Discovery, Innovation and Science in the Historic Environment

RESEARCH

Historic England

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Welcome…

…to this Science Special issue of Research magazine.

In this issue we show how science is used to provide insight into historic people and places, both terrestrial and marine.

In 'Discovery is only the beginning', investigation of the remains of a protected, submerged wreck – the *Rooswijk* – exemplifies multi-disciplinary working and international collaboration. Here, archaeological conservators, material scientists, and specialists in environmental studies and dating, have worked closely to build a detailed picture of the goods and people carried by the vessel on its final voyage. Moving from seabed to coastal waters, 'Waves over woodlands' examines the evidence for past environments that can be found in the inter-tidal zone; the rich interface between land and sea that yields abundant evidence for how landscapes change through time. On land, we see how 'Geophysical survey at Bayham Old Abbey' has been used to reveal hidden remains and produce new interpretive materials for visitors to understand and visualise the medieval space.

Two articles focus on improving conservation methods for historic buildings. The 'Control of biological growth on masonry' explains research trialling different methods for controlling the growth of micro-organisms (e.g. algae) and plants (e.g. lichen) on stone and brickwork to find solutions that are both effective and minimise damage to the historic fabric and environment. In 'Lead roofs and statuary', we see the results of a 20-year experiment to understand and manage lead corrosion; the findings will be synthesised in guidance published later this year. Our ability to run long-term trials beyond the typical 3-year project duration is one of the great public benefits delivered by Historic England.

The final pair of articles relate to adapting historic places for modern use. In 'Are building simulation models a good predictor to understand the real performance of traditional buildings?' the author explores approaches to modelling energy and thermal performance and hygrothermal (heat and moisture) behaviour in traditional buildings, and considers how accuracy of those models might be improved. The issue concludes with news of updated guidance on 'Piling and Archaeology', produced in collaboration with construction engineers and archaeologists, and representing over a decade of research into best practice advice.

Jen Heathcote
Head of Investigative Science.

Front cover image: Close-up of thimbles from the wreck of the *Rooswijk*.

We are the **public body** that **helps people care for, enjoy** and **celebrate** England's **spectacular historic environment**

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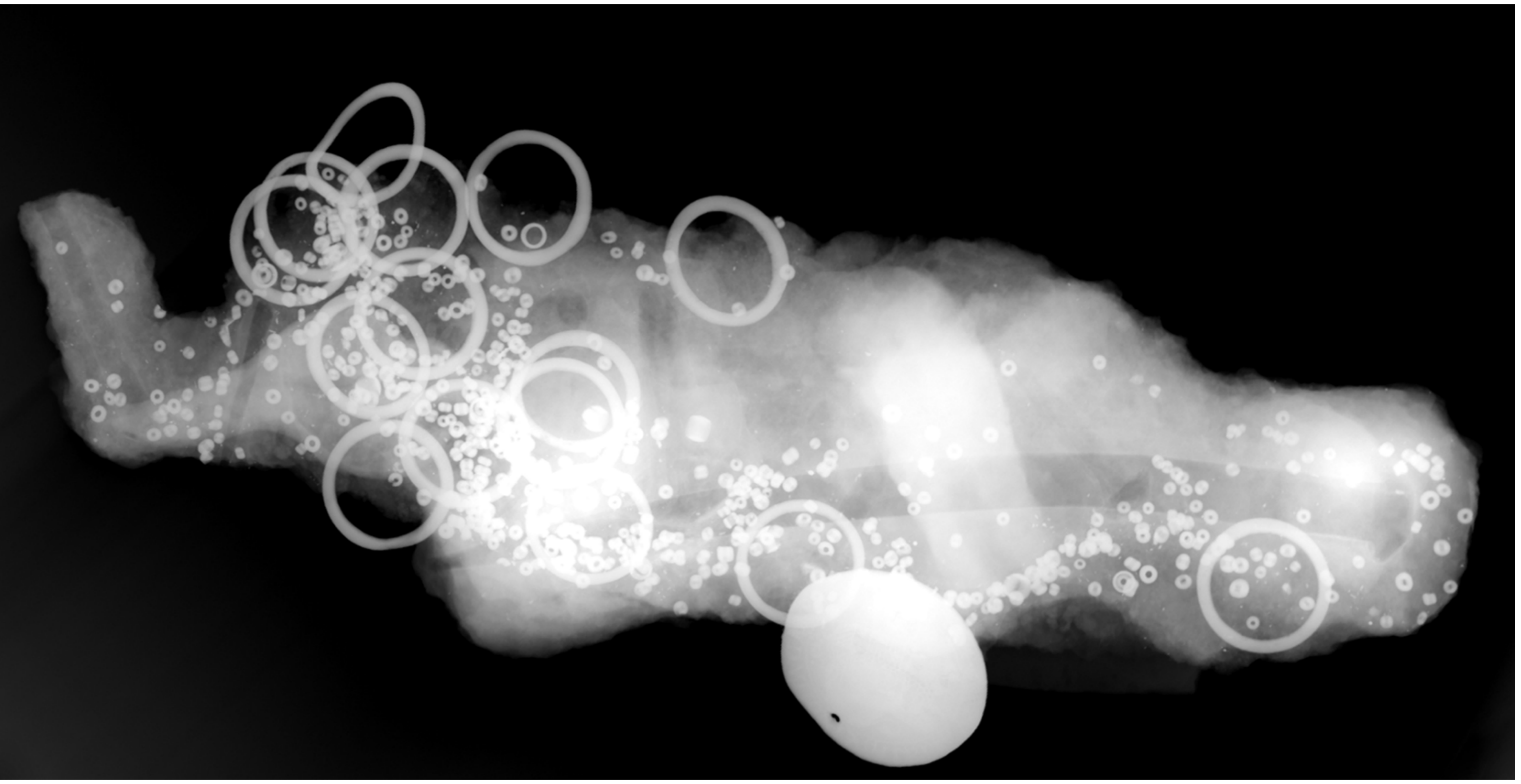


Top and bottom: Concretion from the *Rooswijk* and corresponding X-Ray showing multiple artefacts. © Rijksdienst voor het Cultureel Erfgoed/Historic England

Discovery is only the beginning

How the application of multiple scientific analyses enhances our understanding of shipwrecks.

Shipwrecks and archaeology are an ideal combination not only to grab the public's interest but also to stimulate further research by presenting closely dated material that does not normally survive on terrestrial sites. Historic England is currently involved in the investigation of numerous protected wreck sites, which allows us to employ a number of scientific techniques to identify, analyse and understand artefacts and ecofacts.

Artefacts recovered from the marine environment are classed as unstable and therefore undergo lengthy processes of desalination and conservation. There is good evidence that prolonged storage in water furthers decay, and it is demanding on resources. One of the first tasks is to assess the materials that were recovered.

