforms identifiable from LiDAR data. Understanding the timing of alluviation is, therefore, critical to geoprospection.

Possible recommendations for the future

Many archaeological interventions do not extend to get a full geological sequence at their base (ie the pre-Holocene substrate; eg Pleistocene gravel or Mercia Mudstone). For this purpose archaeological trenches need not be extended to depths below that the development impact, as augering through the base of the trenches would suffice to demonstrate the relationship of archaeological deposits with the underlying natural sequence.

Similarly geotechnical data-logging could usefully make a distinction for cultural deposits as to whether waterlogged or not rather than just making general remarks such as 'overburden' or 'made-up ground'. This could be solved by having an archaeologist available on site when cores are opened up which is not current practice.

More attention should be paid by archaeologists to recording water-table levels on site. This is standard practice for geotechnical workers using drill rigs. However, the latter do not record the presence of waterlogged deposits consistently, as they use terms such as 'wet', 'damp' or 'soft', and interpretation has relied on these to define whether waterlogging might well be present. In fact, waterlogging for the purposes of this project was only inferred from geotechnical data where it could be confidently claimed. Clearly this is another issue that might be usefully addressed.

Geotechnical descriptions are currently of variable use for archaeological purposes in other respects as well ie they tend to be good for identifying the presence of former industry (presumably because part of their brief is to identify potentially contaminated ground).

None of the above is that useful unless these data are easily accessible, so it is suggested that these data form part of a list of essential key information that is recorded for each site – and preferably copied into the HER.

Clearly it is now desirable that the models are updated as new data appear, so that their resolution will improve and they will become ever more reliable. However, there are issues of software availability to address here, as HERs have generally not been constituted technically to facilitate such on-going analysis, and besides are far more likely to need to work with 3-D Analyser rather than RockWorks, were this type of analysis of site data be more routinely carried out. Accordingly it may be necessary to test whether the existing data could usefully be loaded into 3-D Analyst.

The plots also show where data are deficient, so that priority areas for future investigation may now be more easily determined. Clearly the river valley itself continues to form the principal focus of this work, especially now that existing data has been shown to give rise to fresh, and potentially significant, interpretations of the deepest and best preserved deposits, as well as their whereabouts. However, this emerging picture shows potentially a far more dynamic and complex set of circumstances giving rise to exceptional archaeological preservation, and one based on geomorphological and hydrological factors yet to be wholly explained. Aside from that being another subject for investigation, a series of waterlogged deposits (natural and archaeological; Figs 6 and 14 respectively) have now been mapped in discrete areas following the base of the river valley and generally closely associated with Holocene basins in the surface of the Mercia Mudstone. Clearly this interpretation of the data now requires careful testing, especially as much still remains uncertain about how far salt itself influenced the geology, and, thereby, contributed to creating the right circumstances for the widespread and exceptional preservation of archaeological remains.

10 Project archive

All relevant data has been input into a digital format and/or any additional paperwork scanned for archiving purposes. The main project product(s) will be retained in-house by the Archive & Archaeology Service as a planning aid held in Worcestershire HER, and any other reporting (including key archive data) will be via the ADS website and professional journals.

Copyright

11 Acknowledgements

The proposed Project team comprised:

Project Executive/Manager	Derek Hurst (WA: Senior Project Manager)
Project Leader/Expert	Nick Daffern (WA: Senior Environmental Officer)
Project Support	Emma Hancox/Oliver Russell (WA: Historic Environment Record – HER and GIS structure)
Specialist (RockWorks)	Dr Keith Wilkinson, (Reader in Environmental Archaeology, Winchester University)

Specialist Dr Andy Howard (Landscape Research & Management)

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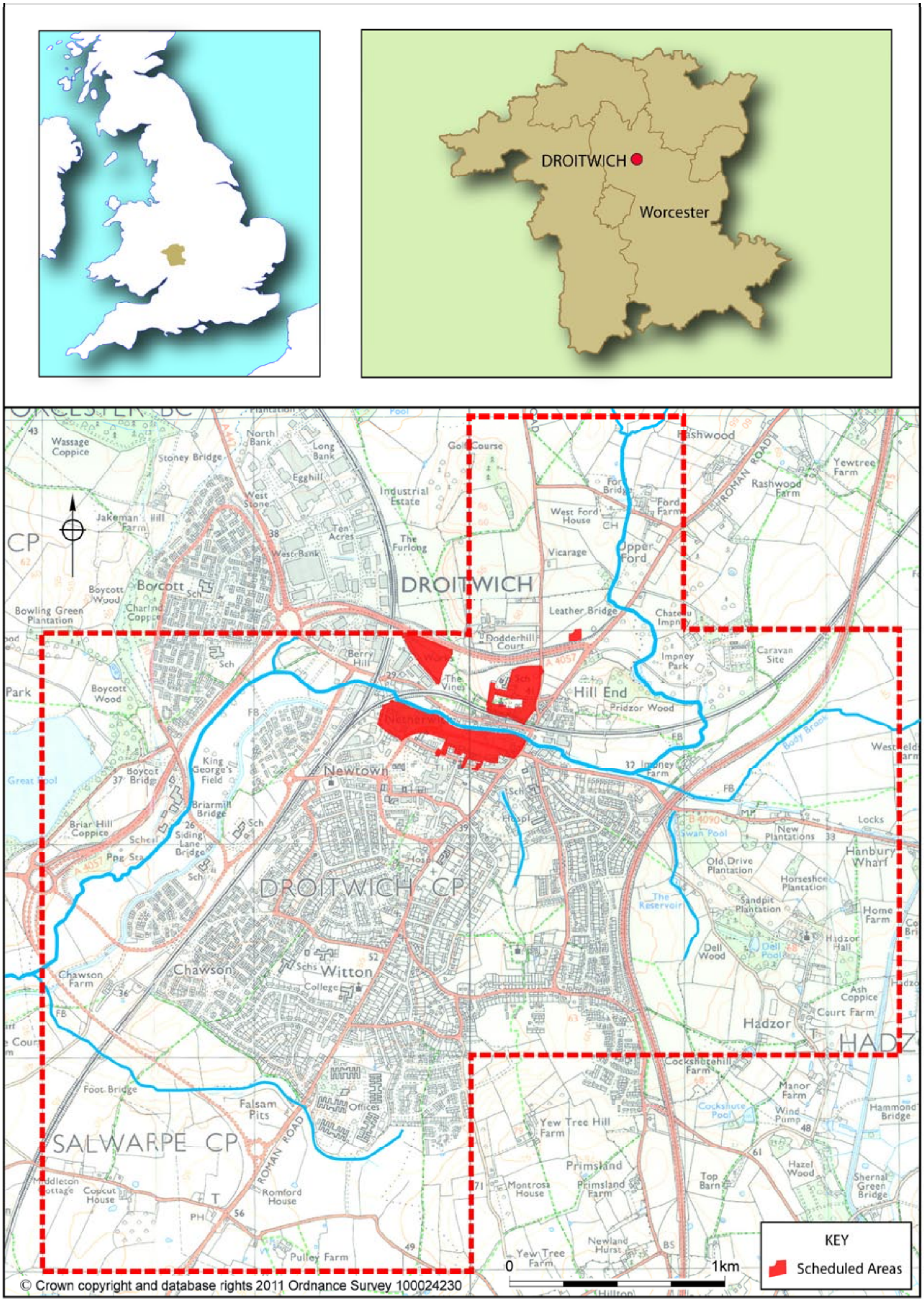
13 Abbreviations

BGS	British Geological Survey
EA	Environment Agency

WAAS	Worcestershire Archive & Archaeology Service



Location of the survey area *Figure 1A*

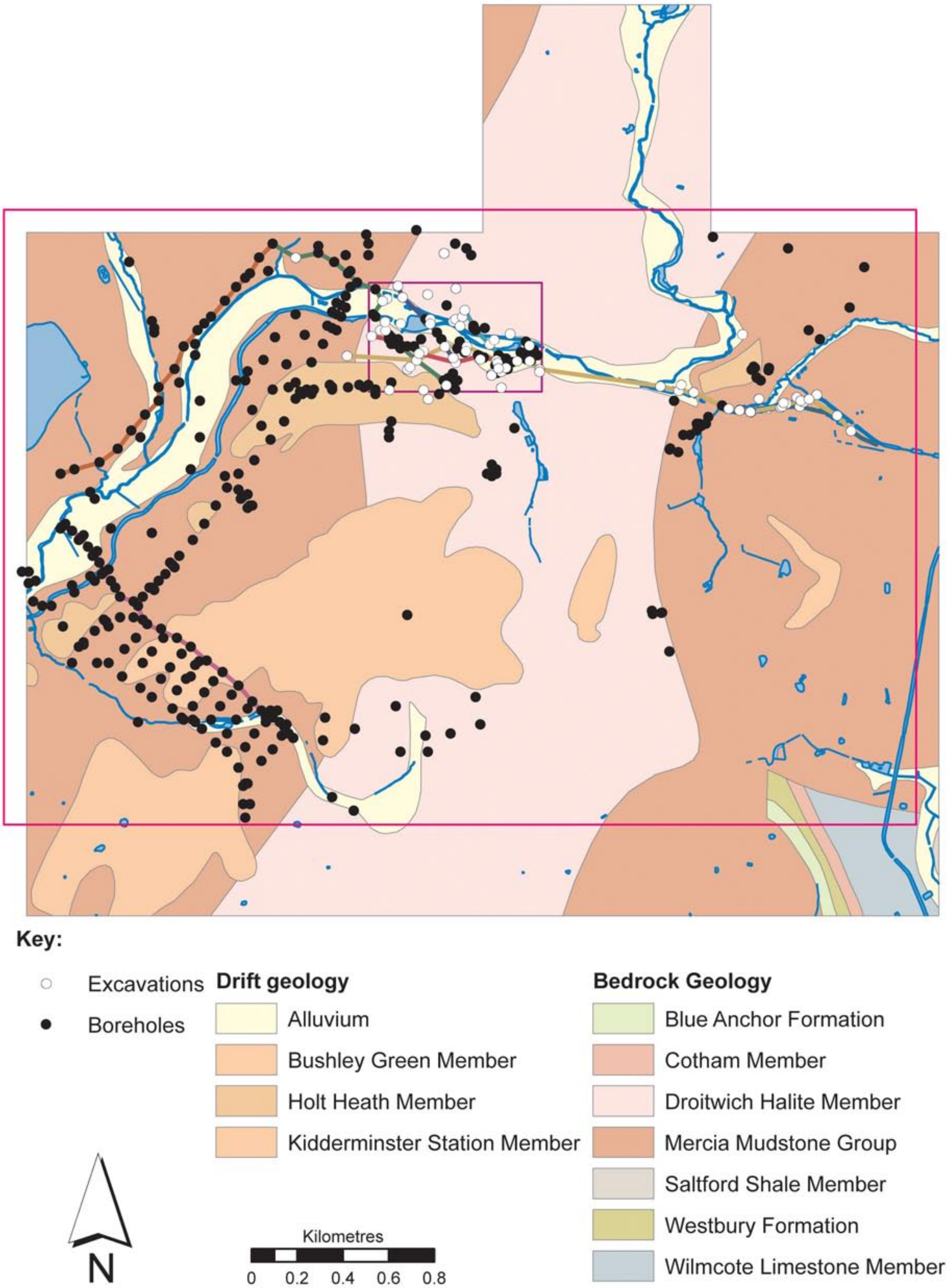


Figure 1b. Location of sites with borehole and archaeological data used in the survey with geology also indicated. Additional inner frame indicates the area modelled in more detail in subsequent figures.

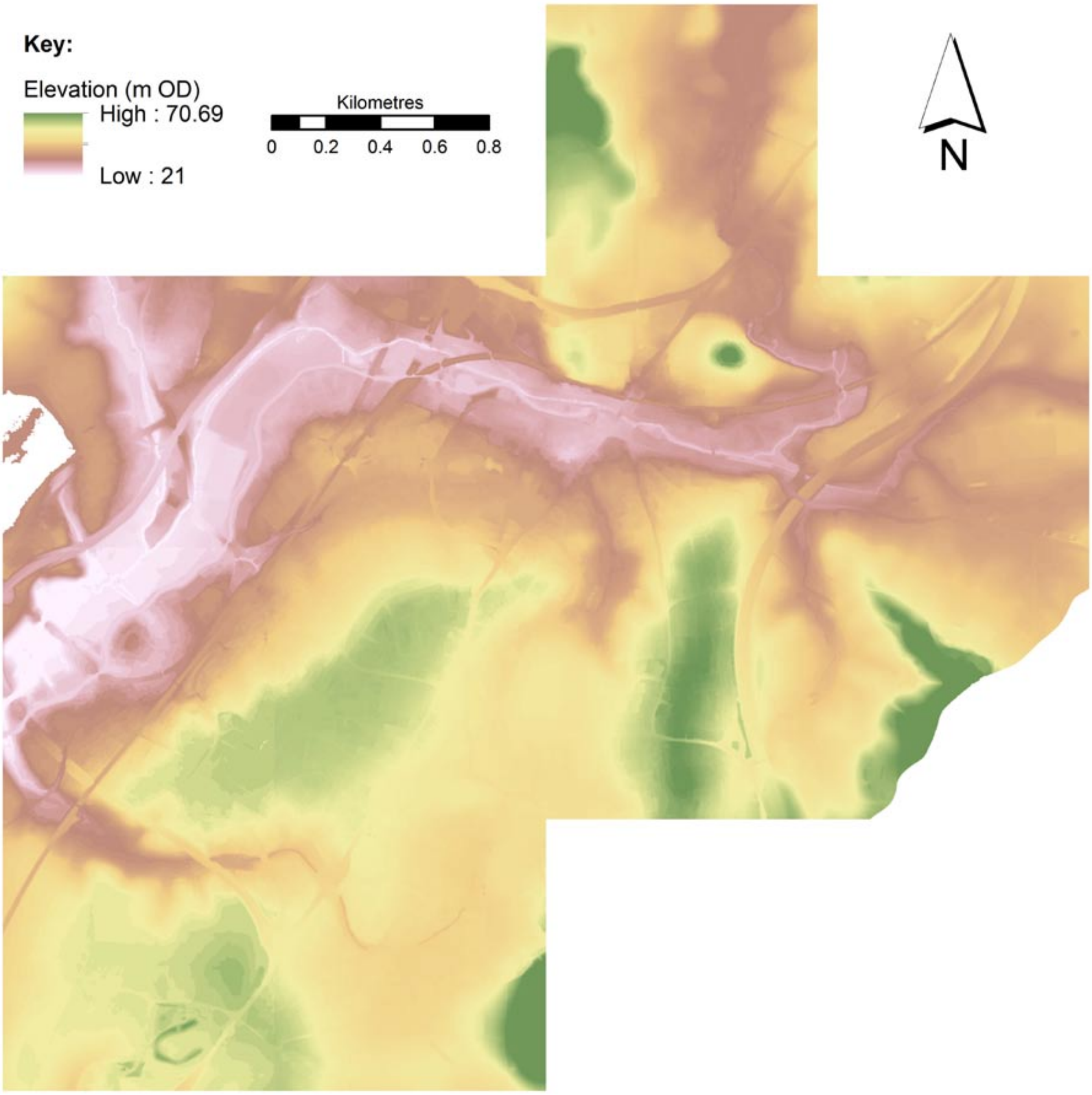


Figure 2. LiDAR plot of the survey area at 1m resolution. Faint traces are evident of the drainage patterns now fossilised in the landscape.

