Historic England

Preserving Archaeological Remains

Appendix 1 – Case studies

Summary

This document is part of a suite of documents about the preservation of archaeological sites. It is a technical appendix to the main text (Preserving archaeological remains: Decision-taking for sites under development) and should be read in conjunction with that document, and where appropriate, the range of planning policy guidance detailed therein.

It contains seven case studies which provide additional detail and context to the advice given in the main text and its various appendices.

Additional methodological detail and technical advice is provided in the following appendices:

Appendix 2 – Preservation assessment techniques
Appendix 3 – Water environment assessment techniques
Appendix 4 – Water monitoring for archaeological sites
Appendix 5 – Materials for use in the reburial of sites

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Front cover:
Carbonised textile from Must Farm.

Contents

Introduction

This document contains case studies which provide additional detail and context to the advice provided in 'Preserving archaeological sites: Decision-taking for sites under development' and related appendices. Topics covered include preservation assessment (case studies 1 and 2), water environment assessment (case studies 3 and 4) and monitoring archaeological sites (case studies 5, 6 and 7). All of the examples relate to waterlogged archaeological sites, because these sites are rare, and decision-taking and management of them is complex. Additional case studies relating to materials for use in the reburial of sites can be found in Appendix 5.

1 Monuments at Risk in Somerset’s Peatlands

A large scale condition assessment exercise was carried out across nine sites in Somerset to look at the state of preservation of known sites to assist future site management decisions.

There are over 50 known wetland archaeological sites which are thought to still survive in the Somerset Levels, 30% of which are scheduled monuments. There has been very limited investigation and assessment of the condition of these sites in the recent past. These sites are at risk from development, coastal and river erosion, and peat wastage and agricultural activity including land drainage. The Monuments at Risk in Somerset’s Peatlands (MARISP) project (Brunning 2013) set out to look at a selection of the most significant of these sites (*see* Figure 1), jointly funded by English Heritage, Somerset County Council and the Environment Agency.

Figure 1
Map of site location.

On each site, limited trial trench excavation was carried out to locate the archaeological features, collect wood and palaeoenvironmental material for preservation assessment, and carry out a programme of hydrological analysis. Excavation did not stop at the top of archaeology but continued down through and sampled all layers present (*see* Figure 2). The hydrological assessment indicated that most of the sites were at risk of seasonal desiccation due to low summer water tables.

The sites assessed included four groups of Neolithic and Bronze Age wooden trackways, a Bronze Age wooden platform, a Late Bronze Age ritual pile alignment, two Iron Age wetland settlements and an early medieval causeway. Three other prehistoric trackways were also investigated but could not be located – at least one of these had been lost to ploughing and peat wastage.

Where sites were located, deposits were recorded and sampled for dating, archaeological assessment and analysis of their state of preservation. Where feasible, wood, pollen, plant macrofossils and insect remains were subject to preservation assessment. Many of the techniques developed, refined and used in the MARISP project form the basis of those described in Appendix 2.

Wood recovered from all sites was degraded, much (80%) of it heavily degraded (*see for example* Figure 3). All showed evidence of some previous (ancient) microbial attack. The similarity between the visual condition of the timber palisade at Glastonbury Lake Village in the image from the 1897 excavations and the more recent MARISP work (*see* Figure 10 in the main document) suggests that a large amount of the desiccation had occurred before or as a result exposure during that earlier excavation.

Figure 2
Excavation at Hardings Alignment, Trench 9, looking west. Scales 1m.

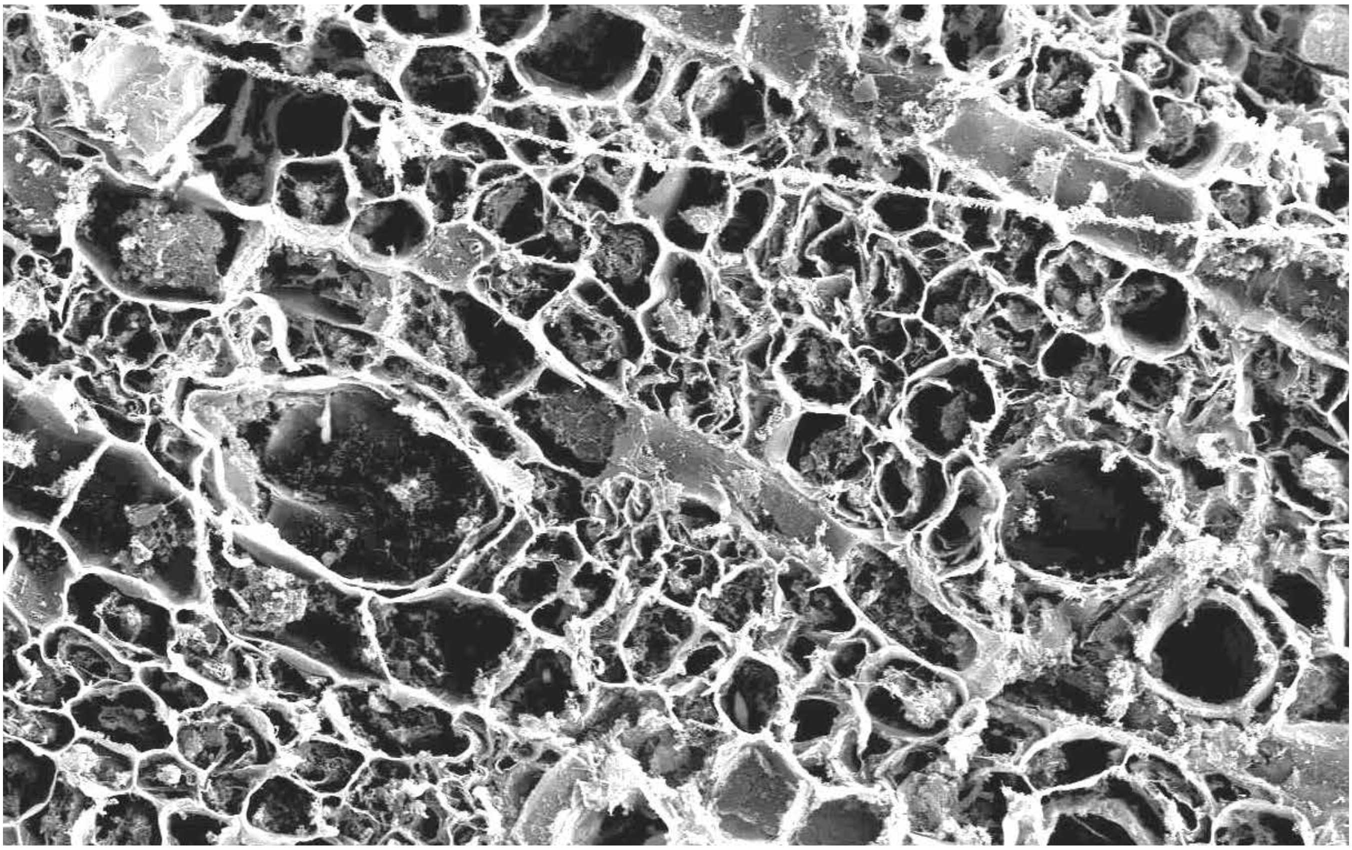


Figure 3
SEM image of degraded oak from Meare.