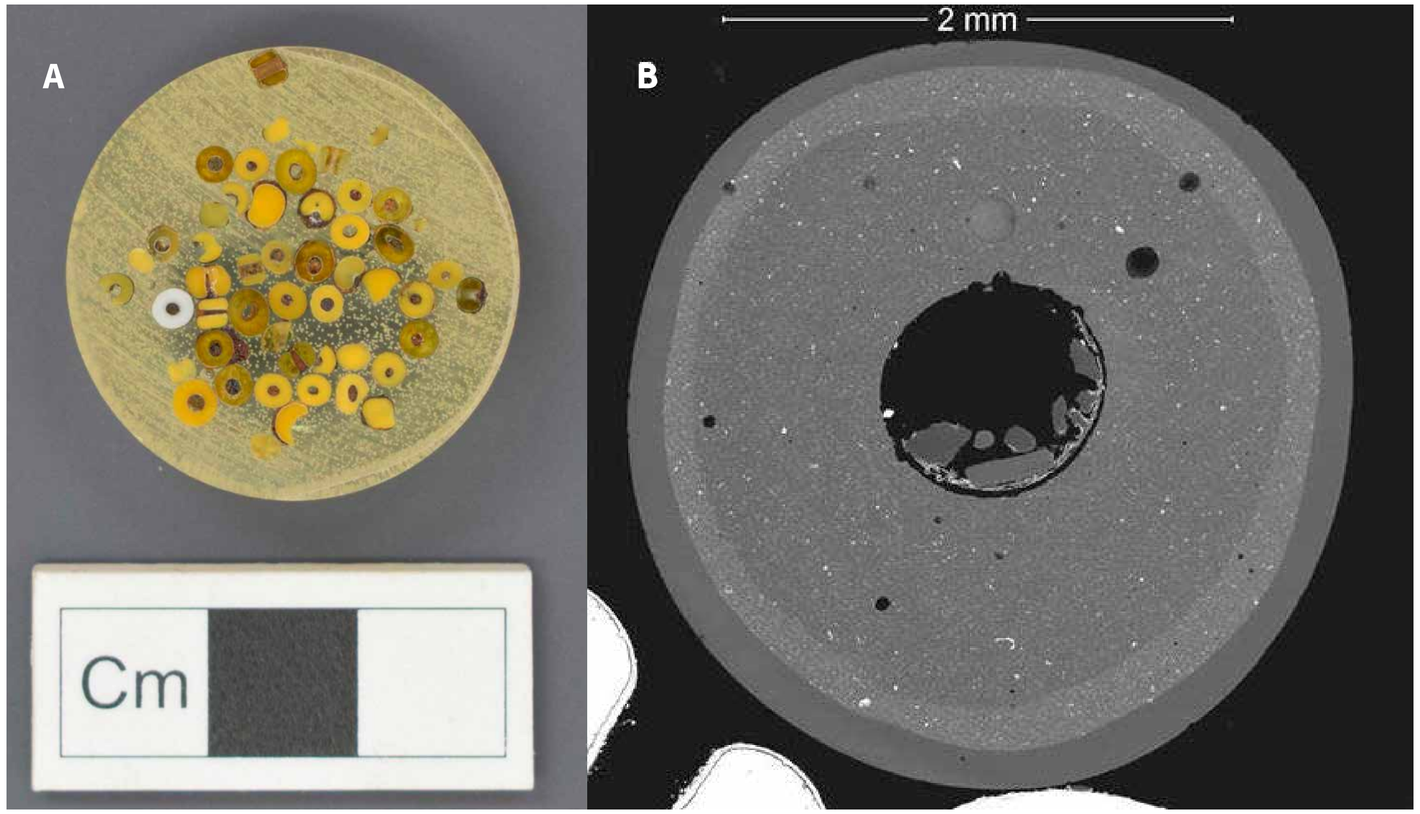
Using X-radiography to assess hidden artefacts

In the case of heavily concreted marine artefacts, techniques such as X-radiography are particularly useful. Not only do they allow for a quantification of multiple artefacts inside concretions, but also give an idea of the materials present and their state of preservation. This information is used to devise and undertake a conservation treatment. In the case of organic materials, desalination is followed by impregnation with polyethylene glycol and vacuum freeze-drying. This technique eliminates the drying stresses caused by the high surface tension which water exerts on the weakened cell and fibre structures of wood or leather artefacts when simply air-drying without impregnation. Conservators spend a lot of time looking closely at artefacts and are often the first to spot unusual materials or anomalies. They are perfectly placed to alert other specialists and often draw on their expertise to identify unknown materials. >>

Conservators spend a lot of time looking closely at artefacts and are often the first to spot unusual materials or anomalies

Left: Selection of glass beads micro-excavated from concretion shown in the previous figure. © Rijksdienst voor het Cultureel Erfgoed/Historic England

Below: (A) Glass beads mounted in resin and polished for analysis. (B) Electron microscope image of a white bead, which is made from two layers of white glass (speckled layers) and an outer coating of clear glass. © Rijksdienst voor het Cultureel Erfgoed/Historic England



the beads are valued by archaeologists, because they provide dateable evidence for long-distance maritime trade

Using material science to reveal new evidence

The *Rooswijk* was a Dutch East India Company vessel which sank on the treacherous Goodwin Sands, off Kent, in January 1740. The ship was outward bound for Batavia (modern-day Jakarta) with trade-goods. Now a protected wreck site, the ship's remains lie at a depth of some 20 metres. Since 2016 Dutch and British maritime archaeologists from Historic England and the Rijksdienst voor het Cultureel Erfgoed (Cultural Heritage Agency of the Netherlands) have worked together to carry out a joint investigation of the site. Even the tiniest finds from the *Rooswijk* tell a story when analysed using modern scientific techniques. X-rays of some of the concretions from the wreck showed bright spots scattered throughout. These areas were excavated by the conservators to reveal glass beads, only a few millimetres in size. Thousands more may have been lost to the shifting sands but fortunately some were trapped in the rust, like insects in amber.

The majority of the beads extracted so far are translucent and opaque yellow, a few are translucent green and opaque white, and a single larger, multi-coloured, chevron bead has been recovered. Huge numbers of glass beads were produced in Europe and exported to Indonesia, the African continent and the Americas, where they were highly valued. From the fifteenth century, European beads increasingly competed with long-established bead makers in the Indo-Pacific. Today the beads are valued by archaeologists, because they provide dateable evidence for long-distance maritime trade.

The design of popular beads remained virtually unchanged for years and many are plain, so chemical analysis is key to identifying different types. Furthermore, the precisely-dated *Rooswijk* beads may also help to answer archaeologists' questions at sites around the world.