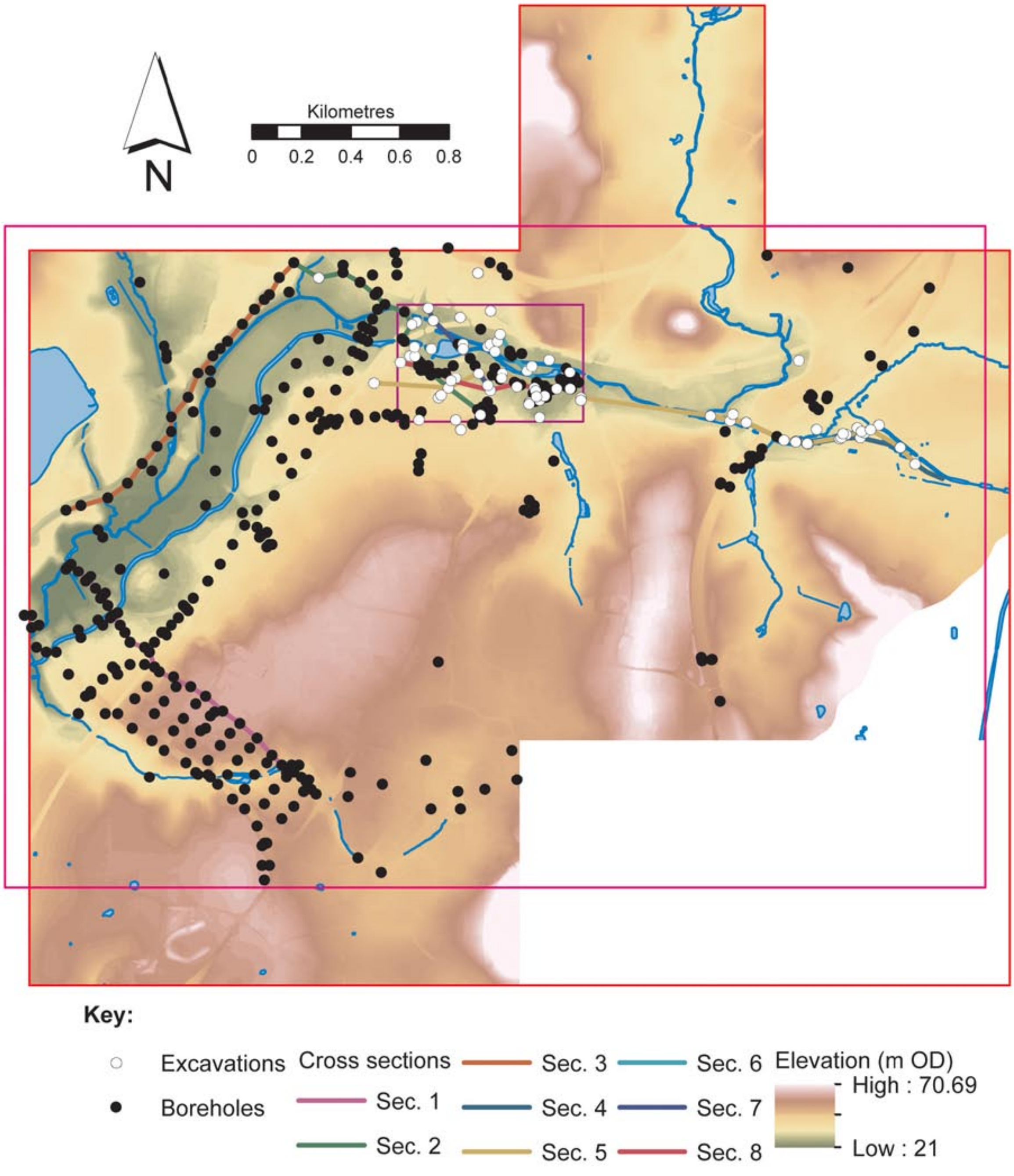


Figure 3. LiDAR plot of the survey area at 1m resolution with all observation points superimposed. Additional inner frame indicates the area modelled in more detail in subsequent figures.

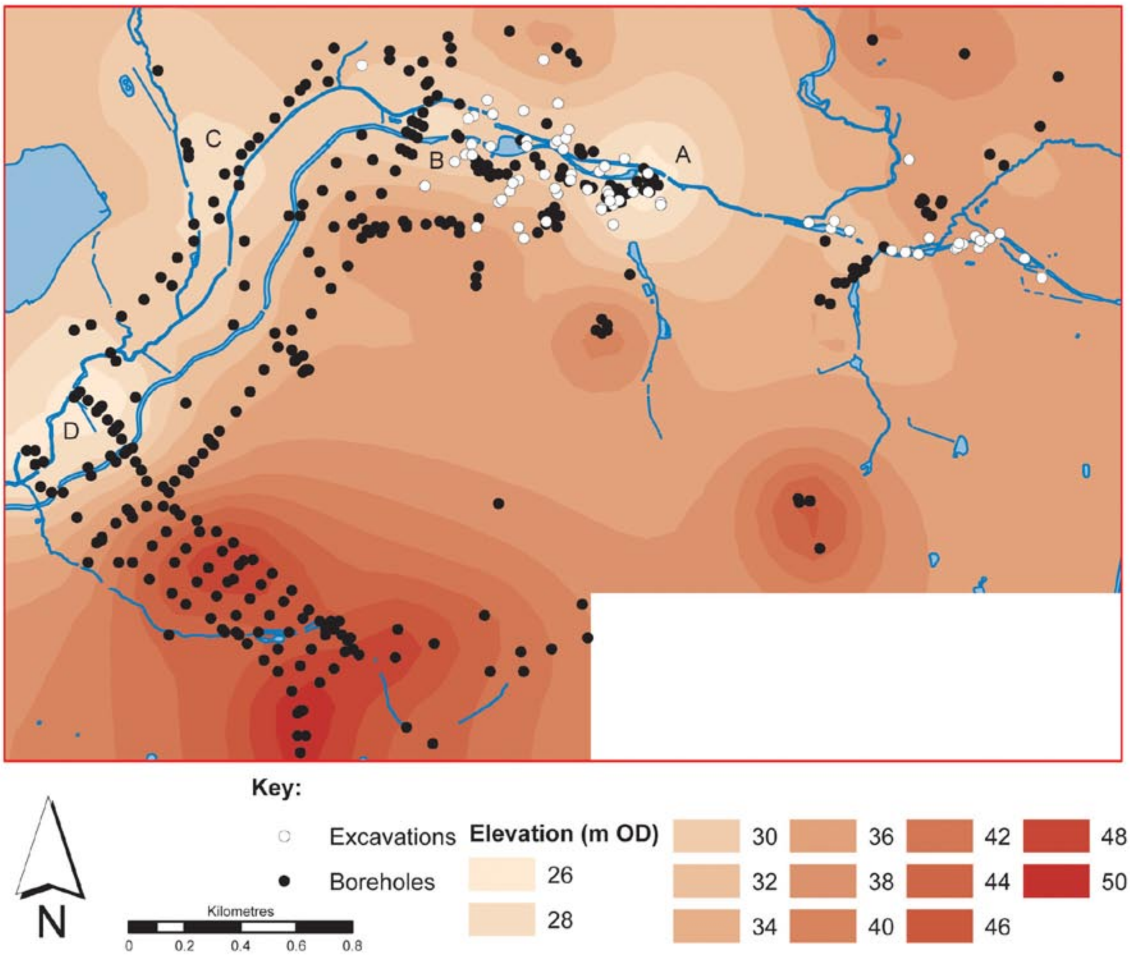


Figure 4. Surface modelling of the underlying Mercia Mudstone geology, which shows an apparent succession of hollows (A-D) along the base of the Salwarpe valley.

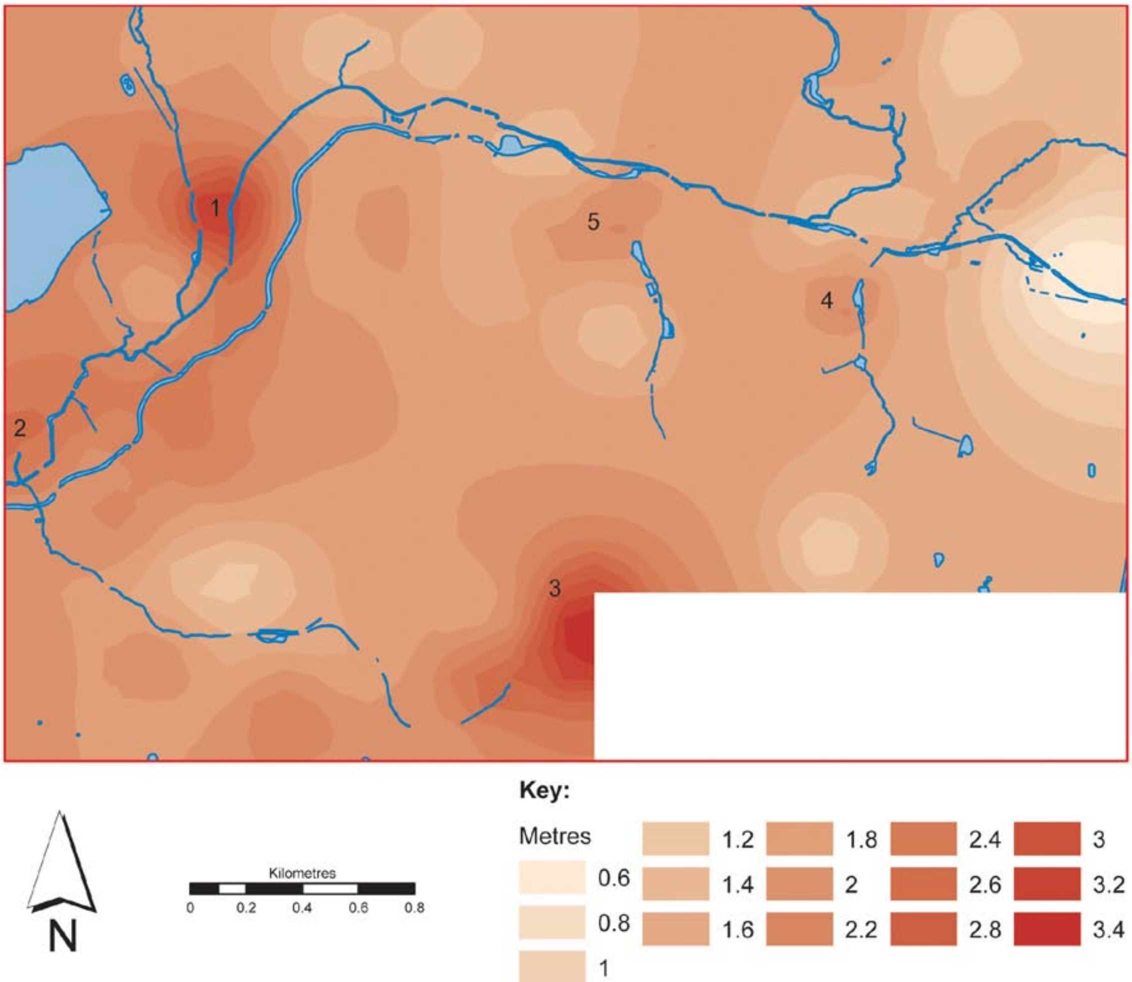


Figure 5. Thickness of alluvium. This shows three pronounced area (Areas 1–3) with several lesser areas (eg Areas 4–5). Areas 1–2 coincide with hollows in the underlying Mercia mudstone geology, while others do not appear to follow this pattern. All (except possibly 3) lie adjacent existing water courses.