Assessment of other material provided subtle distinctions between and within sites, with some sites exhibiting good preservation of pollen, plant macrofossil or insect remains, whilst this evidence at other sites had degraded. The state of preservation of palaeoenvironmental material in the project was used both as a proxy measure of preservation for the sites, but equally importantly, as a measure of whether or not it was possible to undertake further environmental analysis of particular samples. This is because if a sample contains too many unidentifiable elements, the remaining material will no longer be representative of the past environment from which it has come.

Drawing together all of the data, a set of research questions and management priorities were produced for each site. In most cases, increases in summer water levels in the fields containing these sites was recommended to ensure the long-term survival of the remaining archaeological material. However, in a few instances, the existing level of preservation was so poor that rescue excavation to recover the remaining significance of the site was the only viable option.

2 Fiskerton, Lincolnshire

This case study demonstrates why monitoring should only take place after a preservation assessment has been carried out and not before the state of preservation of the site is fully understood.

In 1981, part of an Iron Age timber causeway was excavated in a field in Lincolnshire near the village of Fiskerton (*see* Figure 4). The site was adjacent to an Internal Drainage Board (IDB) drainage ditch, the North Delph, which runs parallel to the River Witham. In 2001, an excavation was carried out in the area between the North Delph and the river. This second excavation also found evidence of the causeway, along with associated finds, including a log boat.

Figure 4
Fiskerton excavation, 1981.

Figure 5
Fiskerton excavation, 2007. Shot is just north of previous figure but wood is now absent.

In 2003, proposals were put forward to create a wet grassland habitat in the field containing the causeway. In order to investigate the likely impacts of this scheme, which included proposals to raise the water levels by blocking up drainage ditches, a monitoring project was initiated (Williams *et al* 2008a).

Data were collected for three years, two of which were after the water levels had been raised. Assessment of these data suggested that water levels were often below the level at which the archaeology was assumed to be located. Subsequent excavation on the site in 2007 revealed that much of the upper 0.6-0.7m of the deposits were oxidised and the state of preservation of any wood was highly degraded. In some parts of the field, only the substantial vertical timber posts remained; the horizontal elements had been entirely lost. Critically, just to the north of the 1981 trench (where one of the 2007 excavation trenches was located), most of the evidence of the Iron Age causeway had been washed away by a later, probably Roman, channel (Rylatt *et al* 2011).

Although this monitoring project has provided useful training for those involved, and been used as a test-bed for complementary studies into degradation of modern, analogue materials, with hindsight, it was a mistake to have undertaken the project in this way. The monitoring was initiated without prior excavation and preservation assessment of the site, and was based on the assumption that archaeological material would survive, because it had been well preserved in the area excavated in 2001.

However, land-use conditions on these two areas were very different. The 2001 excavation was located between the North Delph and the River Witham and thus wet year round; the 1981 excavation was in a field that was then subject to ploughing and drainage over the next 25 years. Had an evaluation been carried out in the first instance, it would have been clear that the site was no longer present in the form seen 25 years before, and that a final 'rescue' excavation to retrieve the site's remaining significance would have been a much better response than the monitoring that was carried out.

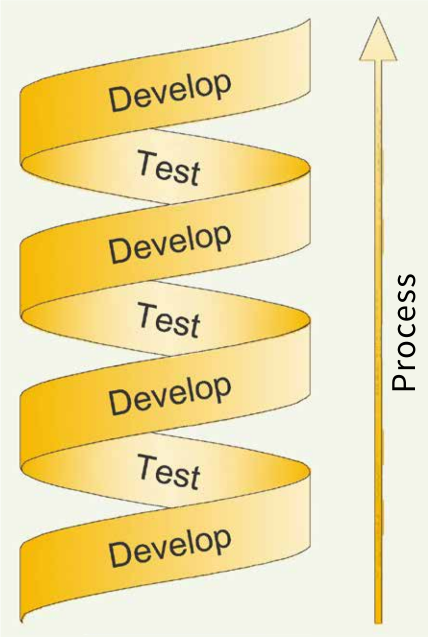
Drawing experience from this site to future work, it is clear that site preservation can vary considerably over short distances and will be exacerbated by different land uses and land-use history. Furthermore, the experience from this project is a reminder that knowledge of a site's previous state of preservation 20 or 30 years ago, is no substitute for a recent and up to date preservation assessment.

3 Nantwich, Cheshire

This case study shows how information collected during Tier 1 and Tier 2 assessments can be used to develop and improve conceptual models, as described in section 5 of Preserving archaeological remains – decision taking for sites under development, and Appendix 3 – Water environment assessment techniques.

The town of Nantwich in Cheshire contains Roman, medieval and post-medieval archaeological deposits of national importance. Much of this material is preserved beneath or within deep (more than 3m), often waterlogged, organic deposits. English Heritage, in partnership with Cheshire County Council, funded a project to assess these deposits and produce a management strategy to address their long term preservation (Malim and Panter 2012; SLR consulting 2007; 2009).

The information gathered during the course of the project up until the 2009 report provided the information needed to produce the Tier 1 and Tier 2 assessments outlined in Appendix 3, as illustrated in Figure 6. This involves the development of a conceptual model (Tier 1) and qualitative review of water balance (Tier 2). These stages are described below in more detail.



Updated assessment (Tier 3)	After recommendations for further ground investigation and dipwell monitoring (outlined in SLR 2009 study) are undertaken
Initial assessment (Tier 2)	SLR Consulting 2009 report
Ground investigation	30 shallow boreholes 3-6m depth 11 dip well installations Single round of groundwater level monitoring Single round of groundwater sampling and water quality analysis
Desk study/Tier 1	SLR Consulting 2007 report

Figure 6
Water environment assessment tiers and previous studies at Nantwich.

Developing a 1st Conceptual Model – Tier 1

Nantwich lies at a crossing point of the River Weaver, which flows north to ultimately join the River Mersey. The river has cut a shallow narrow valley, into a wider deep glacial valley that cuts into the Wilkesley Halite Formation bedrock at depth (more than 40m).

The glacial valley is filled with thick Glacial Till deposits, comprising upper and lower units of Boulder Clay (described as silty, sandy clay with fine gravel) interbedded with a Middle Sands glaciofluvial deposit (sands and gravels). Overlying the Glacial Till deposits are River Terrace Deposits (sands and gravels), and some alluvium (silt / fine sand) associated with the modern river system. Flow within the river is locally supported by a combination of surface water / overland flow from upland areas, and predominantly groundwater from the River Terrace Deposits (RTD). Given the thickness of lower permeability glacial deposits between the terrace sands and bedrock, it is unlikely that groundwater from the halite contributes significantly to the shallower groundwater system.