New insights using environmental science

Due to the waterlogged, anaerobic (oxygen-deprived) conditions at the seabed, organic remains from wrecks can be extremely well preserved. Samples of sediment from within the remains of a wreck site can produce macroscopic remains of plants, insects, bones, shells and microscopic pollen which provide information about food supplies, traded goods, living conditions, construction or packing materials. From the *Rooswijk*, samples of sediment from within various objects have produced seed remains which appear to have been trapped within the objects during or soon after the wreck. A sample from a stoneware flagon, for example, produced numerous fragments of buckwheat (*Fagopyrum esculentum* Moench) seed coat or husks. The inedible seed coats were a by-product often used as a packing medium. The flagon, along with other breakable vessels, was probably packed in a crate with buckwheat husks as protection. >>

While most of the edible plants were presumably on board as food supplies, the coconut shells remain a mystery

Also recovered from the *Rooswijk* were grains of wheat (*Triticum aestivum/turgidum/durum* type), flax (*Linum usitatissimum*), brassica species (*Brassica/Sinapis* sp.), bramble/raspberry (Rubus sp.), cannabis/hemp (*Cannabis sativa*) and, most surprisingly, five coconut (*Cocos nucifera* L.) shells. Seeds of wild grassland plants may derive from hay used for floor covering, bedding, or packing material. While most of the edible plants were presumably on board as food supplies, the coconut shells remain a mystery. Radiocarbon dating would be needed to confirm if the coconuts were contemporary with the ship or likely to be more recent.

Identifying the types of wood used on board ship – for fixtures and fittings, armaments and small arms, or domestic and personal effects – sheds light on past wood selection preferences and practices. When considered together with knowledge of the woods' physical structures and characteristics, we can infer possible reasons as to why certain wood types were considered best-suited.

Analysis of around three hundred wooden remains recovered from the *London* (Hazell and Aitken 2019) has revealed that specific types of wood were used for particular purposes. For example, *Fraxinus* (ash) was predominantly used to make the handspikes for manoeuvring cannon into firing position, as it is well suited to absorbing impact stresses – hence its traditional use for broom handles and snooker cues! *Ulmus* (elm) was used for pulley blocks and gun-carriage trucks as, unlike *Quercus* (oak), it is less prone to cracking; and *Quercus* heartwood was used to make casks as it is almost impermeable to moisture. Examining artefacts closely reveals additional details, such as the bark still present around two of the pulley-block pegs (one of which was probably *Ilex* (holly)) and the decorative insert on the end of the tuning peg.

Dendrochronology tells the story of construction and repair

Dendrochronology or tree-ring dating is a powerful tool that can be used to aid the potential identification of a ship and enhance understanding of the wreck and associated wooden artefacts such as barrels and gun carriages. With appropriate targeted sampling strategies, it can provide dating evidence for the construction of and subsequent repairs to a ship, as well as ascertaining the geographical origin of those timbers, thus providing evidence relating to place of construction and longevity of the ship. >>

Analysis of around three hundred wooden remains recovered from the *London* has revealed that specific types of wood were used for particular purposes

Below left: Three coconuts from the *Rooswijk*. © Rijksdienst voor het Cultureel Erfgoed/Historic England

Below right: Pulley block (SF3052) from the *London* wreck, made of *Ulmus* (elm), with its peg made from a small diameter branch, probably *Ilex* (holly), with some of the bark still attached. Could this have been a running repair on board the ship, using what was available to hand? © Historic England, Angela Middleton

The oak framing timbers and hull planks proved to include timbers of both German and English origin

Applying scientific techniques to wreck sites allows us to paint a more comprehensive picture of our past

Above left: The excavation of the Tankerton wreck by Wessex Archaeology and Timescapes, funded by Historic England. © Historic England, Rod Bale

Its application to the recently listed inter-tidal wreck at Tankerton beach near Whitstable, Kent, revealed that the dated timbers represented at least two phases of felling and three different woodland sources. A construction date towards the middle of the latter half of the sixteenth century was indicated, with major repairs being undertaken within at most two or three decades. The oak framing timbers and hull planks proved to include timbers of both German and English origin, the German timbers appearing to have been felled slightly earlier than the English. The ceiling planks, potentially either coeval with the oak timber repairs or slightly later, were conifer timbers of Scandinavian origin.

The multi-phase, multi-source group of timbers from the wreck at Tankerton highlights both the potential complexities of analysing wrecks and the fundamental information relating to date and provenance of timbers used in the construction and repair of a ship. The evidence from dendrochronology can be integrated into the wider archaeological investigation to complement the information derived from other methods of analysis.

Using science to recover evidence from maritime remains

The work undertaken on the three wreck sites helps us and others to understand these important heritage assets. Both the *London* and *Rooswijk* featured here are currently on the At Risk Register, which is an indication of their vulnerability. The preservation conditions we encounter on wreck sites enable us to redress an imbalance currently prevalent in our archives: materials such as textile, leather or wood only survive in certain conditions, in this case, underwater. Gaining knowledge and information on raw products used, on trade routes or on the equipment and personal effects used by the crew allows us to paint a more complete and accurate picture of our past ■

Above right: A cross-sectional sample from an oak framing timber of English woodland origin, showing damage by marine wood borers. © Historic England, Rod Bale

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Angela holds a degree in archaeological conservation from the University of Applied Sciences, Berlin, and an MSc in Maritime Conservation Science from the University of Portsmouth. She joined Historic England as an Archaeological Conservator in 2007.

Here she is responsible for advising on and undertaking research and investigative conservation on material retrieved from land and marine sites. She has a special interest in the conservation of waterlogged organic materials

Sarah Paynter, DPhil
Materials Scientist with Historic England.

Sarah studied Natural Sciences and worked in industry before obtaining a DPhil in Archaeological Science. She is now a materials scientist for Historic England and Honorary Research Fellow at the University of Sheffield. She uses analytical techniques to identify and investigate a wide range of heritage materials from buildings, collections and archaeological and maritime sites in the UK, from the Bronze Age to the twentieth century.

Ruth Pelling
Archaeobotanist with Historic England.

Ruth is an archaeobotanist with experience of northern European, Mediterranean and North African material. Her current role at Historic England is to provide specialist advice and sector support, to develop internal and collaborative partnership research projects, and to inform national and regional research frameworks. Her research interests include late Roman and early Islamic food and agriculture in North Africa, the past use of bracken, missing plant foods of Neolithic Britain, and aspects of British archaeobotany particularly from the Early to Middle Bronze Age and the early medieval migration period.

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Senior Palaeoecologist with Historic England.

Zoë has a Geography background (Quaternary Science), with research experience in the reconstruction of past environments and landscapes. Her multidisciplinary interests mean that she has worked on diverse projects, from the use of peatlands to reconstruct past climatic conditions to the study of wood use through the identification of archaeological wood/charcoal remains.

Cathy Tyers
Dendrochronologist with Historic England.

Cathy has been a dendro-chronologist since 1984. She oversees all tree-ring analyses commissioned by Historic England, provides advice to a wide range of external partners, and develops national standards. Her research interests include imported conifer timbers in post-medieval buildings, medieval farmhouses in south-west England, and past landscapes and woodland management.