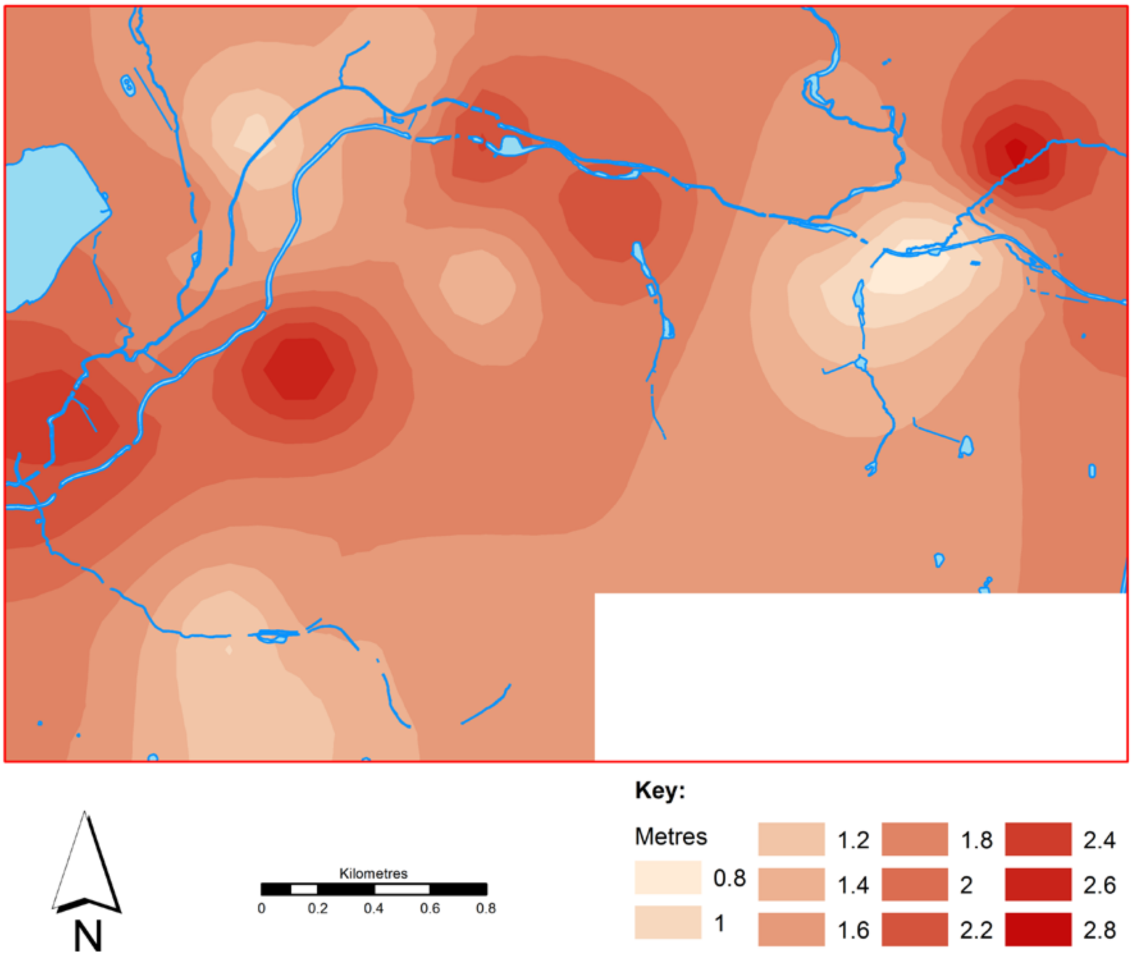


*Figure 6a. Thickness of **organic** alluvium. Where deeper deposits are indicated these are largely in close proximity to water courses.*

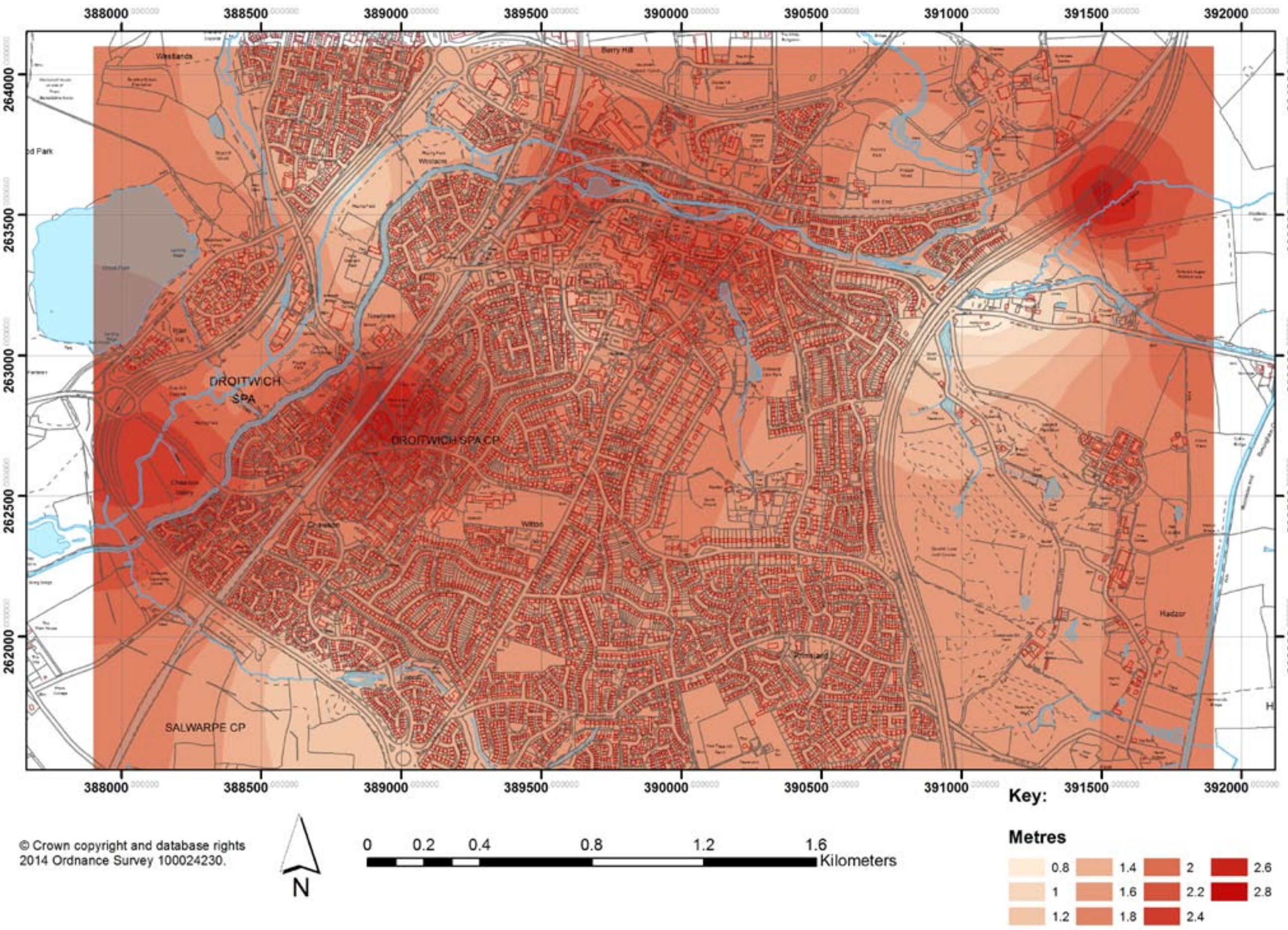


Figure 6b. Thickness of organic alluvium – with modern built environment and georeferencing added.

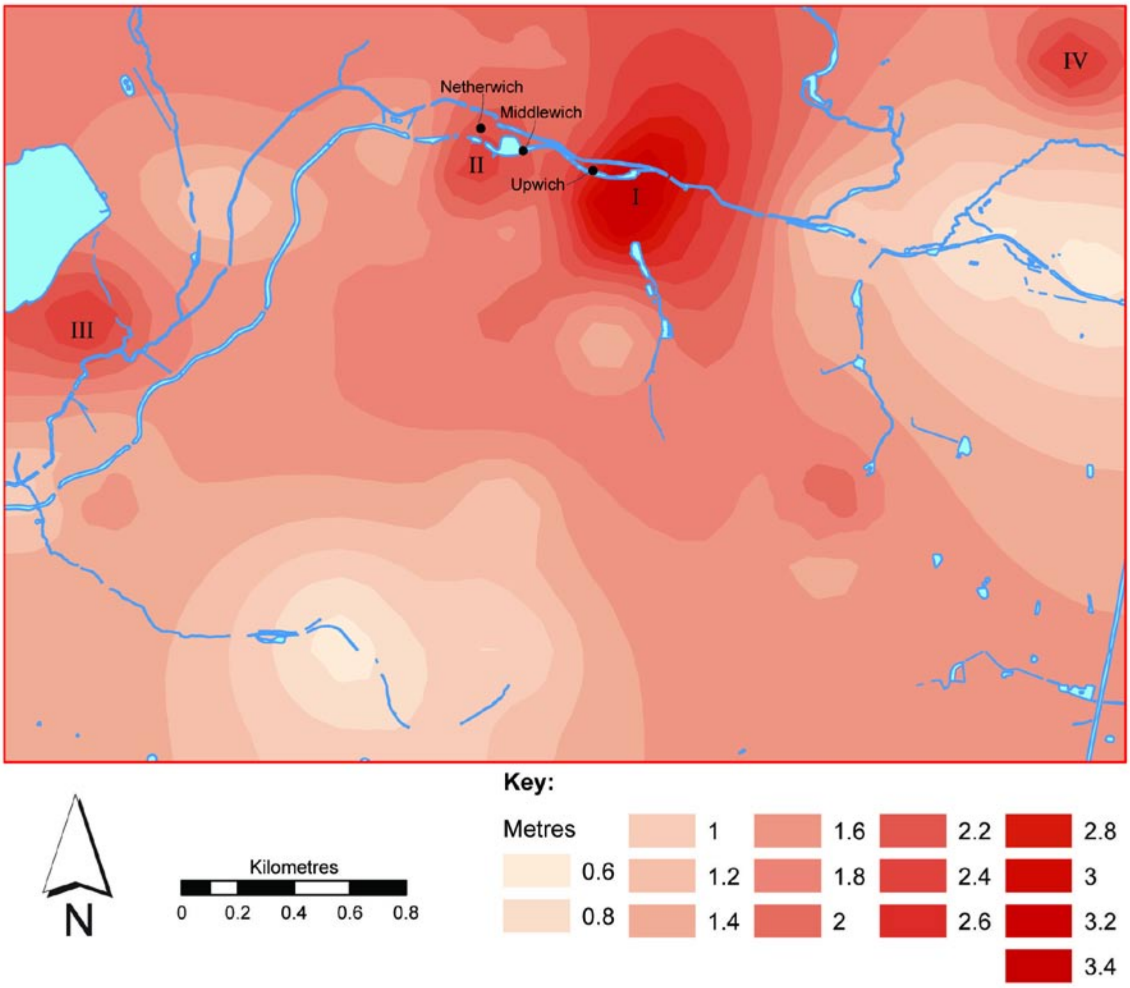


Figure 7. Thickness of cultural deposits. This appears to show four principal areas of thicker deposits. Two of these (Areas I and II) coincide with depressions in the underlying Mercia Mudstone geology (see Fig 4). Area III was surprising but was subsequently identified as an 'Old rubbish tip' based on the label attached to the site by the borehole log! - map regression has suggested this predates the mid 19th century and it, therefore, remains enigmatic.

Historic locations of salt-making activity are also indicated.

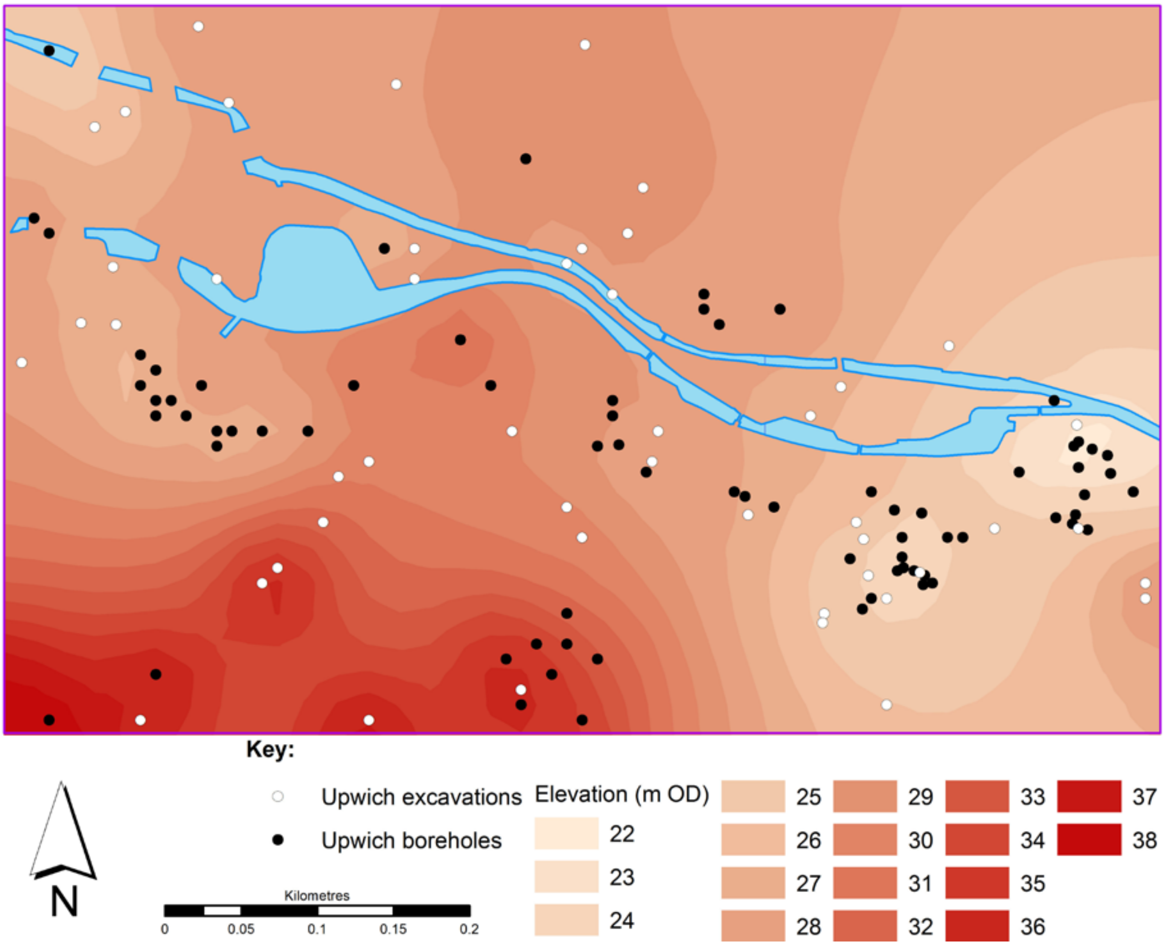


Figure 8. Core survey area: Mercia Mudstone. A large hollow in the Mercia Mudstone surface is indicated on the east side, possibly resolving into two individual hollows at base. A north-south ridge of Mercia Mudstone indicated in centre