Apart from the River Weaver, other more minor watercourses originally existed. Possibly as many as three streams on the west side and four streams on the east passed through the town as they drained into the Weaver. Nineteenth century public health mapping (*see* Figure 7) notes open water channels and drains running through the town. Soils are described as slowly permeable,

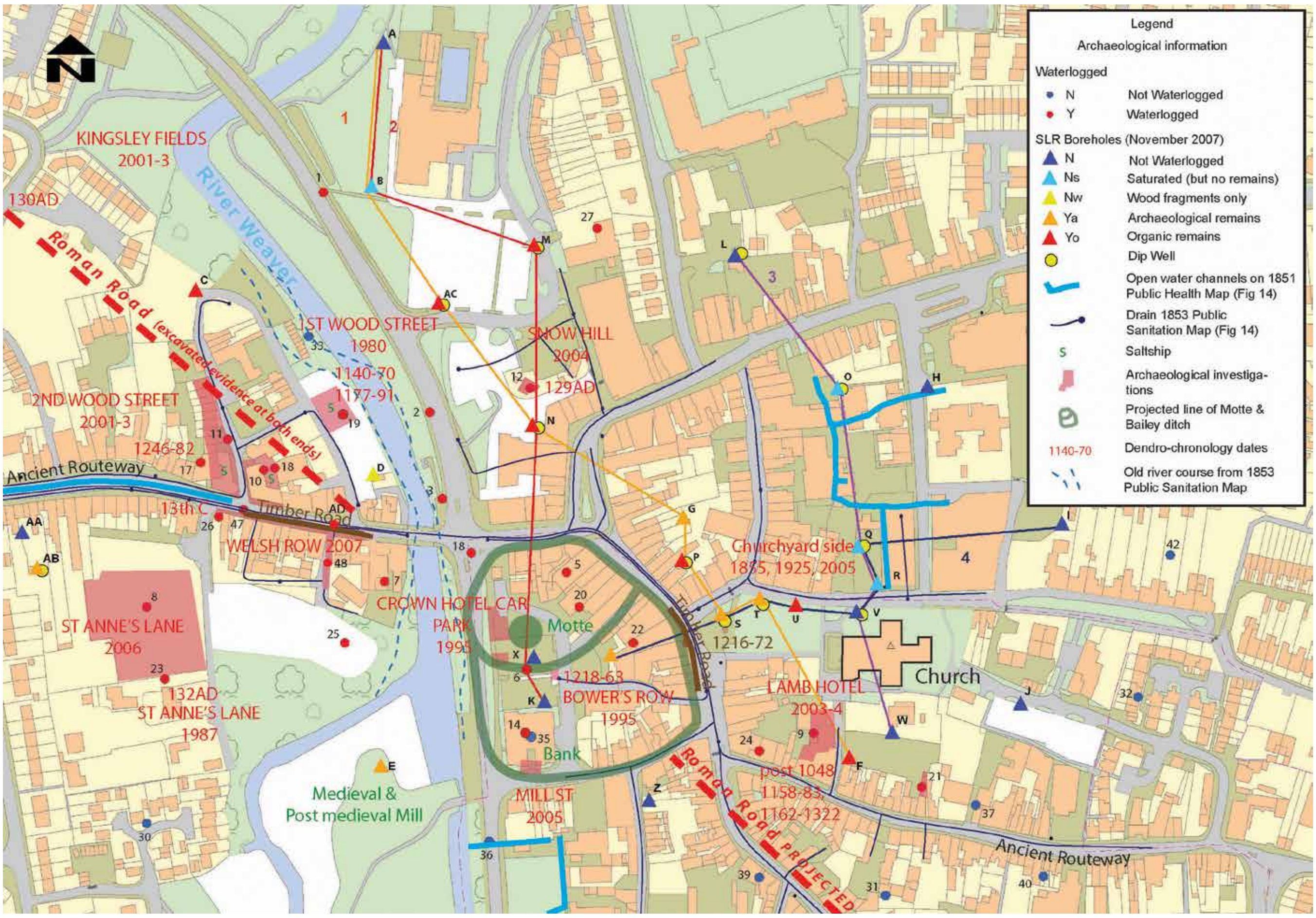


Figure 7
Victorian drainage and archaeological data including boreholes, from Nantwich.

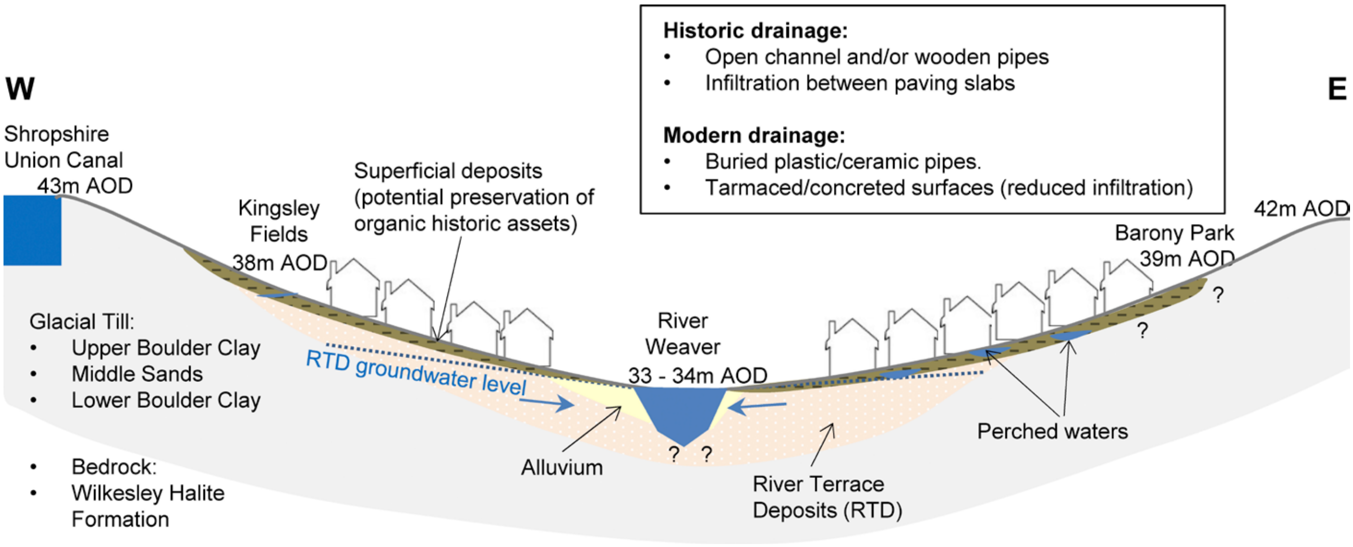


Figure 8
Nantwich conceptual model.

seasonally waterlogged clayey to sandy loams. Historic mapping indicates that to the east (Barony Heath) land was mainly heathland, whilst to the south-west land was wet and marshy with the possibility that Kingsley Fields was wooded.

Recharge from rainfall (either through infiltration of soils, or leakage from channels / drains) is likely to have led to the development of perched waters within the superficial deposits over time. Waterlogged deposits have been recorded in a number of archaeological surveys undertaken in Nantwich. Where encountered the deposits contain organic silts up to 3m in thickness (up to 6m depth in the Snow Hill area).

This information can all be brought together to create a conceptual model (*see* Figure 8). This model suggests that conceptually, waterlogged deposits located close to the River Weaver are likely to be sustained through a combination of infiltration and groundwater from the RTD. Further away from the river, as topographic elevations increase and where RTD are no longer likely to be saturated, the waterlogged deposits are likely to become more dependent upon the maintenance of perched waters through rainfall infiltration and leakage from channels / drains, and capillary action above these perched water tables.