Further reading

Hazell, Z and Aitken, E 2019 *The* London *protected wreck, The Nore, off Southend-on-Sea, Thames Estuary, Essex: Wood identifications and recording of wooden remains recovered between 2014 and 2016*, Historic England Research Report **15/2019**, available at: http://research.historicengland.org.uk/

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Middleton, A 2016 *Conservation of surface recovered artefacts from the* Stirling Castle *Protected Wreck*, Historic England Research Report **45/2016**, available at: http://research.historicengland.org.uk/

Middleton, A Pascoe, D and Paynter, S 2017 *Conservation of surface recovered artefacts from the* Invincible *protected shipwreck site*, Historic England Research Report **18/2017**, available at: http://research.historicengland.org.uk/

Middleton, A Camidge, K Paynter, S and Gleba, M 2018 *Investigation and conservation of surface recovered artefacts from* HMS Colossus, Historic England Research Report **26/2018**, available at: http://research.historicengland.org.uk/

Waves over woodlands

Exploring remains of prehistoric landscapes preserved in England's intertidal zone.

If you were looking for evidence of former prehistoric woodlands, you'd be forgiven for not heading straight to the seaside...

...but dotted around our coastline are the remains of former land surfaces – peat deposits and submerged forests – sitting within the intertidal zone. Every so often, particularly after a storm, remnants can become exposed, such as those at Redcar, in Cleveland, for example, revealed by Storm Emma in 2018. Others, however, are always visible when the tide recedes.

In this article we describe these drowned landscapes, their significance and value, and, using a case study, illustrate how we are exploring the best ways to study, record and monitor them. >>

Overview of the southern part of the exposed intertidal peat / submerged forest deposit at the Pett Level coast, looking approximately south-west (June 2008). © Historic England, Damian Grady

What are intertidal peats and why are they there?

Intertidal peats and submerged forests are the remains of land surfaces which formed when sea levels were lower, and which have been drowned by subsequent relative sea-level rises. Whilst the majority formed during the Holocene (the current warm period beginning at the end of the last ice age), some exposures, for example those along the Norfolk coast, are older.

Although they are sometimes referred to as 'petrified' forests (coming from the Greek word *petros* for rock or stone), they are not actually fossilised. Instead, they are preserved due to the wet site conditions; the waterlogging restricts decay processes by limiting the amount of oxygen available for decay organisms to function.

Why are intertidal peats important?

The organic remains that are preserved within the deposits vary from the micro – for example, pollen grains, diatoms (microscopic, single-celled algae), insects, and seeds – to the macro – the trunks and stumps of the trees themselves. They provide valuable information on past environments and landscapes, as well as being suited for scientific dating (radiocarbon and dendrochronology). They can also preserve direct evidence of human activity and presence through associated archaeological remains and features such as artefacts and footprints.

The location of these deposits in the intertidal zone means that they can be at threat of loss through erosion, so it is important to record them to capture their evidence. Having ways of producing resource assessments and of monitoring deposits over time will help to identify research priorities for intertidal peat deposits by targeting those that are most at risk.

These deposits are also carbon rich, potentially releasing carbon dioxide and methane into the atmosphere when eroded.

How are we studying them? The case study: Pett Level

Since 2014 Historic England has been involved with work investigating and recording part of an intertidal exposure at Pett Level, East Sussex. Initially we funded research led by the University of the Highlands and Islands analysing the organic remains themselves. This was followed by further research led by Historic England which is comparing the effectiveness of a range of site-scale recording methods.

Given that the full length of the exposure extends for about 2.5 kilometres along the coastline (from Cliff End in the south west, to Winchelsea in the north east), a smaller, discrete area of exposure about six hundred metres long was chosen as the target for these studies.

Excavation, coring and analyses

With help from the local community more than two hundred exposed tree remains have been recorded and identified within this area. They show that the woodland consisted mainly of wet-loving trees; alder and ash, together with oak, willow, birch, yew and hazel. The size of these trees is very impressive, with trunks of alder and ash up to eleven metres in length. This represents only the part of the tree that has been preserved, suggesting that some trees were substantially taller when alive.

Together with recording the trees, the peat itself was investigated through a series of auger transects along the peat shelf. This involved manually pushing a chambered auger down through the peat and then bringing it back up to record the sediments trapped in the chamber. This coring showed that the deposit consists of multiple peat layers which vary in number and thickness across the site; in places the uppermost peat layer is around two metres thick. At two locations test pits 1x1x1 metres were dug into the peat in order to take samples for analysing the pollen, plant macrofossils and beetle remains. All of these techniques allow us to look at how the landscape at Pett Level has changed over time. >>

organic remains provide valuable information on past environments and landscapes, as well as being suited for scientific dating

Right: Digging one of the test pits. © ORCA, Thomas Desalle

We have been able to date the woodland at Pett Level through radiocarbon dates on seeds and buds taken from the basal and upper layers of the peat, together with radiocarbon dates and dendrochronological (tree-ring) studies of the trees themselves. This work was co-ordinated by Dr Peter Marshall and Cathy Tyers (both of Historic England). The dates have shown that woodland was present from at least 4,400 BC to 1,500 BC, from the Late Mesolithic to the Middle Bronze Age.

Putting all of the information together, we have worked with graphic artist Dr Alice Watterson of the University of Dundee to provide an interpretation of how this area of the Pett Level would have looked around 4,000 years ago. >>

The dates have shown that woodland was present from at least 4,400 BC to 1,500 BC, from the Late Mesolithic to the Middle Bronze Age

Reconstruction of the site during the Early Bronze Age (by Alice Watterson, for Project 6920) based on the palaeoenvironmental records. © ORCA/Alice Watterson

Aerial recording and interpretation

The first phase of this aspect of recording work took place in 2016 using high-level (aeroplane) and low-level (drone) aerial recording techniques. Multiple types of imagery were acquired, including traditional RGB (red-green-blue) photographs, multi-spectral and thermal images, and video footage. The photographs were processed to produce orthorectified images (that is, free from distortions) using Structure from Motion (SfM) methods (https://historicengland.org.uk/research/methods/terrestrial-remote-sensing/specialist-survey-techniques/). A digital elevation model (DEM) was also produced. The newly-collected data, together with existing information from other sources (such as the Environment Agency), were then visually interpreted. They were used to map the inferred extent of the peat deposits, and other feature types, such as individual procumbent tree trunks, were also mapped where they could be distinguished.