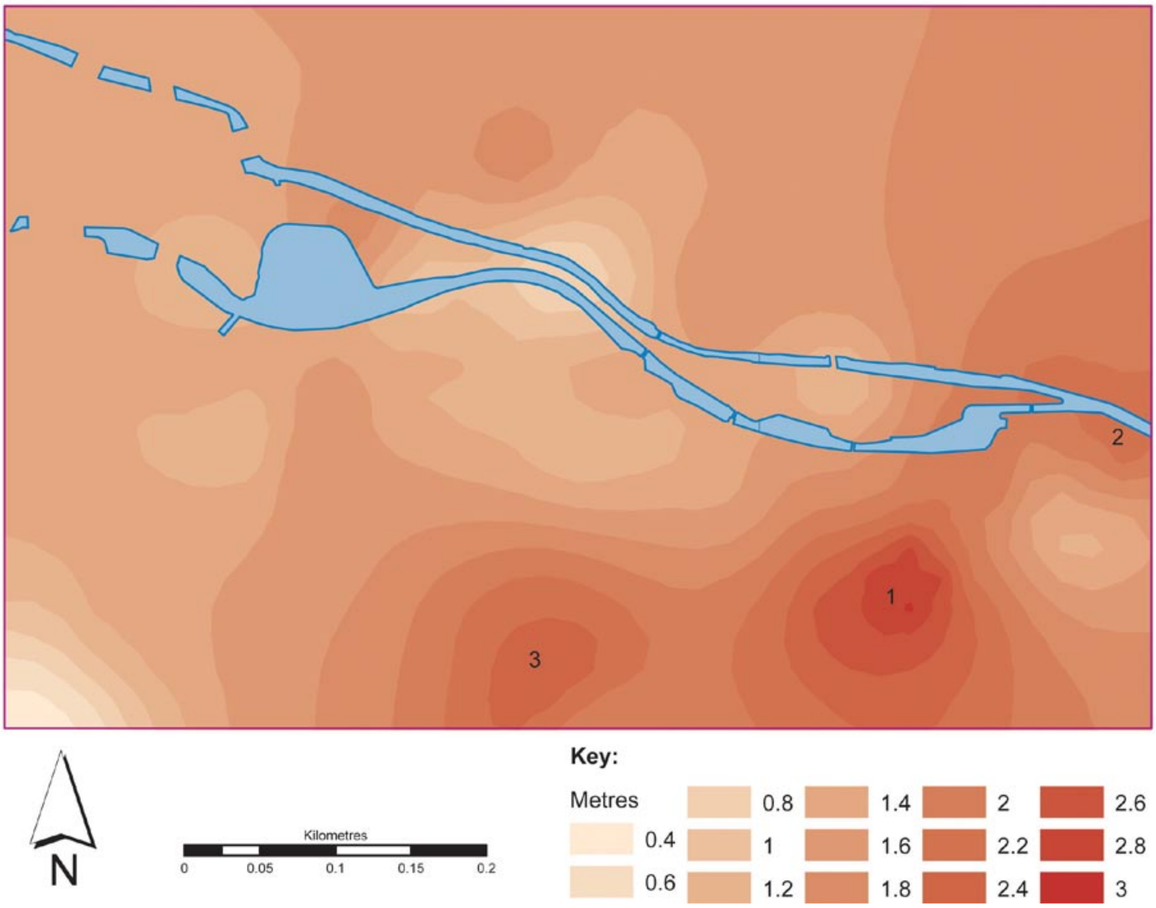


Figure 9. Core survey area: thickness of alluvium. Three areas of general alluvium deposition are indicated in the south-east and central southern area of the plot; the most easterly examples (1–2) are coincident with hollows in the underlying Mercia Mudstone surface (cf Fig 8). Alluvium to the west of this (3) is more problematic, as it appears to coincide with a raised area of the underlying Mercia Mudstone. There seems to be a possibility that alluvium here coincides with a possible earlier river channel (cf Fig 2), though colluvium should also not be ruled out before specific investigation (Andy Howard, pers comm).

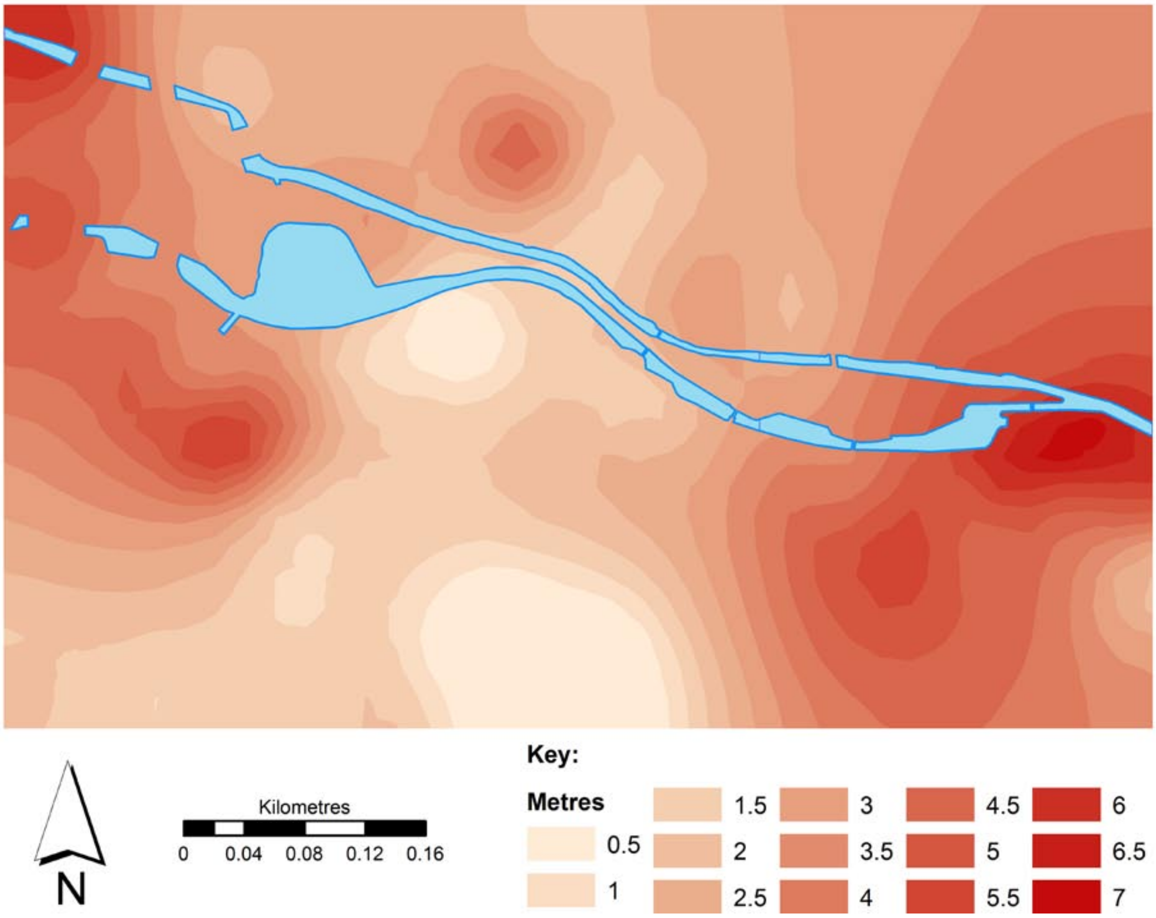


Figure 10. Core survey area: thickness of Quaternary deposits. The plot indicates major areas of Quaternary deposits to the east and the west with a small area in the centre (north side). To the east this coincides with a considerable hollow in the underlying Mercia Mudstone surface, and, to the west, with two lesser hollows. The small central (north side) deposit may be anomalous.

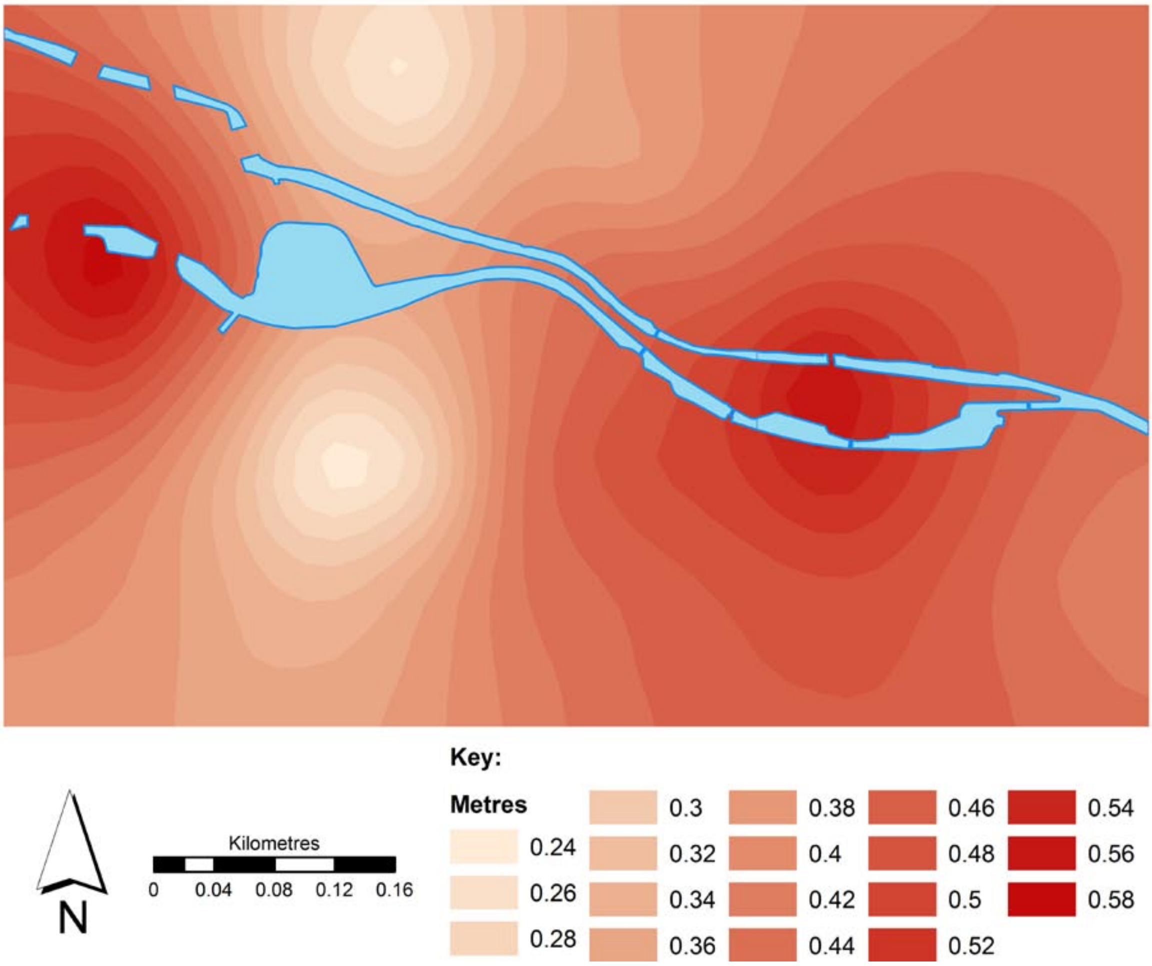


Figure 11. Core survey area: thickness of Roman deposits. Two major areas of thicker Roman deposits are indicated, the one to the east being in the area later known as Upwich.

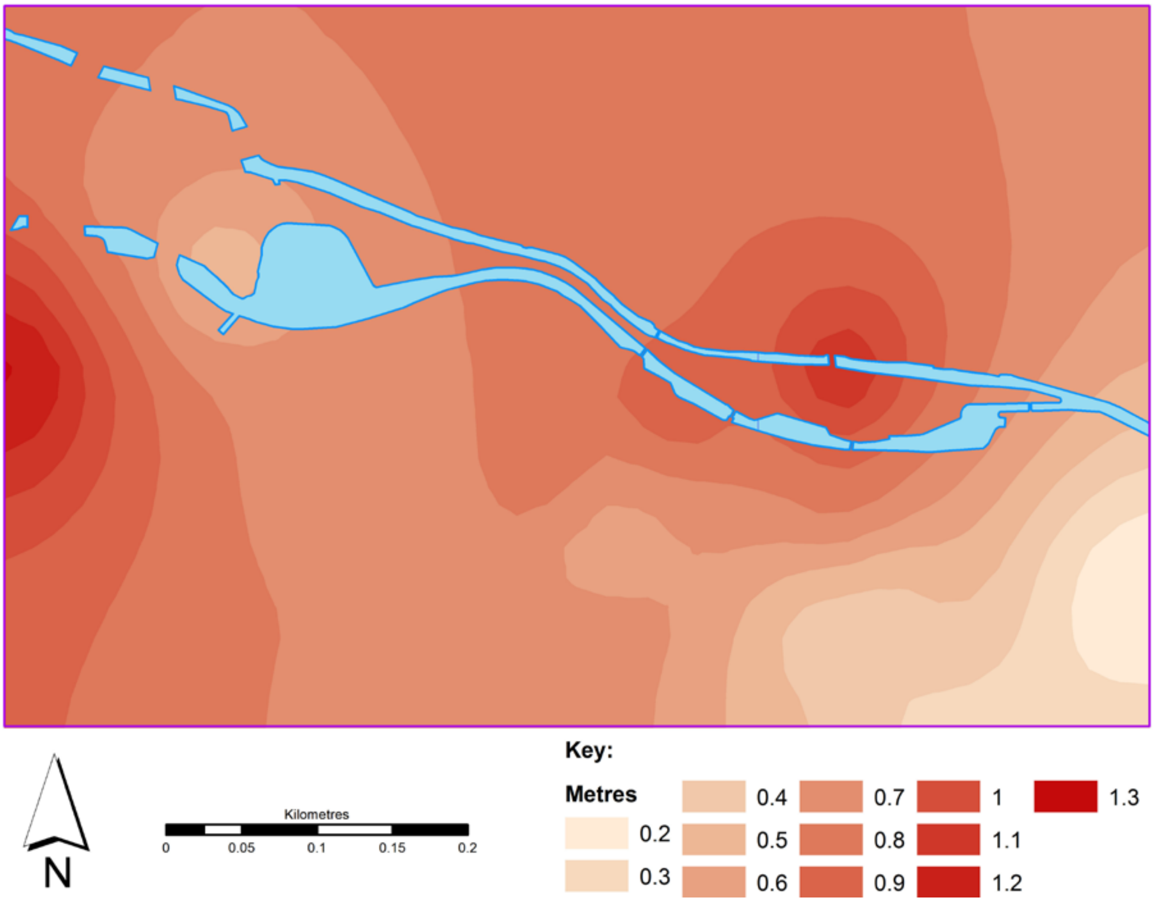


Figure 12. Core survey area: thickness of medieval deposits. Two major areas of thicker medieval deposits are indicated. Though the easterly coincides with Roman deposits at Upwich (ie the main brine well site from at least mid Saxon period), that to the west is on the side of sloping ground in the general area of another historic salt-making focus (Netherwich). Interestingly the thinness of the medieval deposits along the main medieval street axes (ie urban area) is indicated by default.