Undertaking a Water Balance Qualitative Review – Tier 2

Historically such hydrological / hydrogeological conditions may have been sufficient to maintain preservation conditions for some of the waterlogged archaeological sites located a greater distance from the River Weaver. However, with the modern development of the town, in combination with changing climate, recharge to the underlying perched groundwater system is likely to have declined due to:

- open channels becoming in-filled, reducing the number of recharge pathways
- wooden pipes being replaced with ceramic or plastic pipes, leading to reduced leakage
- housing becoming more dense and widespread, reducing the amount of open space on which rain can fall
- modern surfacing being more impermeable, with surface run-off channelled to sewers / drains rather than infiltrating to ground.

This reduction in recharge to the shallow perched groundwaters may in some locations threaten the sustainability of water balance conditions (and hence site preservation potential). This is discussed theoretically for three scenarios in Nantwich in Figure 9.

Through qualitatively considering the water inputs and outputs to the perched groundwater system at different times of year, and different locations away from the River Weaver (Scenarios A-C), it is possible to broadly understand when and where water systems may be likely to be under stress (either throughout the year, or during particular seasons / circumstances). This enables monitoring and any additional investigation, to gather further quantitative data for a Tier 3 assessment and design of potential mitigation measures, to be targeted.

Depending upon location and the likelihood of underdrainage (that is the loss of water from overlying deposits to those below) to the RTD (in combination with reduction in recharge), perched waters and waterlogged deposits may experience a varying degree of water stress.

In some areas, such as close to the River Weaver (scenario A), the impacts of water stress are likely to be less significant and restricted to a limited amount of time during the year.

With increasing distance from the river (scenarios B and C), increasing difference in elevation between perched waters and RTD groundwater levels is likely to result not only in an underdrainage scenario (either during a summer period or permanently), but also an increasing dependence upon recharge waters to maintain waterlogged conditions for the long-term preservation of archaeological deposits. With any decrease in recharge, the model suggests that such deposits are likely to come under increasing periods of water stress, becoming more marginal in terms of suitability for long-term preservation of waterlogged remains.

This case study is developed further in Appendix 3 to provide additional information on the three water balance scenarios, as well as discussing how a Tier 3 assessment would be implemented.

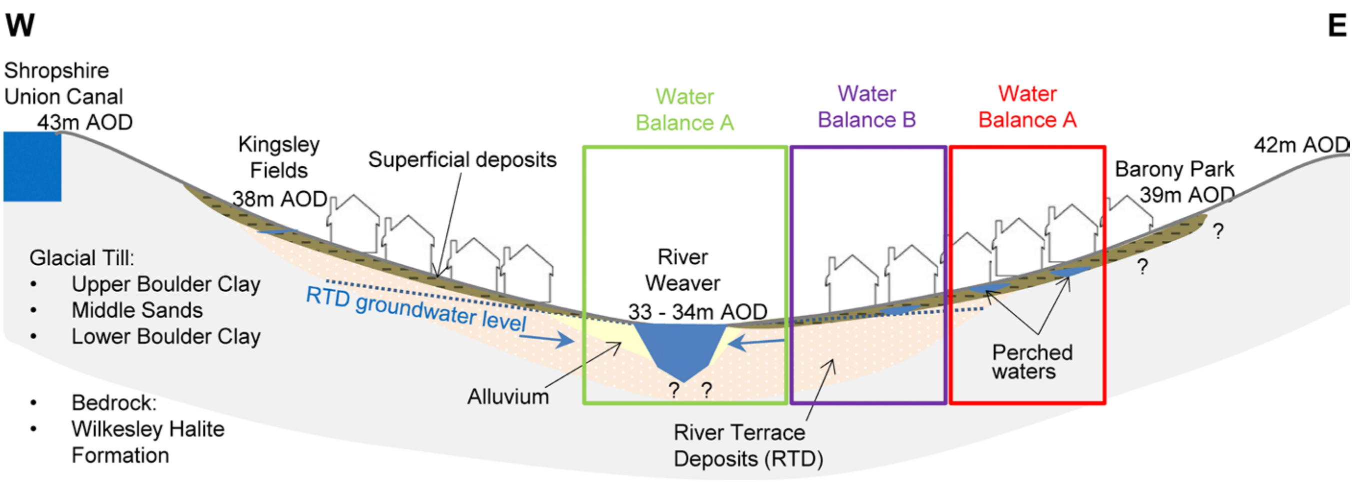


Figure 9
Water balance scenario locations.

4 Flag Fen, Peterborough

This case study describes how a Tier 4 numerical model was used to understand how water moved around a site, in order to aid future site management.

Excavations were carried out by DigVentures (2012) to investigate the state of preservation of the Flag Fen causeway. This work indicated that not all of the 60,000 timbers that make up this scheduled Bronze Age structure (Pryor, 1992) were permanently saturated. This meant that they were at risk of desiccation and degradation. To understand what was influencing water levels on site and to look for possible solutions to raise these levels, Historic England (then English Heritage) commissioned a hydrogeological study. JBA Consulting undertook the work; their final report (JBA 2015) is available on the Historic England website (see also Wagstaff *et al* 2016).

The hydrogeological work involved all four tiers of assessment outlined in Appendix 3, from the development of a hydrogeological conceptual model (Tier 1) right up to the construction of a computer-based numerical model (Tier 4).

Conceptual models, created for both catchment (Figure 10) and site (Figure 11) scales indicate the predominant geological characteristics of the site and surrounding area, in addition to the various hydrogeological influences on water levels, such as the drainage ditch (the Mustdyke), visible in Figure 11. Data were collected from the Environment Agency (EA) and Internal Drainage Board (IDB) to quantify these conceptual models (Tier 3) and to build a numerical model (Tier 4). Additionally, groundwater level monitoring data from the site of Flag Fen were also available from previous programmes of monitoring. The presence of these data meant that further groundwater data collection was not necessary.

Both the existing water level data and the numerical model suggest that across the site, summer water levels are routinely below the top of archaeology, meaning that the timber posts are no longer saturated and therefore at risk of degradation. Having verified that the constructed numerical model effectively represented the conditions on site and in the catchment, it was used to test a number of scenarios to investigate ways of raising water levels on site to make long-term preservation more viable. These scenarios were defined in discussion with Historic England staff and included the diversion of the Mustdyke away from Flag Fen, the creation of a wetland to the south of the site, as well as scenarios to test the sensitivity of the catchment to changes in climate and additional development pressure.