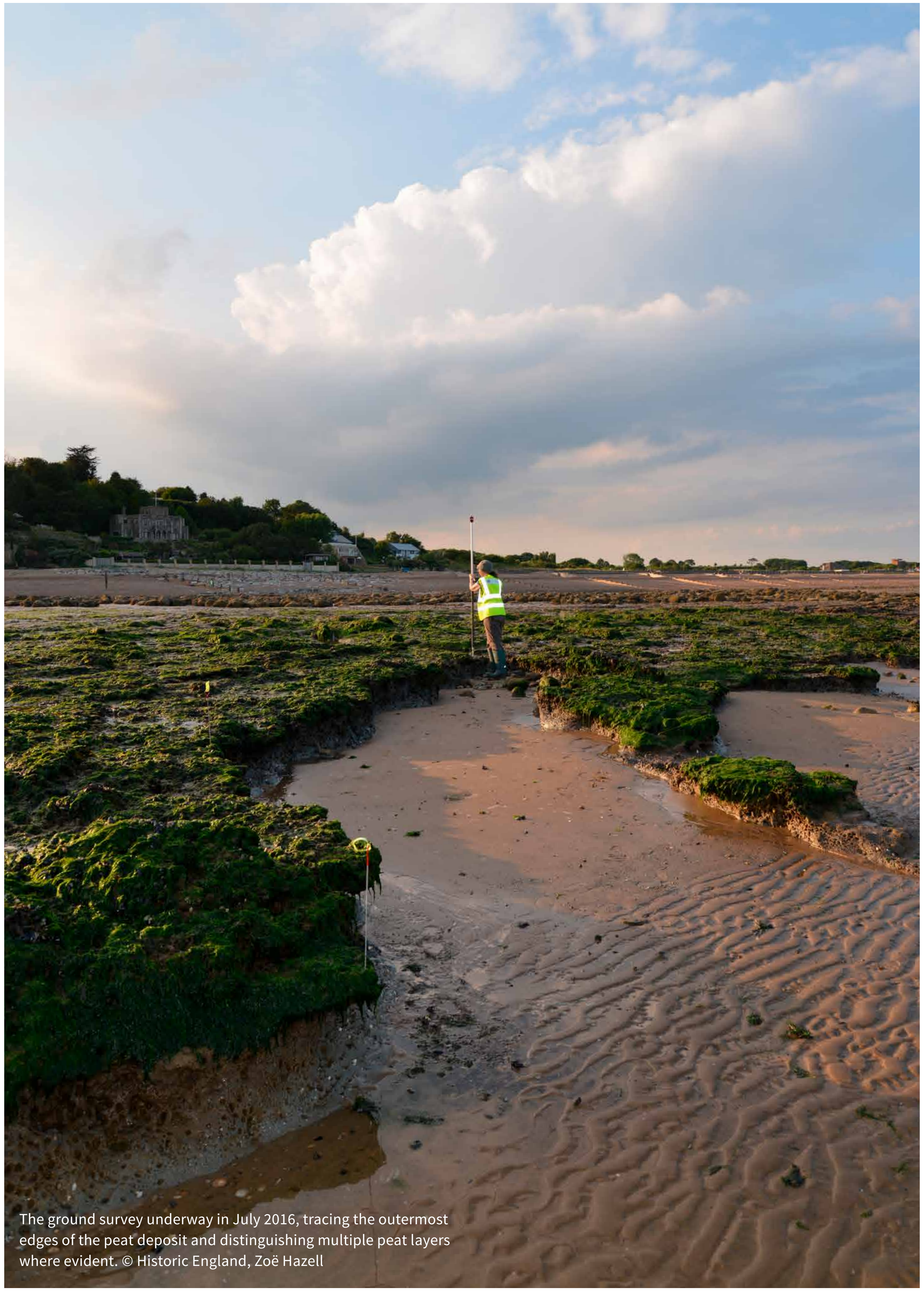
Soon after the aerial surveys, on-site recording was undertaken on foot, mapping the outermost limits and extent of the exposure as seen at ground-level. This produced a dataset which could be compared with the aerially-obtained datasets and the aerial image interpretations. Most recently, in 2018, small-scale sediment coring investigations were carried out to explore the deposits below the surface in order to test the thermal imaging results obtained in 2016.

Work to quantitatively compare all the datasets using a GIS (geographical information system) is in progress. Two ground-based survey outlines of the exposure currently exist, one produced in 2014 by Dr Timpany, the other in 2016. The current plan is to revisit the site for recording in 2020. This will involve a further ground-based survey for comparison, as well as a repeat of the aerial-survey data acquisition.

If successful, the use of aerial recording will be hugely beneficial in identifying, recording and understanding such deposits and furthermore in recognising and monitoring any changes over time, be they vertical and/or horizontal. The advantages of using rapid and remote recording techniques in situations where the time available for recording is short, and where accessing intertidal zones on foot can be dangerous, are clear. >>

Above: The site during the high-level recording (July 2016), showing one of the black-and-white target boards used to geo-locate the aerial photographs. Note the identifiable procumbent tree trunks and the areas of overlying boulders. © Historic England, Damian Grady

The advantages of using rapid and remote recording techniques where time is short and access sometimes dangerous are clear



The ground survey underway in July 2016, tracing the outermost edges of the peat deposit and distinguishing multiple peat layers where evident. © Historic England, Zoë Hazell

Continuing palaeoenvironmental work

Although Dr Timpany's work funded by Historic England (Pr6920) has drawn to a close, research continues at the site, assisted by CITiZAN (the Coastal and Intertidal Zone Archaeology Network). Regular site visits with community volunteers involve further recording and sampling. Plant macrofossils from the site (Test Pit 1) are currently being analysed as part of a dissertation project by an MSc student at the University of Leiden.

Warning!

Take care! The fact that these sites are located in the intertidal zone means that there are inherent dangers associated with visiting them. Always consult tide times and seek local advice when planning a visit and bear in mind that access may require permission unless using public rights of way ■

Acknowledgements

The aerial recording project (Pr7218) was a collaboration between multiple Historic England teams within what is now the 'Policy and Evidence: National Specialist Services' division. In particular, thanks to Damian Grady (high-level aerial recording), Fiona Small (aerial investigation and mapping) and Vicky Crosby (ground survey). Skyeye (now Terra Drone) carried out the low-level recording.

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Zoë has a Geography background (Quaternary Science), with research experience in the reconstruction of past environments and landscapes. Her multidisciplinary interests mean that she has worked on diverse projects, from the use of peatlands to reconstruct past climatic conditions to the study of wood use through the identification of archaeological wood/charcoal remains.

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Further reading

CITiZAN (Coastal and InterTidal Archaeology Network), more information at: https://www.citizan.org.uk/

Coastal peat database, more information at: https://historicengland.org.uk/research/current/heritage-science/intertidal-peat-database/ Work is underway transferring the records to ARCHES

Timpany, S 2018 *Archaeological and Palaeoecological Investigation of the Submerged Forest and Intertidal Peat at Pett Level, Sussex: Assessment report*. Version 6. Unpublished report for Historic England, Project No. 6920

Revealing lost buildings at Bayham Old Abbey

New results shed light on the abbey's hidden remains.

Geophysical survey at Bayham Old Abbey has provided key information about lost parts of the monastic complex. The results will be used to inform management of the site with the potential to present new interpretation in the future.

Bayham Old Abbey, situated in a quiet rural location on the Kent/Sussex border south east of Royal Tunbridge Wells, was founded shortly before 1211 by monks, originally from Prémontré in north-east France, belonging to a monastic order known as the Premonstratensians or White Canons. Further building and later modifications continued through to the fifteenth century. The abbey comprised a range of monastic buildings as well as the church – cloister, chapter house and infirmary, although the extent and layout of the infirmary have hitherto not been well established. The abbey was suppressed by Cardinal Wolsey in 1525 and its buildings were largely destroyed. The surviving impressive ruins were partly repaired in the eighteenth century to provide a romantic view for Bayham Old Abbey House within a landscape designed by Humphry Repton. The estate later passed to the Camden family.