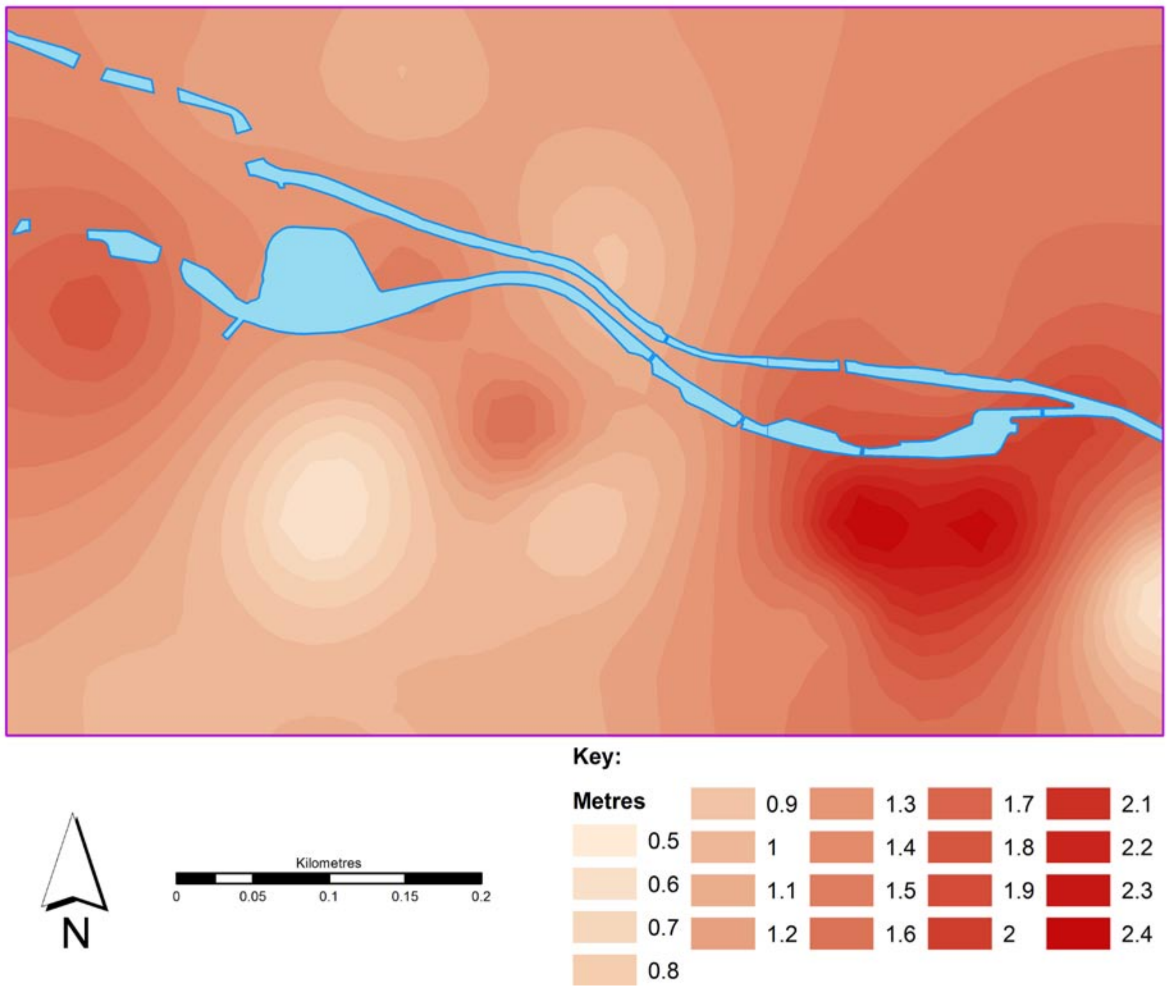


Figure 13. Core survey area: thickness of post-medieval deposits. This shows the continuing build-up of deposits in the Upwich area, primarily infilling the hollow in the Mercia Mudstone. Lesser build-up occurred in the Netherwich/Middlewich areas and along the main medieval/post-medieval street axes.

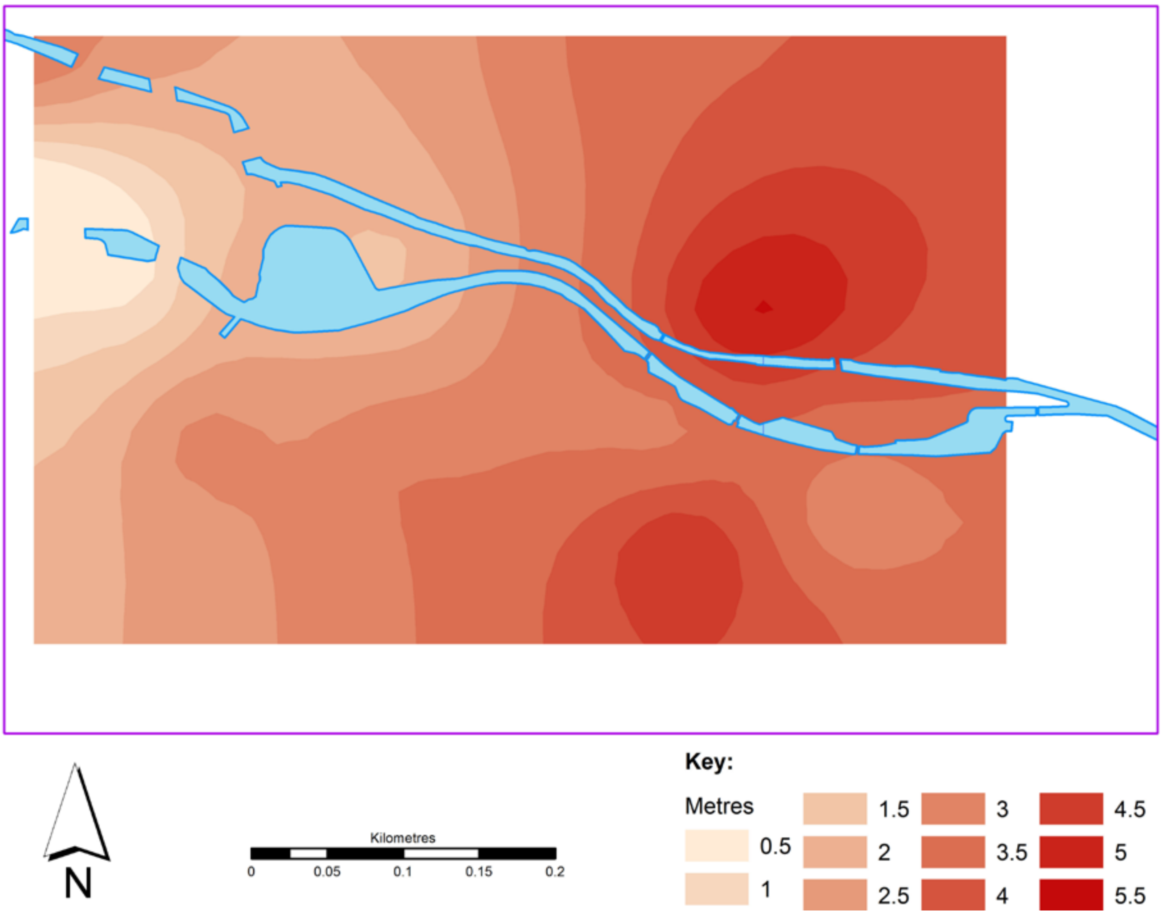


Figure 14a. Core survey area: thickness of ***organic*** *deposits. The greatest depths of organic deposits are in the lower parts of the valley but not in those parts of the area that have been recorded as having the lowest Mercia Mudstone surface (cf Fig 8). One area of greatest waterlogged depth is indicated by borehole data (north of the Upwich site) and has yet to be confirmed by archaeological excavation (see also Fig 22 section). The other seems to be a false echo generated in the data, as it occurs in an area of no data. A severe reduction in the potential for good preservation seems to be indicated going westwards, presumably due to both deposits suitable for persistent waterlogging and the prerequisite conditions for waterlogging being less prevalent. Such a pattern does, however, require more data before it can be verified, as in some cases it is still entirely based on borehole readings and the nature of any archaeological survival has yet to be seen.*

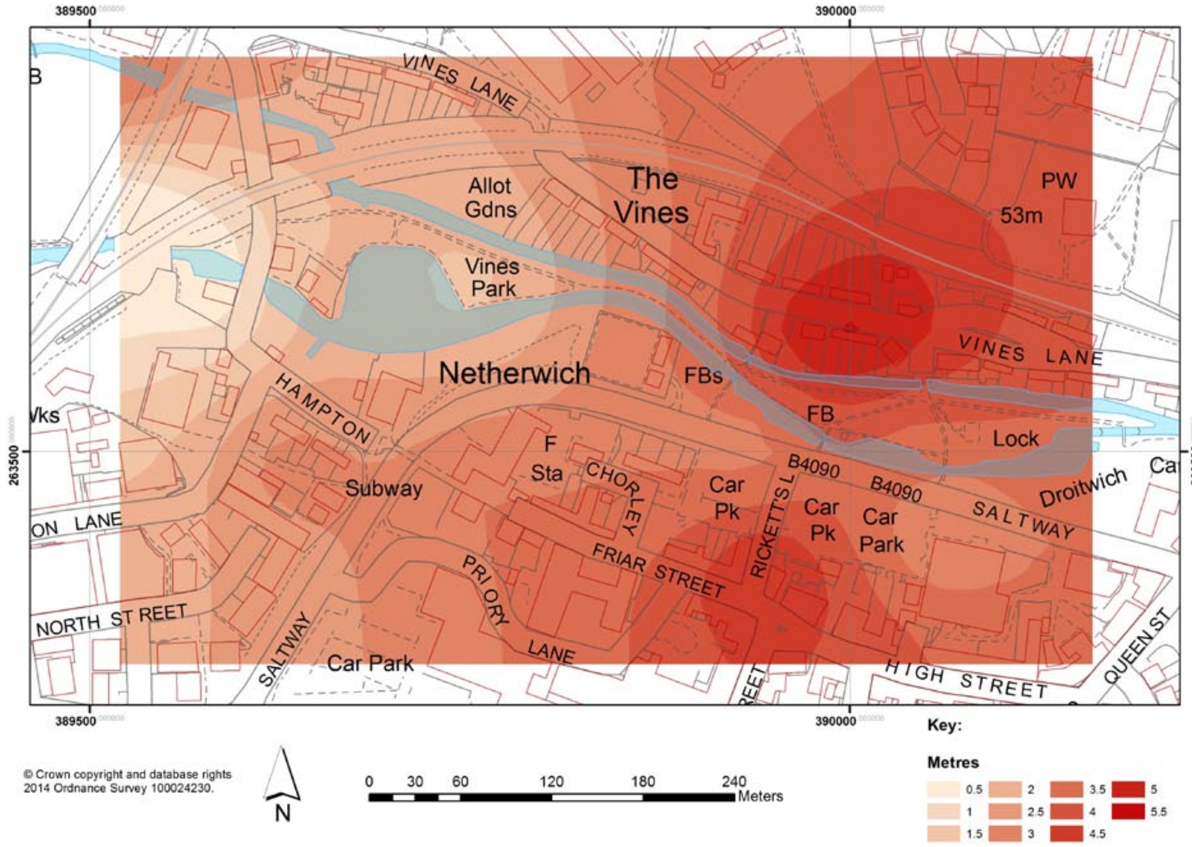


Figure 14b. Core survey area: thickness of ***organic*** *deposits. – with modern built environment and georeferencing added*