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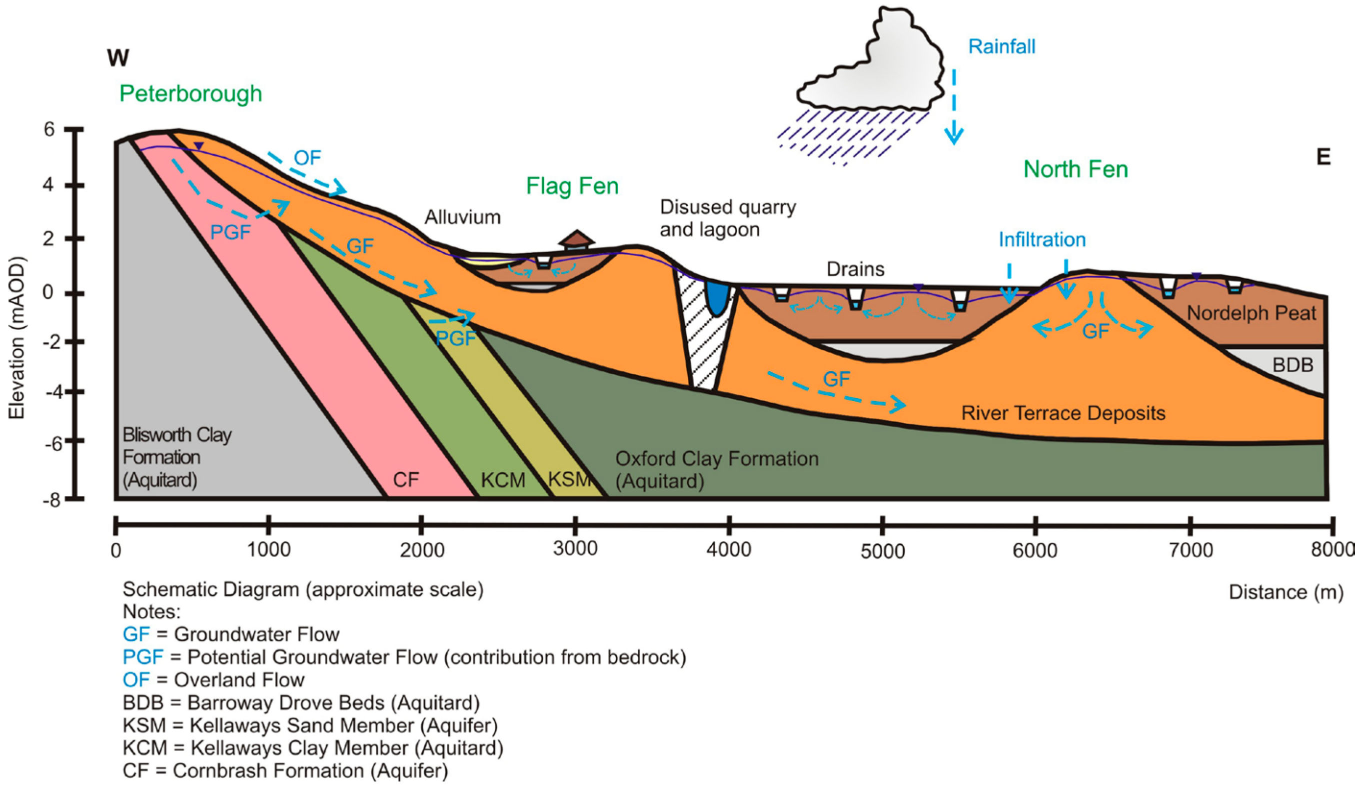

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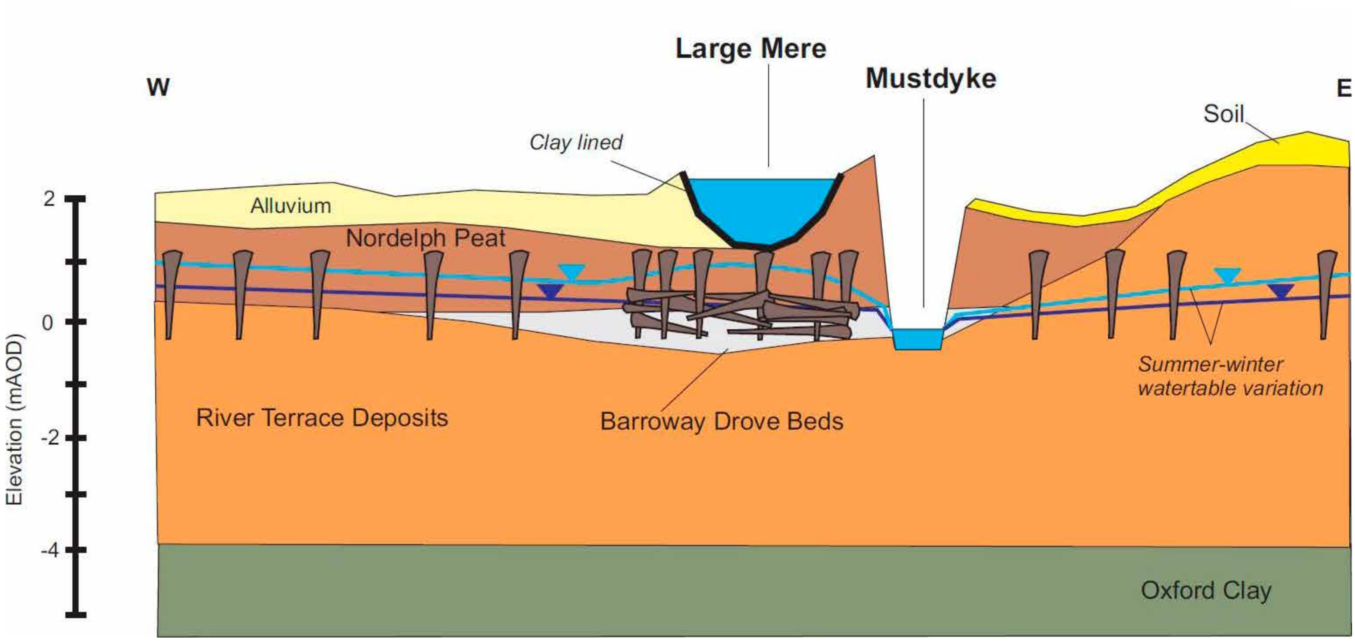

Figure 10
Hydrogeological conceptual model of the study area showing the relationship between the bedrock strata and the overlying superficial deposits.

Figure 11
Hydrogeological conceptual model of the area around Flag Fen showing the relationship between the water table and the Bronze Age wooden structures.