The need for better understanding

Both the remains of the ruined abbey and a later Dower House – built to house a widow of the Camden estate – are in the care of the English Heritage Trust. The Trust requested a geophysical survey to clarify the development of the abbey and help the public to understand and enjoy the site. Specific questions for the geophysical survey were:

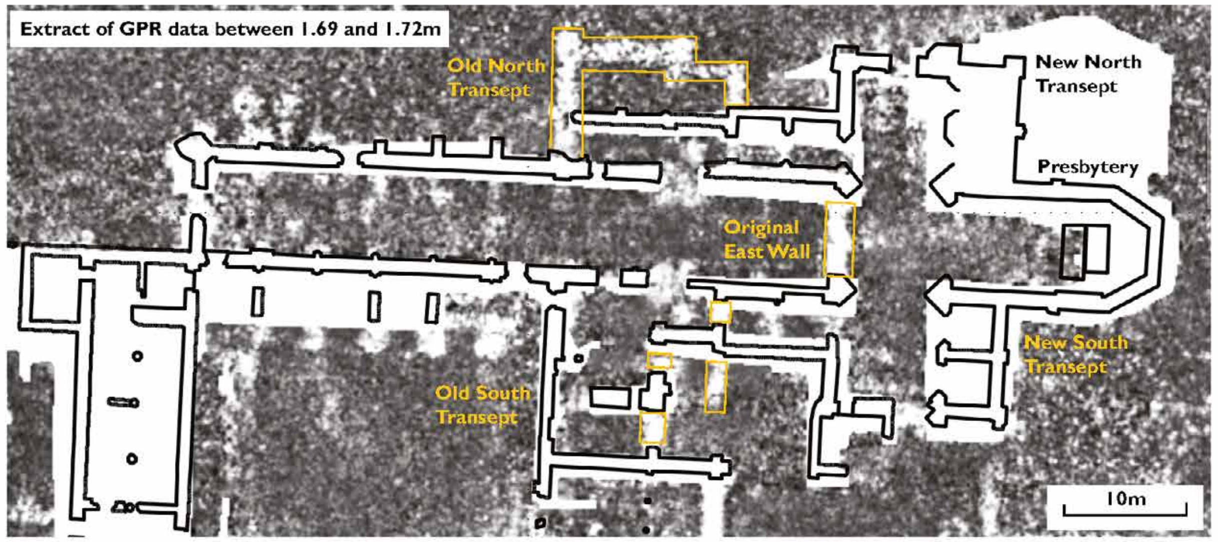
- where was the east wall of the original church, which was enlarged during the late thirteenth century to form the transepts and presbytery surviving at the site today?
- and where was the infirmary range, which is not represented by any of the standing remains?

We decided that a closely spaced ground-penetrating radar (GPR) survey using a vehicle- towed system would be best to cover the majority of the guardianship site, although careful driving was required to manoeuvre the lightweight all-terrain vehicle through the abbey ruins. >>

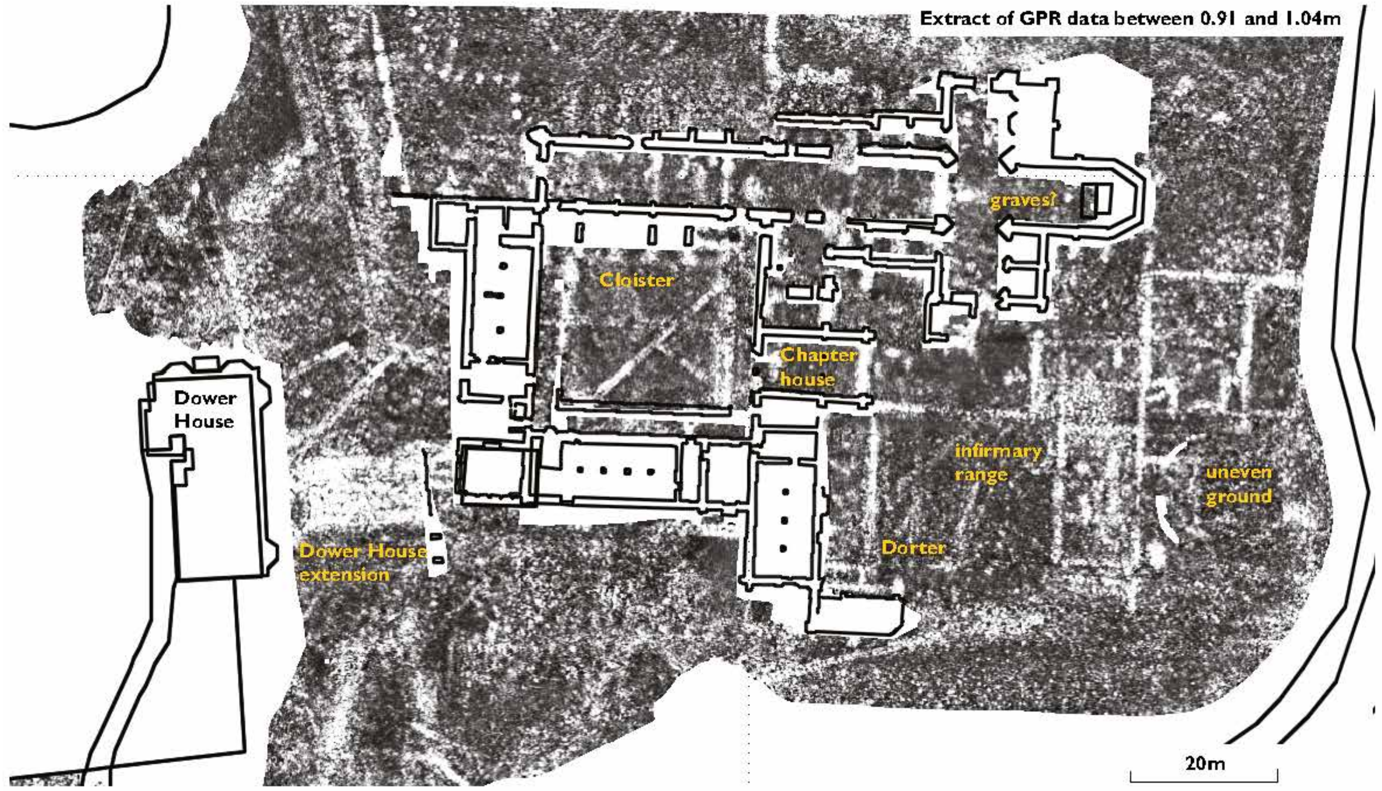
English Heritage requested a geophysical survey to clarify the development of the abbey and help the public to understand and enjoy the site

Top: View to east along the nave towards the remains of the enlarged church.
© Historic England

Bottom: A perfect fit for the GPR antenna through the chapter house.
© Historic England



Above: Deeper walls in the GPR data reveal the foundations of the old church. © Historic England



Above: Significant remains were found throughout the shallow GPR survey data. © Historic England

Identifying the original east end of the church

The GPR data provided a detailed image of the buried remains to a depth of about three metres from the current ground surface. Foundations of the early thirteenth-century church still survive and produce strong GPR reflections, imaged as bright-white responses in the deeper data. The foundations of the east wall of the original church have been clearly detected from a depth of 0.65 metres as a substantial structure, approximately 1.5 metres wide, reaching far into the ground to support the superstructure of the building. Combining this new information with evidence from the building fabric of the ruins has established for the first time the plan of the abbey church before it was enlarged. It might be noted in addition that the level of detail provided in the GPR data is of such high resolution that in the near-surface results it is possible to discern both tree roots and individual mole runs immediately beneath the lawn, demonstrating that the technique is a powerful tool for identifying both archaeological and natural features.