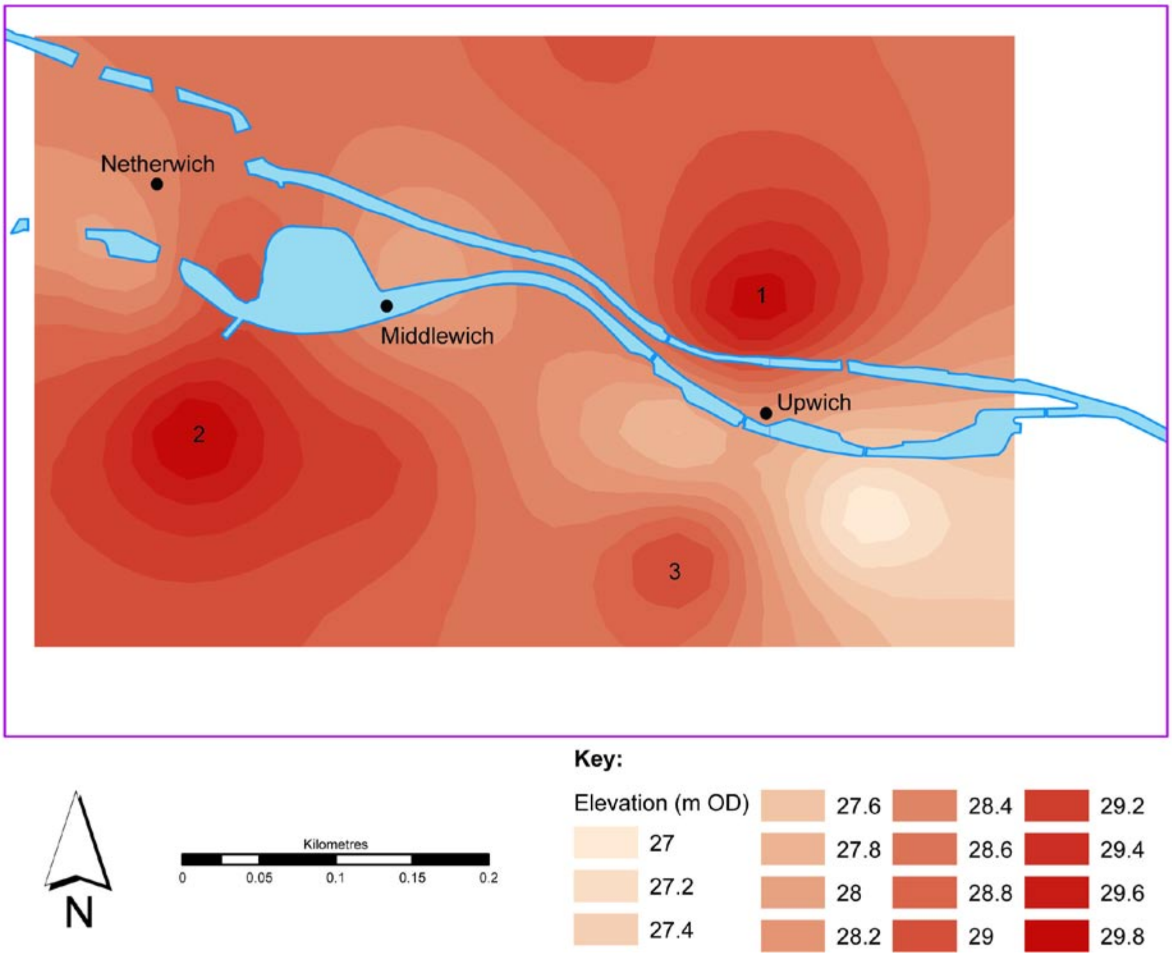


*Figure 15. Core survey area: **surface** of **cultural organic** deposits. This plot indicates that, in some areas, the top levels of waterlogged deposits are relatively high, presumably indicating areas of good waterlogging, and, therefore, survival. Both the main areas occur in the vicinity of known centres of earlier salt production activity from the post-Roman period onwards (ie Upwich and Middlewich). The lesser area (centre south) appears to be a problem with the interpolation creating false positive ie this does not correspond to any data.*

Historic locations of salt-making activity are also indicated.

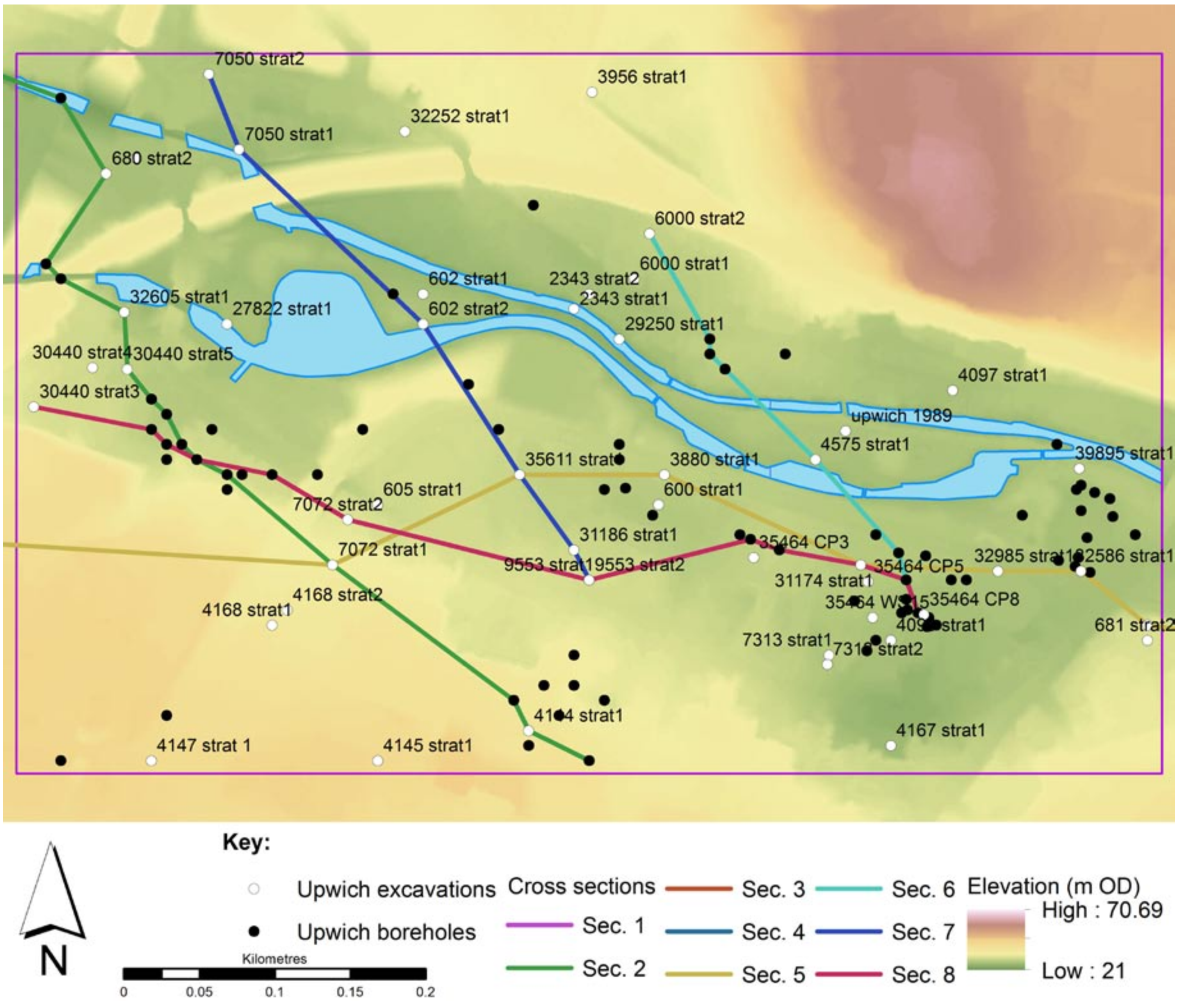


Figure 16. Core survey area: LiDAR plot with all observation points superimposed and with locations of cross-sections indicated.

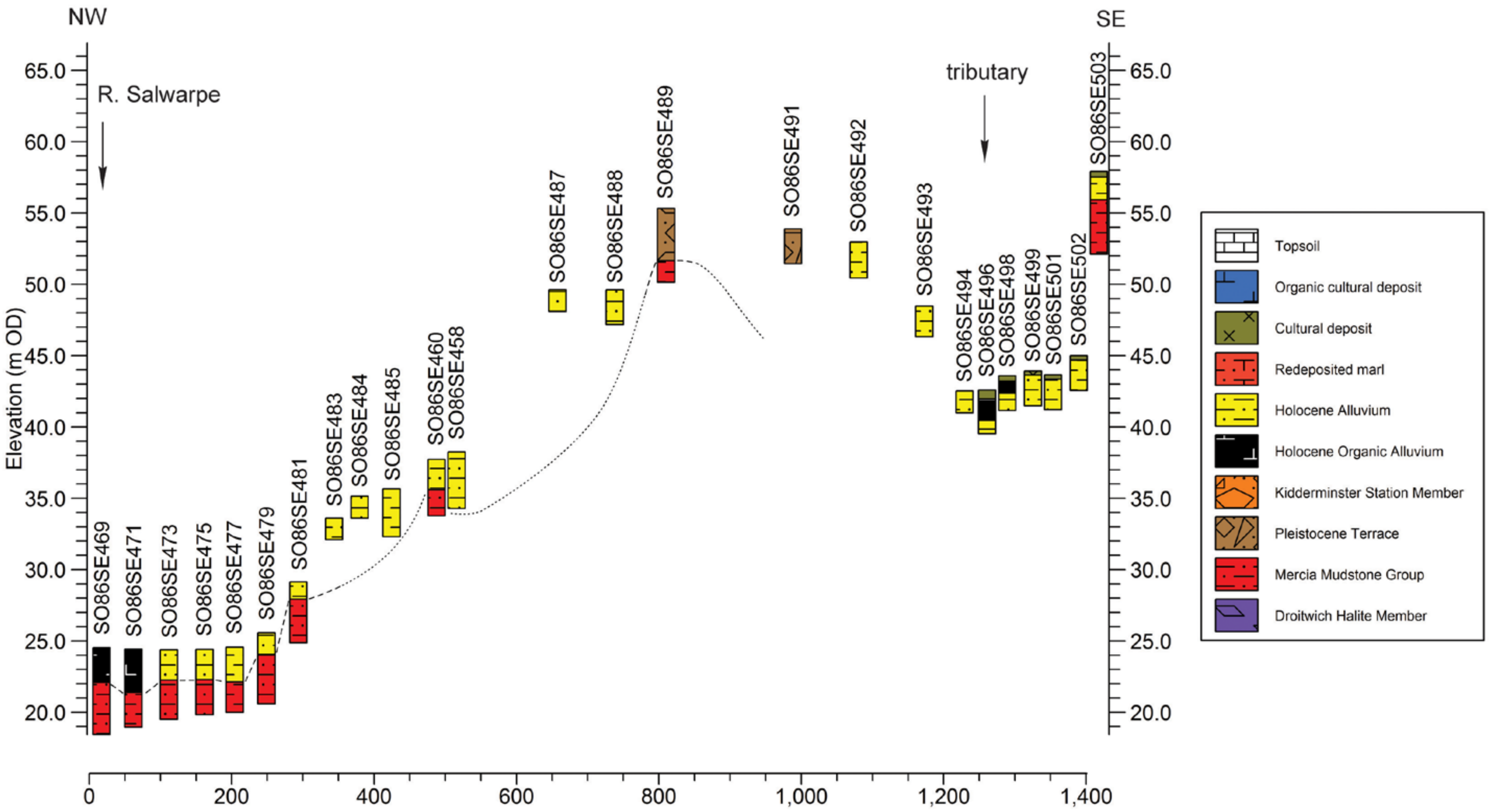


Figure 17. Cross-section 1 (west to east; for location see Fig 1b (lower left)). This section runs from the River Salwarpe in the west up the east side of its valley before crossing obliquely a small tributary. It reveals areas of organic alluvium associated with both the main river and the tributary. There is a very abrupt change in the upper surface of the Mercia Mudstone towards the eastern end.

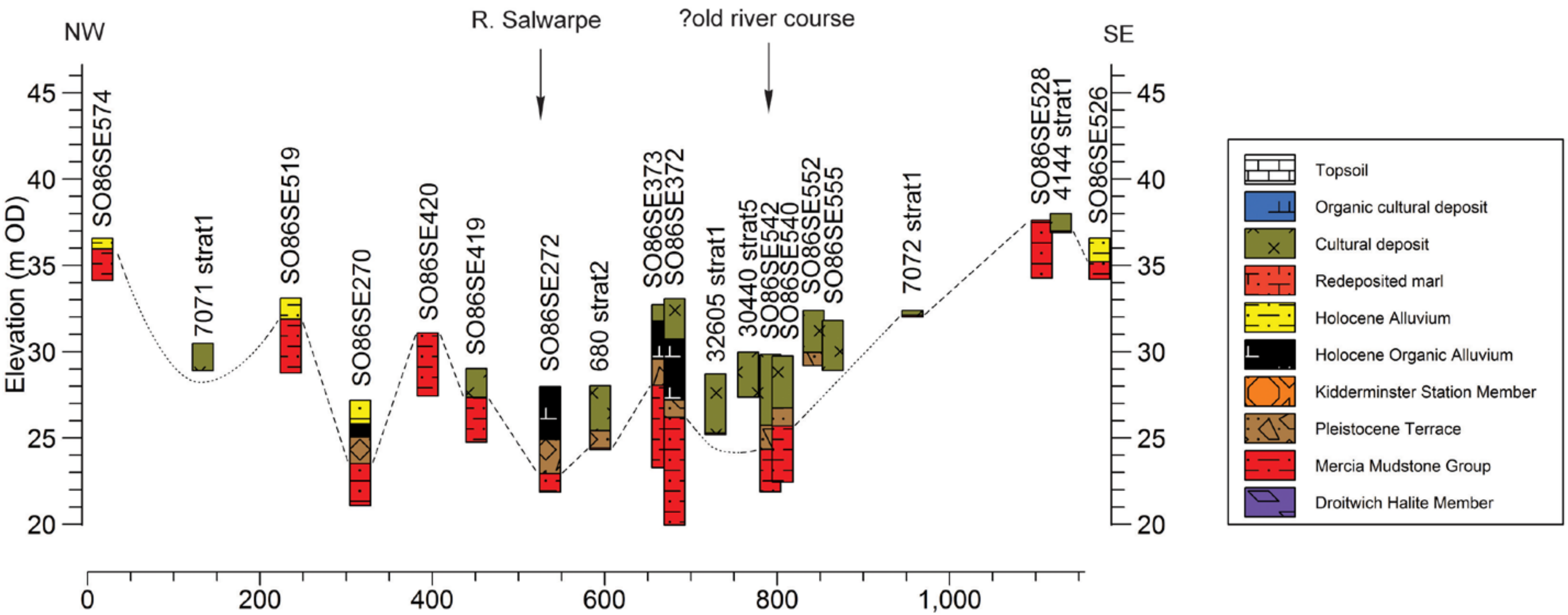


Figure 18. Cross-section 2 (north-west to south-east; for location see Figs 1b and 16). This section crosses the main river valley in the vicinity of Netherwich/Middlewich, former salt production foci. It shows the presence of organic alluvium in general vicinity of the river. A possible palaeochannel is indicated to the south (left) of the present course.