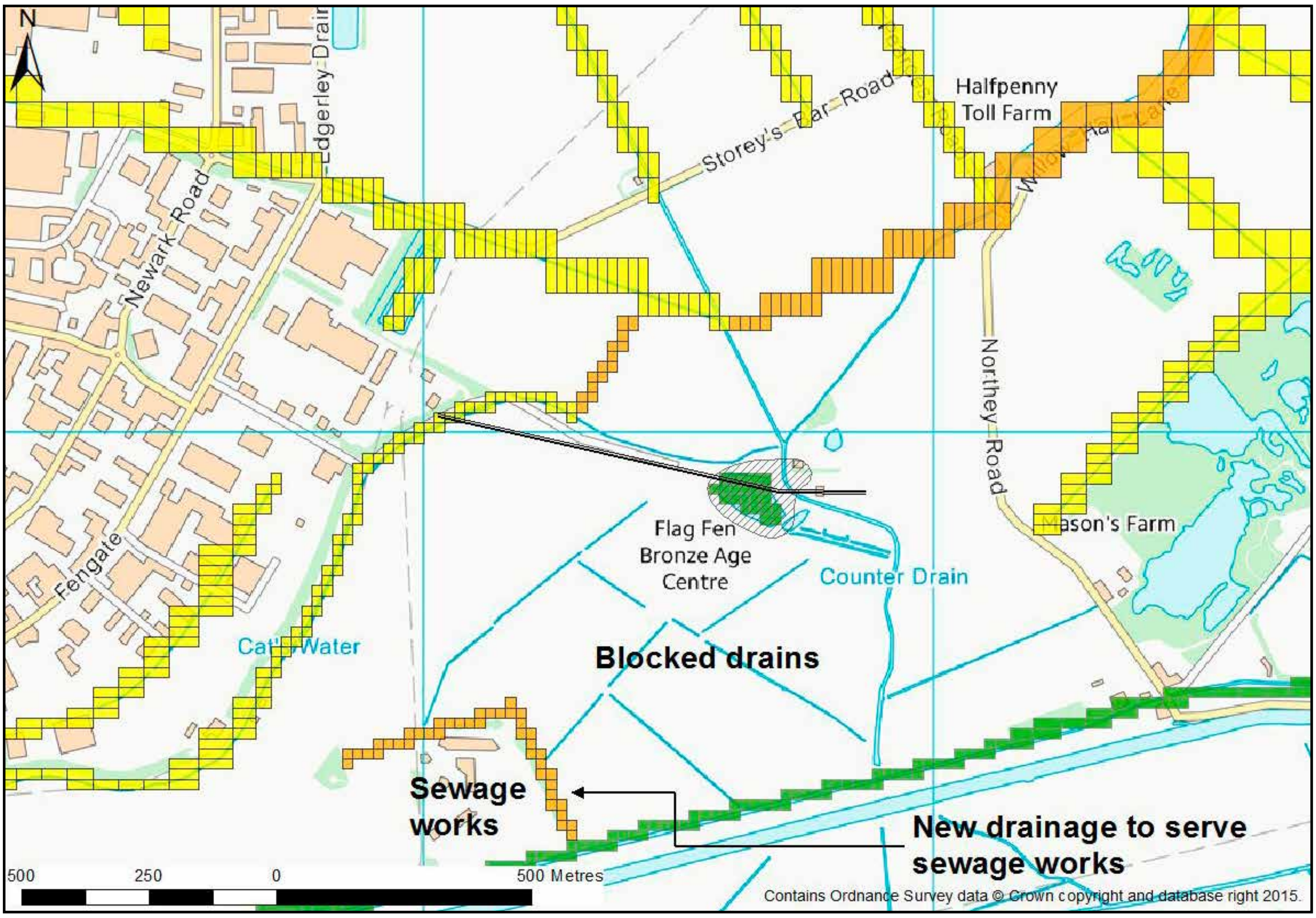

Figure 12
Ditch diversion modelling scenario 2, with new or deepened drains in orange.

One of the drainage ditch diversion scenarios (*see* Figure 12) did potentially indicate a large enough rise in water levels that all of the timber posts could be permanently saturated throughout the year. The other scenarios did not suggest year-round saturation would occur. The model also demonstrated that surface water infiltration (rainfall) only played a minor role in the maintenance of water levels as neither nearby development (where it was assumed that less rainfall would enter the soil as it was diverted into the mains drainage network) or reduced rainfall from climate change had a significant effect on modelled water levels.

The modelling and reporting work cost less than £25k ex VAT, and took six months to complete. This represented good value for money as it provided Historic England staff with a thorough evidence base with which to commence discussions with landowners and relevant water authorities (EA / IDB) to affect changes to improve the management of the site.

5 Shardlow, Derbyshire

This case study provides an example of where monitoring was carried out on a site where it was possible for excavation to take place if other mitigation measures failed.

During the excavation for a quarry haul road, a Bronze Age boat was discovered within a palaeochannel (Williams *et al* 2008b). As the quarry company already had experience of the excavation and conservation of one log boat elsewhere in the quarry, they were keen to re-route the haul road to avoid impacting the boat and the costs of excavation and conservation.

Figure 13
Boat before reburial.

Limited evaluation of the boat was undertaken, but it was not fully exposed at any point in order to minimise degradation (*see* Figure 13). A visual inspection of the boat identified that tool marks were still visible within the base of the boat. A Sibert drill assessment of the wood was carried out which indicated that the areas sampled (a part of the boat that would have been out of the water when the boat was in use and that was exposed during excavation) was not well preserved; it had a moisture content of 410%, which is categorised as highly degraded.

Nonetheless, based on the visual inspection of the boat (and the fact that the wood assessment was done on a sample of wood that was always likely to be more degraded), the decision to rebury the boat was taken. With hindsight, preservation assessment of the boat should have been carried out earlier in the decision making process, and more areas of the boat should have been subject to detailed assessment. Likewise, a water environment assessment should also have been undertaken.

A clay cut-off was constructed around the boat to isolate it from dewatering taking place in the rest of the quarry. Monitoring equipment was installed at three positions along the boat to observe whether the severe water stresses that were likely to be present outside the cut-off (from dewatering to enable quarry working) had any impact on the boat and its surrounding deposits.

In this case, because the haul road could be moved, a mitgation scheme could be designed to rebury the boat. Although all involved in the decision were fairly confident that appropriate conditions for long-term preservation could be re-established, there was the reassurance that if monitoring data indicated deteriorating conditions, it would be possible to excavate and conserve the boat. The quarry were prepared for this option and documents were drawn up by the quarry's consultant to prepare for this possibility (Richmond 2003).

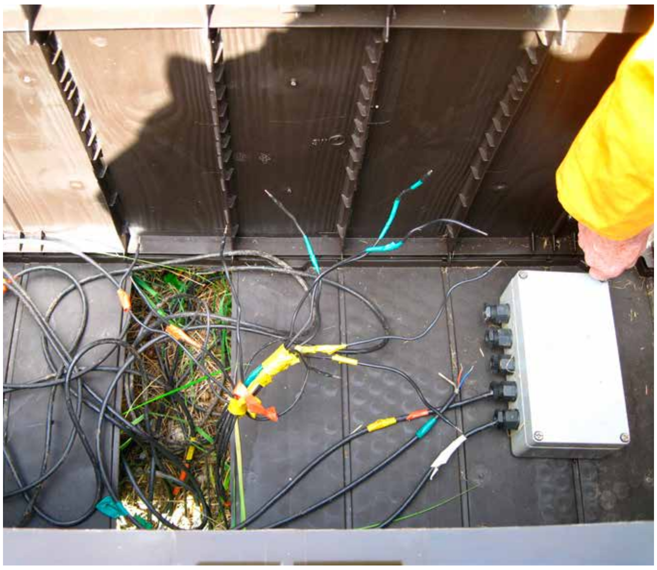

Figure 14
Cables from the vibrating wire piezometers and redox probes at Shardlow, housed in a large plastic box to protect them from the elements.

The clay cut-off and reburial scheme has worked well, as monitoring data show that the boat has been below the water table for the majority of the last ten years, and redox data indicate that reducing conditions, conducive to long-term preservation, prevail. A review of monitoring data was carried out at the end of 2014. It concluded that as large-scale quarry dewatering operations in the vicinity of the boat had now finished and the site had effectively faced all of the water stresses to which it could possibly be subjected, further monitoring was not necessary, as the mitigation strategy had successfully returned the boat to the burial conditions before its discovery. Further detail on this site and the monitoring data are provided in Williams *et al* (2016).