Around the cloister and beyond

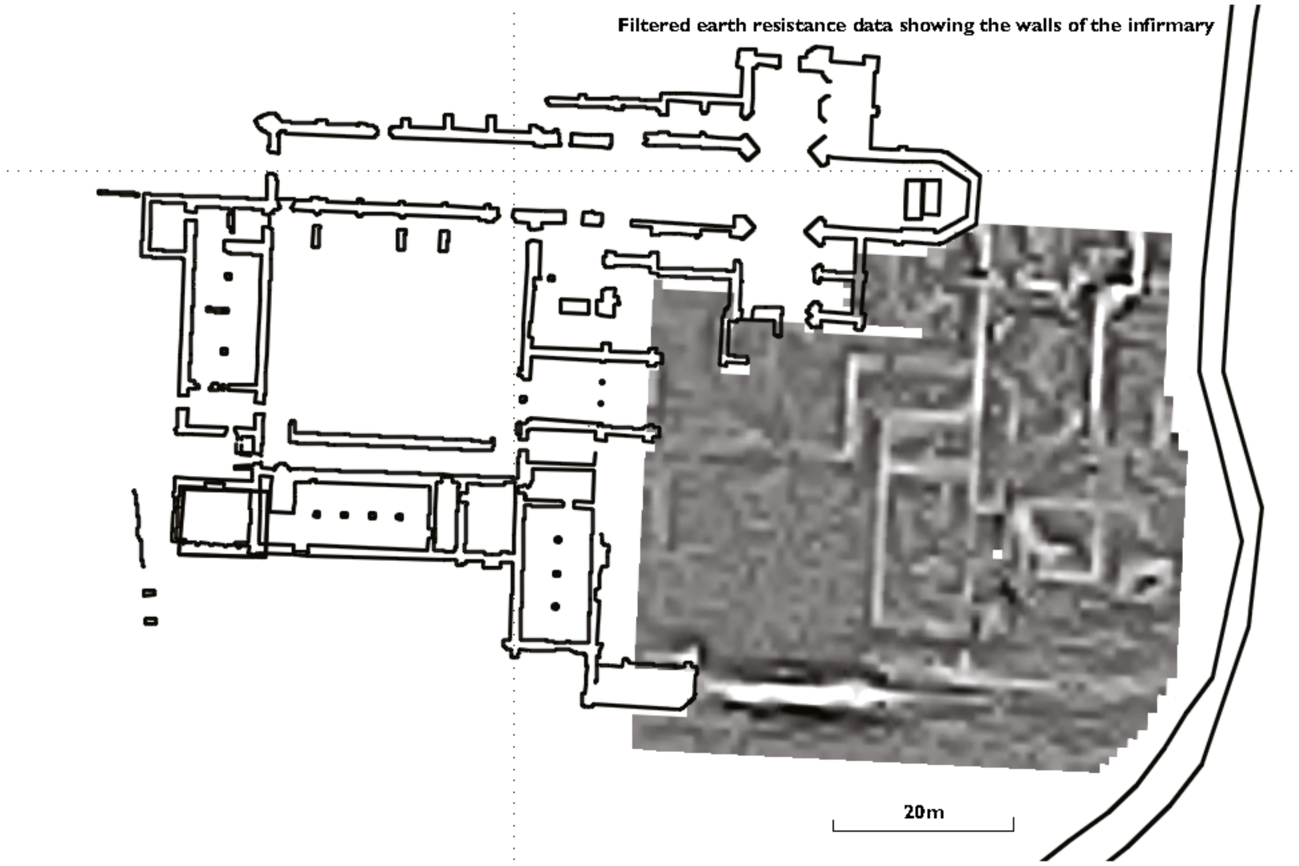
The plan of the original buildings around the cloister was not known with any precision. The wider area survey helped to confirm the location of the east wall of the chapter house and revealed a much larger suite of rooms at the south-east corner of the cloister, alongside the monks' dormitory, known as a Dorter, which was located on the upper floor above an undercroft. Perhaps more surprising was the extensive range of buildings associated with the site of the abbey's infirmary to the east of the cloister, where no standing building remains currently survive above the ground surface. Wall footings in this area, appearing in the more shallow images of the data, demonstrate the former existence of structures around a large hospital building, together with some additional ancillary buildings to the north and a courtyard garden, between the infirmary and the Dorter to the west, similar in location to that found in other Premonstratensian abbeys. >>

Combining this new information with evidence from the building fabric of the ruins has established for the first time the plan of the abbey church before it was enlarged

The area to the east of the infirmary, where a group of mature trees had previously stood, was very uneven and the GPR antenna was unable to get good contact with the ground surface. However, a targeted survey using the slower earth-resistance technique provided equally clear results, especially after treatment of the data with a filter to enhance the appearance of buried walls. Despite the uneven ground the metal probes used to collect the data were able to make contact with the underlying soil and the results show more detail of the infirmary buildings extending into this area hidden under the rough ground.

Presenting the survey results

The results of the geophysical survey are available as a full research report and are available to be incorporated into new interpretation of the site in the future (https://research.historicengland.org.uk/Report.aspx?i=15866). To help visualise the full GPR data set an animation of the data has been superimposed over a plan of the abbey remains (https://www.youtube.com/watch?v=vM27wyCov2w), showing how anomalies due to different structures occur at varying depths from the surface, thus informing the future management of the site ■



Above right: Survey images for remains detected in rough ground. © Historic England

The authors

Neil Linford PhD
Senior Geophysicist

Neil has experience across a wide range of applied geophysical techniques. Whilst his PhD research focused on the magnetic properties of archaeological sediments, he also has expertise in all aspects of the use of GPR. He is an editor of the journal *Archaeological Prospection*, has served as the chair of the NERC Geophysical Equipment Facility, and recently co-edited "Innovation in Near-Surface Geophysics" featuring contributions on many aspects of archaeological geophysics.