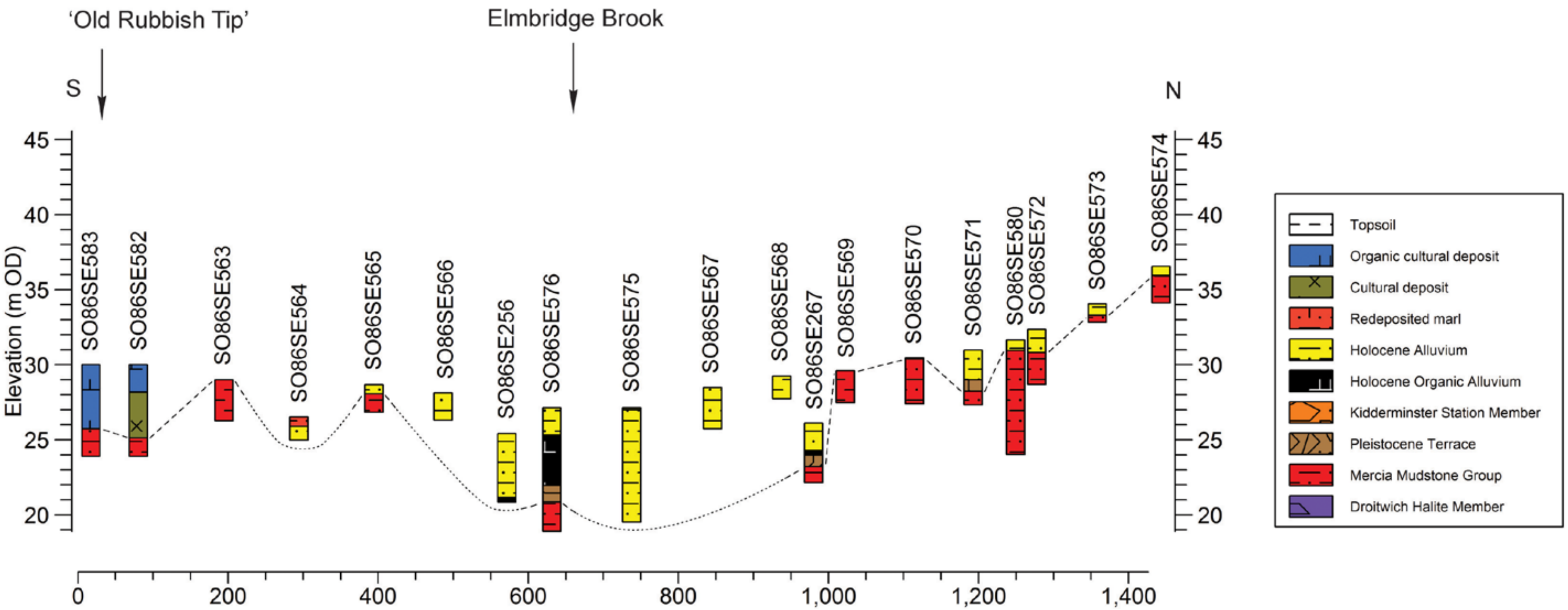


Figure 19. Cross-section 3. (south to north; for location see Fig 1b (upper left)). This shows a section across a small tributary of the River Salwarpe with some irregular organic alluvium deposits associated. The waterlogged cultural deposits to the west are labelled on the borehole log as 'Old rubbish tip' but, presently, there is no corroboration of this from archaeological or historical sources.

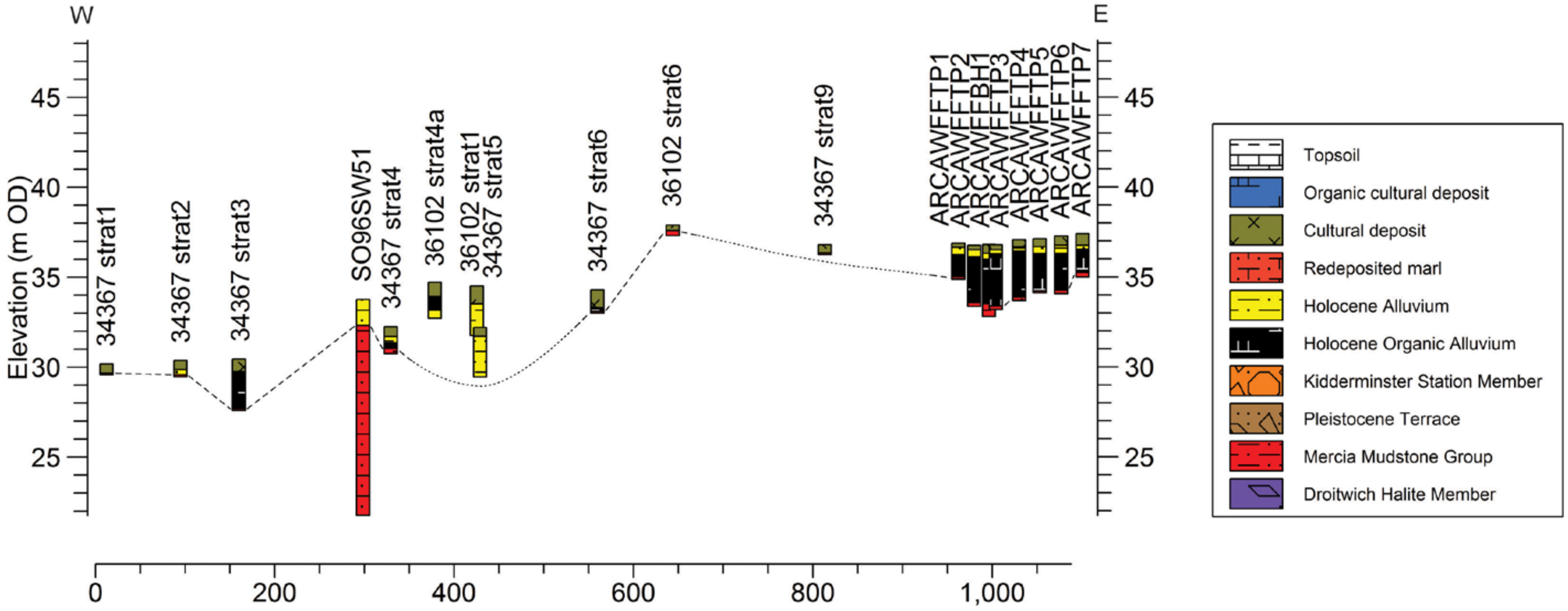


Figure 20. Cross-section 4 (west to east; for location see Fig 1b (centre left)). Detail of the east end of Fig 21 (see below). This shows the considerable extent of organic alluvial deposits to the east of Droitwich, though it is currently unclear whether backswamp or numerous palaeochannels account for this (A Howard, pers comm).

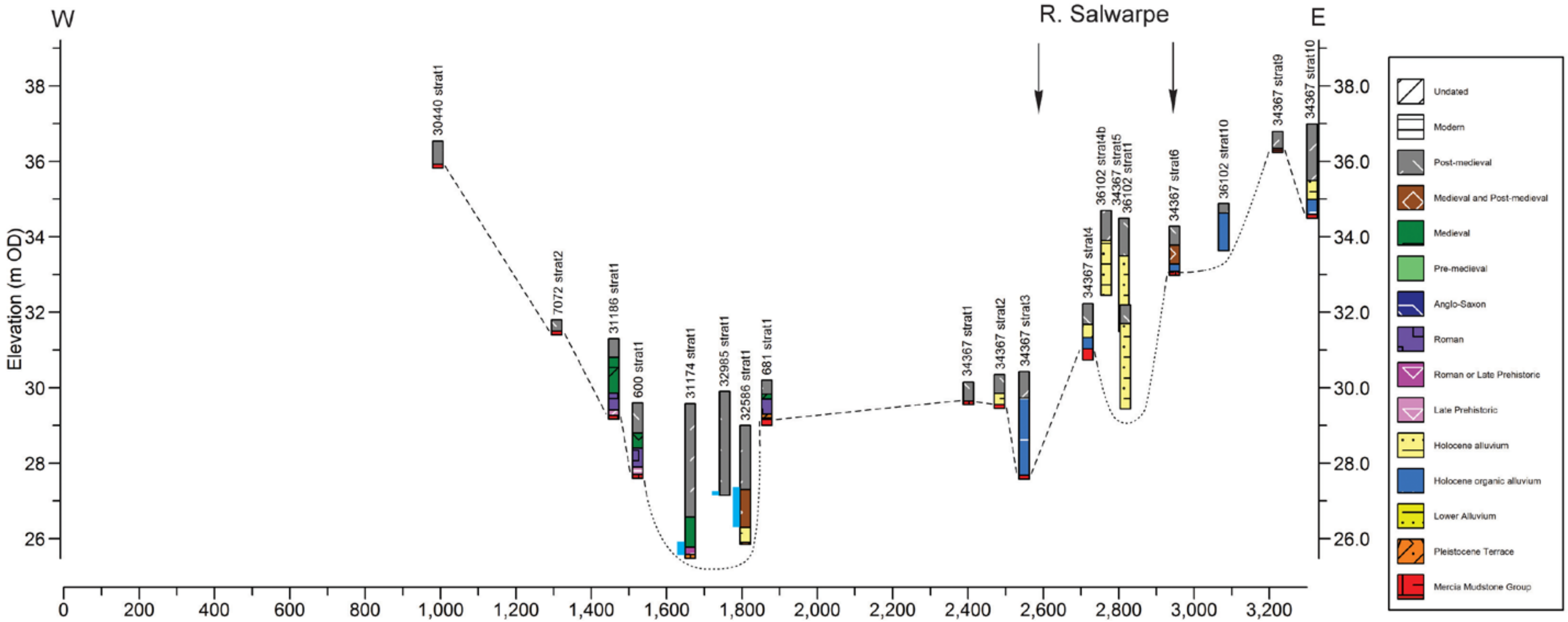


Figure 21. Cross-section 5 (west to east; for location see Figs 1b and 16). This long section reveals extensive deposits of organic alluvium associated with the vicinity of the river to the east. The central portion shows a large and abrupt hollow in the surface of the Mercia Mudstone (between sites WSM 32586 and 681), and this presumably represents subsidence, as it coincides with the known brine run of historic times (Poole and Williams 1980). This is associated with waterlogged cultural deposits and the extent of waterlogging in cultural deposits is indicated by a separate vertical blue line to the side of the column sequence.

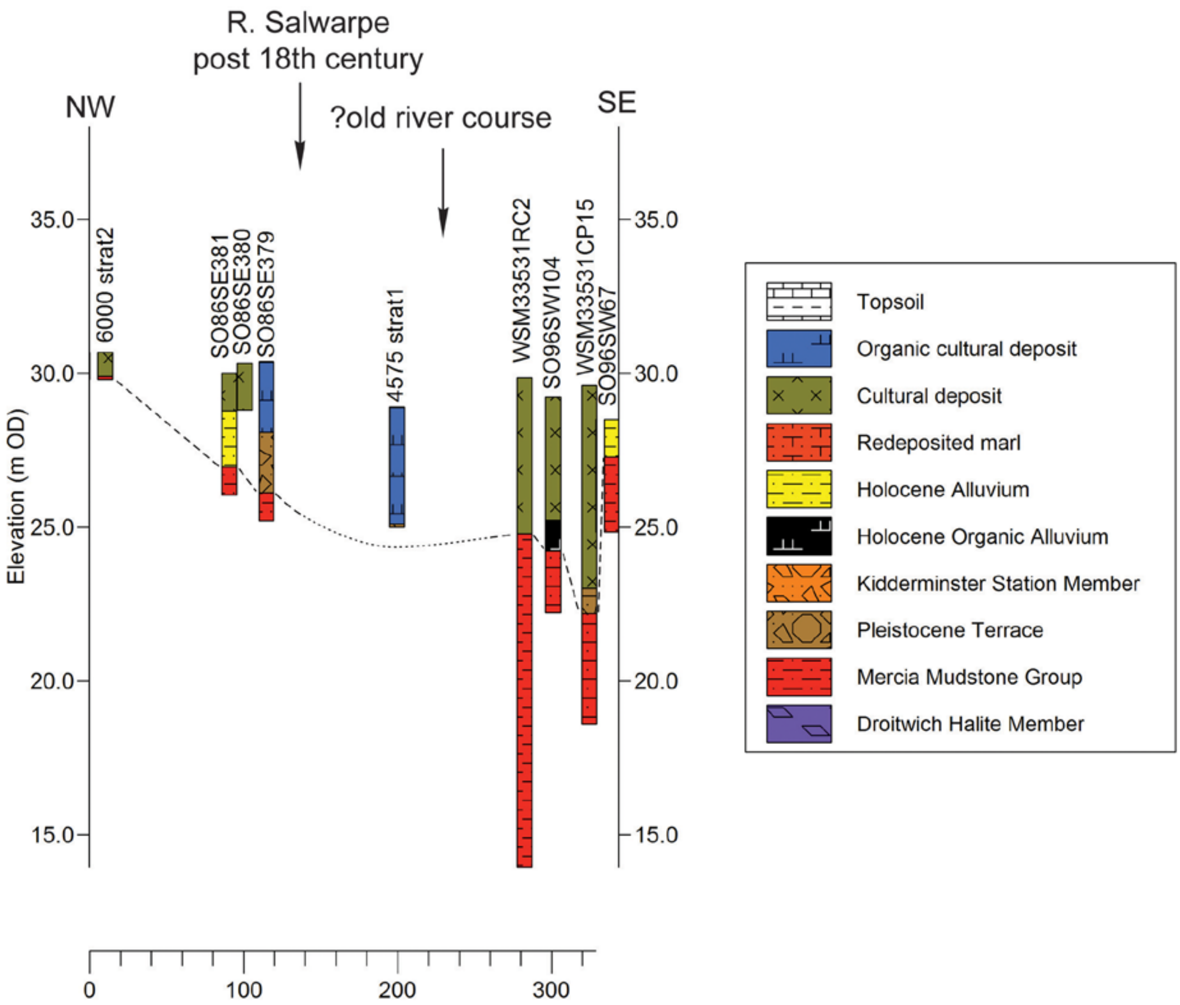


Figure 22. Cross-section 6 (north-west to south-east; for location see Fig 16). This shows the great extent of build-up of cultural deposits in the Upwich area and just to its south, which coincides with a deep depression in the underlying Mercia Mudstone. Where archaeological excavation has taken place, this has indicated a great depth of associated waterlogging and there are also some (incidental) indications of this from borehole data. This section should be viewed with Cross-section 5 to show the localisation of deeper (and waterlogged) deposits in this area. As with Cross-section 5 there is an indication of very abrupt discontinuity in the surface of the Mercia Mudstone (most evident on the eastern side), presumably an indication of subsidence.