To provide long-term protection to the site, an obvious next step would be for the site to be put forward for designation. This would provide added recognition of the site's significance and encourage its continued positive conservation management. It would also mean that any proposed future changes to the management of site, particularly those that might not require planning consent, would still receive appropriate scrutiny.

6 Guy’s Hospital Roman Boat, Southwark

This case study describes how a building was redesigned to allow potential future access for excavation if mitigation measures fail. It also details the legal and financial mechanisms that have been set up to ensure that if monitoring data do indicate deteriorating environmental conditions, that sufficient money and legal controls exist to ensure the excavation of the boat.

In 2009, a proposal was put forward to construct a 14-storey Cancer Care building within Guy’s Hospital, on the site of the remains of a Roman boat (a scheduled monument), which at the time, was simply buried beneath a road. Initial discussions centred on the philosophical issues surrounding this, quickly followed by examination of the practicalities. To begin with, the Hospital Trust wished to excavate the boat, as the radiotherapy treatment rooms needed to be below-ground. However, clever design and shielding meant these could be located above ground so leaving the way open to leave the boat *in situ*.

This clearly raised challenges, however; planning law in England requires the significance of the heritage to be considered in line with the public benefits of the proposed scheme. In this case, with clear need for additional cancer treatment facilities in this part of London, it was important to consider whether the building could be constructed, whilst successfully retaining the boat *in situ*. Furthermore, *in situ* conservation and retention is always the preferred option for scheduled monuments, where their long-term survival is certain.

Design parameters were explored, and it was deemed feasible to proceed, in part because the boat was buried over 4m below ground. This left space to transfer the building load, via a massive transfer beam, away from the boat. A trial pit was opened to see if any remains of the boat survived (it had not been seen since 1958). Visually well-preserved timber planks and nails thought to represent the middle part of the boat were found. At the time no detailed preservation assessment was made of the wood.

Archaeologists worked closely with the building’s designers. From the outset it was clear that more was needed than a scheme which simply covered and monitored the site, which had no solution if the monitoring data showed deterioration. The design brief for the building therefore included a practical way of excavating the boat from beneath the new building. Accordingly, the foundations were designed with a ‘corridor’ to allow for such an excavation, and at ground level, the space through which excavations would be sunk has been protected from development by the planning authority.

A water environment study was carried out which indicated that a period of further burial should be viable. However to ensure that the additional development didn't impact on existing conditions, monitoring points (containing a multi-parameter sonde – *see* Appendix 4) have been installed around and over the remains of the boat. These have been instrumented to record redox, pH, temperature and water level data *in situ*, which are then downloaded to a laptop every six weeks. The building was designed so that rainwater from the roof is fed into a permeable layer above the boat to assist natural groundwater levels, and in addition, a very simple system with a tap has been built in should natural ground water and rainwater provide insufficient water flow into the site.

A legal agreement was devised and has been signed by the Hospital Trust and Historic England, establishing a timetable and trigger levels for the monitoring scheme, with various events identified within the agreed timetable. The trigger levels are associated with water level and redox values. The agreement is for joint meetings annually for formal data review, although Historic England will review the data as they are gathered. An initial monitoring period of five years has been identified. If monitoring data show stability and are below trigger levels at five years, then monitoring will cease.

If the data are less clear cut, then an additional monitoring period of three years will occur. If the data have stabilized and are below trigger levels then monitoring will cease after eight years, but if the trigger levels are consistently breached at eight years, then it will be concluded that the boat is in danger, and should be excavated. The Hospital Trust will have one year to plan and fund the project (in the middle of an extremely busy hospital) and gain all the necessary permissions.

Figure 15
The trial pit showing the central planks, ribs and nails.

This scheme is complex and has involved a great many people, from the structural engineers designing the foundations around and above the boat, the Hospital Trust project managers ensuring value for money, the lawyers and the archaeologists. The associated costs are not negligible. However, this scheme, unlike most other monitoring scheme in the UK to date, ensures a robust monitoring project with clear directions at each point on the timetable, leading either to cessation of monitoring, or excavation.

7 Must Farm, Cambridgeshire

This case study describes a mitigation and monitoring exercise that ultimately led to the excavation of the site, following review of the data. It highlights the difficulties of monitoring highly complex sites, the importance of expert review panels and the fact that even with the best designed and executed schemes, long term preservation is not always feasible.

An evaluation excavation at Must Farm in 2006 identified part of a Bronze Age structure, assumed at the time to be the floor of a house that had collapsed into a river channel following a fire. Archaeological material was exceptionally well preserved. Finds included wooden artefacts

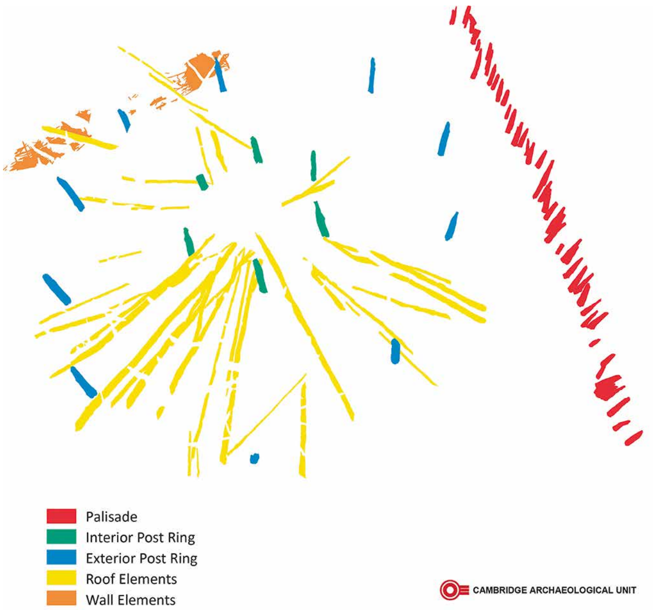

Figure 16
Plan of Must Farm site, produced during excavation.

(bowls etc) and timber construction material, fabric, glass beads, metalwork and even ceramic food vessels complete with contents. Figure 16 shows the layout of part of the settlement, with an external palisade fence, timber uprights on which the houses were built, with the collapsed roof from one of the houses radiating out from the centre. Below these roof timbers is a layer rich in finds relating to the occupation of the settlement which also fell into the river during the fire, termed the 'cultural horizon'.

At the time of its discovery, the decision was taken to preserve the site rather than excavate it. The small trial trench was backfilled with Oxford Clay to prevent oxygen ingress (and in part using polystyrene blocks to reduce the weight of soil pressing on the unexcavated area of the trench). A clay bund was constructed on the quarry pit side of the site, and the exposed face on this side covered with 300mm clay to prevent drainage northwards. In 2007, boreholes were drilled to install equipment for monitoring water level, pH, redox and soil moisture. The original methodology using clusters of redox probes and narrow gauge piezometers was enhanced in 2009 by installation of deeper dipwells and Time Domain Reflectometry (TDR) probes.