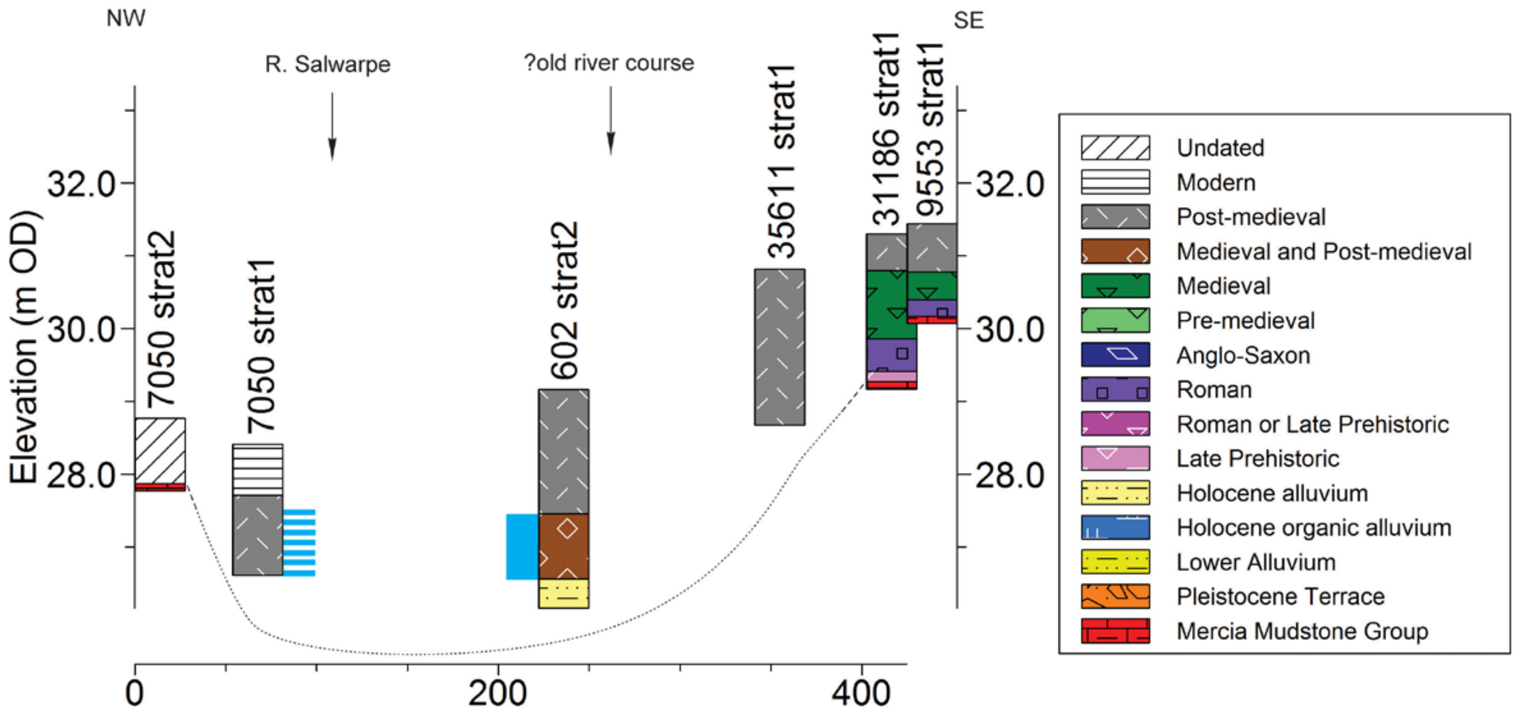


Figure 23. Cross-section 7 (north-west to south-east; for location see Fig 16). It is evident that most of the interventions across this part of the valley have not been taken down enough to reach natural geology, and there are clear signs that deposits are potentially quite thick and, therefore, deep. Waterlogging has been established for the central (and deepest) part of the section. It is noticeable that prehistoric and Roman activity seem to be confined to the higher ground at the southern end of the section.

Note - the extent of waterlogging in cultural deposits is indicated by a separate vertical blue line to the side of the column sequence.

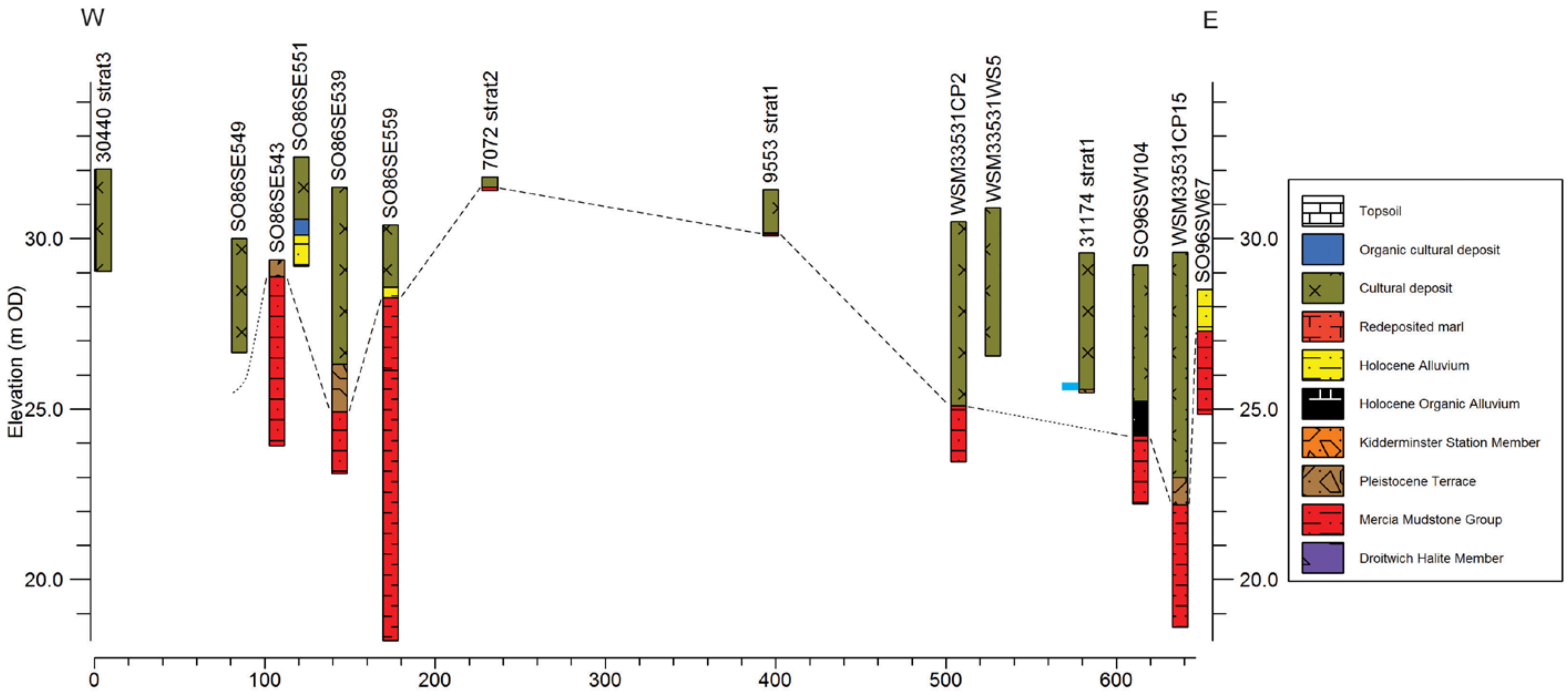


Figure 24. Cross-section 8 (west to east; for location see Fig 16). This section skirts the southern side of the valley and neatly crosses the ground either side of the underlying ridge of Mercia Mudstone (see Fig 8). It shows undulation in the underlying surface of the Mercia Mudstone to the west of the north-south ridge, and, to its east, that thick cultural deposits are infilling a large hollow at this location (presumed subsidence), at the base of which there are waterlogged deposits. The abrupt change in level at the extreme eastern end of the section does seem to be compatible with subsidence being the prime cause of this, resulting in a fault on the east side, indicating where the subsidence was most pronounced.

APPENDIX

Products list – as stated in proposal with status reporting updated

Product number	Product title	Purpose of the product	Composition	Derived from	Format and presentation	Allocated to	Quality criteria and method	Person/group responsible for quality assurance	Person/group responsible for approval	actual completion date
P1	Interpolated deposit model of urban waterlogged deposits	model of known deposits; and predictive model, and definition of gaps in knowledge	based on Rockworks file via Excel worksheets	Selective and interpreted data	KW to advise	KW	KW	KW/DH	KW/DH	Sept 2013
P2	GIS layer within HER	primarily for use for archaeological planning purposes	Arc GIS file	Rockworks	KW to advise	HER	KW	HER/KW/DH	HER/KW/DH	accepted mid 2013
P3	Summary report	dissemination of project results	text report (digital - Word) database (Excel) - key site data	n/a	standard WA format	Derek Hurst	standard WA format	Derek Hurst via ADS	S Woodiwiss	see report cover date
P4	publication of results (even if the project doesn't work) in a professional journal	To explain what was tried and how it worked so that others can assess the likelihood of success with similar standards of data.	paper-based report (Word)	Summary report	*The Historic Environment: Policy and Practice*	Derek Hurst, Nick Daffern and K Wilkinson	journal editor	Derek Hurst	Simon Woodiwiss	tba
P5	Guidance for HER for uploading new data to augment the waterlogged deposits model	to enable updating and therefore maintaining currency of model	Word document	for new interventions	standard WA format	Derek Hurst and HER	Derek Hurst and HER	(Derek Hurst and) HER	Simon Woodiwiss	in progress
P6	notification of results to professional archaeological network	Dissemination of the data	Digital upload via website	Summary report	OASIS report	Derek Hurst	OASIS standard	Derek Hurst	Simon Woodiwiss	tba

Risk log - updated

Risk number	Description	Probability	Impact	Counter measures	Result in practice	Estimated cost	Actual cost
R1	Acquisition of LiDAR data - ie experience has indicated that dealing with EA has caused delays in the past due to long time elapses getting responses	low -	medium	Initiate purchase of LiDAR data asap.	no issue	£540 - PM time rescheduling project	£0
R2	Limitations of dataset due to project strategy of depending primarily on consolidated and interpreted archaeological data and **excluding** bulk input of lithological data	low - as project is focussed on defining location of waterlogged remains rather than explaining their presence	high - Undermining of ability to interpolate and model data, as a result of severely compromising ability to understand geomorphological processes to significant detriment of the project	Run early review of data to try and assess whether this is a problem, but ultimately no solution as incorporating lithological data would require a different and much more expensive project	sufficient geological data was incorporated to allow broad sequences to be defined	n/a	£0
R3	Since project team is across several organisations programme management could be difficult to avoid disruption	medium	high	Avoid an over-tight timetable and check on planned periods of absence	delays were caused by members of the project team having limited availability due to commitments to their main employer	£540 - PM time rescheduling project	£540
R4	Quality of data may be insufficient to provide enough valid (especially levelled AOD) points of observation for useful interpolation to be attempted	low - as project methodology should render this low	high	project methodology (ie use of DTM ie precise ground modelling) is currently thought to minimise this issue	This was a problem for parts of the survey area, and was minimised by identifying a core area and being aware of false positives in the plots	n/a	£0

Risk number	Description	Probability	Impact	Counter measures	Result in practice	Estimated cost	Actual cost
R5	Quality of input data may prevent meaningful results **and** this may not be realised immediately as any interpolated model would first have to be tested as opportunity arose - PILOT TESTING NEEDED ONCE TOOLKIT FINALISED .	unknown	No immediate risk to current project, but final impact would be 'high' = but not known until after results of project applied	None	Better understanding of the nature of the RockWorks product meant that degrees of confidence were varied according to nature of the data in the plots – extended captions were used on each plot to alert user to such issues. It is acknowledged that more data can only be beneficial and that, therefore, it will be some time before confidence can be achieved in the whole plots – confidence is liable to vary across zones according to distance from centre.	n/a	£0
R6	Relative novelty of methodology may leave unseen pitfalls	low-high	unknown	Maintain close liaison across disparate parts of the project team to identify any difficulties at earliest opportunity.	Additional pitfalls were identified during the project relating to the output of RockWorks and more draft plots were done than intended at the outset. The absence of a RockWorks specification for this type of project may be worth addressing as part of the Toolkit programme.	unknown	£1000
R7	Predictive model product may not be adequate to purpose as this depends on its ease of use and its ability to be updated by HER -	low	no immediate impact on project - not known until after results of project applied	TESTING NEEDED **BEFORE** TOOLKIT FINALISED TO TEST APPLICABILITY OF PROJECT METHODOLOGY BOTH IN TERMS OF MODELLING AND EFFECTIVE UPGRADABILITY OF THE DATA IN HER - not part of this project	HER has successfully adopted plot of organic deposits, but it remains in question how the new data can be updated – ie closer liaison with HER is needed at the stage of Toolkit development	n/a	£0
R8	Loss of archives ie moving offices in March 2012	low	high	ensure move is done carefully - though partially under outside our control	none	£2700	£0