Figure 17
Monitoring equipment installed at Must Farm, including clusters of piezometers and in the distance deeper dipwells under blue cover.

Baseline data had been collected as part of the original evaluation in 2006, and further geochemical testing of the sediments was undertaken in 2009 when TDR probes were installed. Monitoring data from the piezometers and dipwells were collected on a fortnightly basis by an experienced groundwater hydrologist. Hydrological boreholes adjacent to the site and within the surrounding landscape, together with characterisation of the permeability of the general sedimentary sequence, provided a detailed dataset to place the site within a hydrological model.

Regular monitoring review meetings took place between the site owners (Hanson Building Products – now Forterra), their archaeological consultants responsible for the monitoring (SLR Consulting and York Archaeological Trust), the minerals planning authority's (Cambridgeshire County Council) planning archaeologist, English Heritage (now Historic England) and a number of other parties, including the University of Cambridge and Cambridge Archaeological Unit (CAU) who had first excavated the site.

Monitoring data indicated that across the site, water levels were above the highest known archaeology for the winter months, but that during the summer, these levels fell below the height of archaeological remains in the southern part of the site, recorded in the evaluation. Soil moisture data demonstrated that when water levels did fall during the summer months, some moisture was held by capillary action in the area containing the most important archaeological deposits. Redox data for the site indicated that reducing conditions were largely present, but no redox data were available for the cultural horizon when the water level dropped in the summer months so the full impact of these seasonal fluctuations was not fully known.

The effect of these fluctuations and the protection (from decay) provided to the waterlogged archaeological remains by the soil moisture became the focus of prolonged discussion within the monitoring review meetings. Following several years of data collection and meetings it was clear that the existing conditions were not optimum to ensure the long-term preservation of the site. Prior to a monitoring review meeting in December 2014 the site owner's consultant tabled a design to isolate the archaeological site from the rest of the quarry (as was done at Shardlow – see case study, but using buried plastic sheet piles to create the sealed wall around the site), and with a water pumping system constructed to maintain permanently high water levels during periods of low rainfall.

Although this proposal could have resulted in raised water levels, it would have involved further (limited) disturbance to the site to install the sheet piling, and relied upon regular intervention to maintain water levels by pumping. This would have put the site at risk in the event of equipment failure, and the long-term future was also not guaranteed – it wasn't clear what would happen to the site and the mitigation infrastructure after clay extraction ceased or if it changed ownership. This solution was also not without cost to the site's owners – the engineering and further monitoring costs to implement this new scheme could have easily matched that spent on monitoring to that date, and if the new scheme didn't work, funding for excavation would still have needed to be found.

Historic England staff present at the meeting (the Inspector of Ancient Monuments and the Senior Science Advisor) acknowledged that this new strategy might lead to the rewetting of currently unsaturated deposits. However, they also suggested that as it was not possible to maintain water levels above the level of the archaeological remains all year round without artificial intervention, the long-term risk to the site would, in their view, be managed better through excavation to recover the remaining significance of the site before it was potentially lost. In this particular instance, because the site was of such unrivalled significance, Historic England was also willing to offer some funding (through its emergency funding programme) to help with the costs of this excavation (because

Figure 18
Must Farm during excavation.

the scale and complexity of the site was beyond that which the site owners might have otherwise expected to have encountered and because the owners had met all of their obligations regarding archaeological conditions).

At the time of writing this case study, mid-way through the final excavation, it is clear that the decision to excavate the site was a sensible one. Although there is no significant evidence that the fluctuating water levels seen in the six years of monitoring data have led to degradation of the most significant parts of the site (ie the occupation layer), damage and decay in other areas is visible, which corroborates the level of decay recorded in 2006, coincident with the average water level maintained in Must Farm quarry pit from the 1970s to 2006. For example, the tops of the wooden posts have dried out and split (*see* Figure 19). This damage has occurred in deposits where oxygen has entered. The deposits containing the roof timbers and the occupation layers are only 20cm lower than where the degradation stops on these vertical posts. This suggests that although in the short term conditions conducive to preservation were being maintained for the most significant parts of the site, water levels only needed to drop a little further for a far greater proportion of the site to be at risk of decay.

This may seem like an unusual site to choose for a case study, since it has been excavated rather than preserved. However, it illustrates a number of key points from this suite of advice documents.

Firstly, that the initial data collection stage is key. Must Farm is a highly complex site. The conditions leading to the preservation of organic remains (fire and subsequent quenching in a river followed by burial within silty clay deposits) has meant that the site contains both waterlogged organic and charred organic material. There is also a range of other non-organic material types present. As a result, there are many challenges to the preservation of this wide range of material types. Additionally, the sequence of sediments beneath and above the cultural horizon consisted

Figure 19
Radial cracking is visible at the top of timber posts, indicating they have dried out.

of low permeability silts, which lay within the capillary fringe or tension saturated zone above the water table. This is therefore not a 'typical' rural wetland site.

The site's location on the edge of a clay extraction pit exerts a local dewatering pressure. Previous uncontrolled excavation and service trenches (dug before the presence of the archaeological remains was known) in two areas around the site (which have been backfilled with bricks) has also made control of the local water environment difficult. The surface of the site was covered with other brick waste, making it very hard to install the monitoring equipment, and by the end of the monitoring period, some of the redox and soil moisture probes were no longer operational. The measurement of redox within these sediments was particularly challenging as redox probes are best suited to monitoring within saturated deposits, rather than in sediments where soil moisture is held in pores through capillary action.

Although a lot of information was collected prior to making the decision to retain the site within the quarry rather than excavate it, the project team have also learnt a lot more about the sediments and the way water moves around the area during the course of the monitoring work. In particular, it was not clear at the start that it would be quite such a challenging location, nor that past uncontrolled excavation and current quarry extraction would impact as much as they have on water availability. If decisions were made again about this site, using all the methods and tools described in this advice (for example water environment studies), it is probable that the results would have suggested that without active management to keep water levels elevated, there was insufficient water available to secure the long-term future of the site.

Secondly, this does provide a very good example of the ways in which a well constituted monitoring review board (which has specialist knowledge and a willingness to challenge interpretation of the data) can maintain a proper overview of how well a reburial and monitoring scheme is progressing. It would have perhaps been even more effective if clear trigger levels had been set in advance, and agreed by all parties. A legally binding framework, as set out in the Guy's Boat case study, would have provided additional clarification of roles and responsibilities of board members and the actions that needed to be taken if results didn't match the appropriate standards.

Finally, this case study highlights the fact that sometimes, even the best designed mitigation strategies need to be rethought, reworked, and occasionally abandoned if it is clear that conditions for long-term preservation are not being met. When that happens, it is essential that the plan B for saving the site exists (as has been demonstrated here, and as is discussed for Shardlow and Guy's Boat).

For Must Farm, the plan B chosen was excavation, although other options, such as the proposal to isolate the site with a cofferdam and artificially manage water levels could have been explored in more detail and may have provided a way to retain the site in situ until the water stresses exerted by quarrying had ceased to impact on water availability. In this instance however, it was felt that the long-term risks and uncertainty would be managed better by immediate excavation.

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