Andy Payne
Geophysicist

Andy has specialised in the practice of archaeological geophysics since the early 1990s, working widely across England and occasionally in France, Spain and the Channel Islands. He has contributed to numerous reports and publications. His archaeological career has also included working on excavations in Orkney and on the site of the Roman amphitheatre in London.

Paul Linford, MSc
Geophysics Manager

Paul has worked as an archaeological scientist for English Heritage and Historic England since the mid-1980s and is head of the latter's Geophysics Team. He has particular interests in archaeomagnetic dating and in developing the team's caesium magnetometer array. Paul is also Treasurer of the International Society for Archaeological Prospection and a member of the Geological Society's Near Surface Geophysics Group committee.

Further reading

Geophysical survey, more information at: https://historicengland.org.uk/research/methods/terrestrial-remote-sensing/geophysical-survey/
https://historicengland.org.uk/advice/technical-advice/archaeological-science/geophysics/

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Linford, N and Payne, A 2017 *Bayham Old Abbey, Frant, East Sussex: Report on Geophysical Surveys, October 2017*, Historic England Research Report **72/2017,** available at: https://research.historicengland.org.uk/Report.aspx?i=15866

Microorganic growth on stone war memorials conceals inscribed lettering. Understandably, custodians wish the names and inscriptions to be legible so that the honoured are remembered. However, repetitive cleaning can erode and even damage the masonry. © Historic England

Control of biological growth on masonry

Research into the effectiveness and sustainability of methods for controlling biological causes of deterioration in historic stone and brickwork.

Historic England and our partners have several initiatives to research the control of micro-organic growth (such as bacteria, algae and fungi) and higher plants (such as lichen and moss) that frequently exist on porous stone and brick. We want to better understand the effectiveness of current methods and find solutions that are kinder to the historic masonry and more environmentally friendly.

Damaging growths

Organic growths contribute to the natural, aged patina that gives masonry its appealing aesthetic on historic structures. However, moss indicates and sustains high moisture levels, which can damage masonry, and some lichen and bacteria actively cause deterioration. Algae provide nutrients for other biological growth and the discolouration which they cause is often unsightly and disfiguring. Changes in climate, particularly in temperature and in the frequency and intensity of rainfall, are resulting in an observed increase in 'greening', indicating more active algal colonisation. Public perception finds this discolouration unacceptable, leading to a desire to remove it through cleaning. >>

We want to find solutions that are kinder to the historic masonry and more environmentally friendly

Cleaning may not always be the right answer

Cleaning is not only costly, but potentially exposes the masonry surfaces to damaging intervention. Conventional cleaning with water is effective, but this seemingly benign intervention causes some loss of the surface, and overzealous cleaning (for example, with high pressure jets) can cause roughening of the surface as well as significant damage. Frequent cleaning might satisfy public demand, but threatens the durability and survival of the fabric.

Risks of existing chemical treatments

Algicide, biocides and bioinhibitors have been used regularly in conjunction with other cleaning methods to kill biological growth and reduce its regrowth. Commonly based on quaternary ammonium compounds (QACs) that have been proven to be harmful to the environment and wildlife, their use is becoming more restricted through Health and Safety legislation. Moreover, their performance and longer-term efficacy has been observed to be extremely limited.

Testing the effectiveness of chemical treatment

Consultants commissioned by Historic England are carrying out research to understand the effectiveness of currently available proprietary biocides and whether they have any longer-term influence on the condition of the masonry. Our consultants are using four techniques to measure and monitor the presence of organic growth.

- ATP (adenosine triphosphate) luminometry, which measures the type of molecule present in growing micro-organisms;
- sugar analysis to measure the amount of nutrients present;
- photography and photospectrometry to measure surface colour change.

Left: UVC irradiation of microorganisms by suspended UVC bulbs in a room at Newport Roman Villa, Isle of Wight. Control requires a sufficient dosage, which is based on the wattage of each bulb, its distance from the treated surface and time of exposure. © Historic England

These small-scale trials have identified that some proprietary biocides are more effective than others on the natural stones tested – Portland and Lincolnshire limestones. Early results indicate that some of these biocides stop being effective after three months. However, even those that kill algae only restrict the regrowth of bacteria and fungi. The monitoring of the performance of the biocides will continue, collecting data for several more months.

We also intend to explore further partnership research into other biocidal applications, such essential oils and enzymes.

These trials also reveal that the chemical and physical properties of the stone surface (either directly or due to their influence on the micro-organic growth) and surface orientation (horizontal or vertical) play a significant part in the effectiveness of the biocide treatment and the rate of recolonisation. Further investigation of the bioreceptivity of different natural stones is planned to better understand this occurrence.

Using ultra-violet irradiation to inhibit growth

With the limitations of chemical treatments, an alternative potential method of control is by ultra-violet C (UVC) germicidal irradiation. When applied by UVC lamps at sufficient dosage, the treatment causes genetic damage to microorganisms that impedes their reproduction. It is widely used in building services and the food and medical industries.

Historic England and its partners (the University of Portsmouth and Isle of Wight Council) are undertaking trials at Newport Roman Villa to determine the potential, limitations and parameters of the technology on historic masonry surfaces. It offers real benefits over chemical treatments, as it is non-invasive, does not affect inorganic surfaces and has the potential to reduce regrowth over a longer period of time. However, as it is dangerous technology, it needs to be subject to stringent health and safety risk assessments and controls. Therefore, it can really only be used indoors.

Results are positive to date, indicating that it can be an effective method of eradication and control, by means of regular re-treatment. Further research aims to identify potential limitations and risks that may occur on other sites. Guidance on its use will eventually be published ■

The authors

John Stewart
Senior Architectural Conservator

John trained in architectural history and conservation and is currently employed at Historic England. He is undertaking trials of the control of microbiological grown on masonry with UVC irradiation and research in the conservation of fibrous plaster. He was co-editor the Historic England book *Mortars, Renders & Plasters in the Practical Building Conservation* series.

Clara Willett
Senior Architectural Conservator

Clara worked as a hands-on conservator and manager in private practice for almost a decade and has been with Historic England for another fifteen years. In her role as an architectural conservator she brings experience in the deterioration and conservation of various materials: stone, render, lime mortars and terracotta. She manages the nationwide building stone database project: the Strategic Stone Study. She co-edited and contributed to the *Earth, Brick and Terracotta book in the Practical Building Conservation* series.

Further reading

https://historicengland.org.uk/research/current/conservation-research/care-of-buildings/#Section3Text

Lead roofs and statuary: understanding, monitoring and conservation

Treating corrosion and staining in historic lead work.

‘Lead is certainly the best and lightest covering, and being of our own growth and manufacture, and lasting, if properly laid, for many hundred years, is without question the most preferable’. Sir Christopher Wren’s acknowledgement of the longevity of lead ignores the fact that it can be subject to attack which can either drastically shorten its life or radically change its appearance. Historic England, currently and in its previous guise as English Heritage, has been researching two problems; underside corrosion and topside staining.

Underside corrosion

In the latter decades of the twentieth century, a significant number of historic lead roofs were suffering corrosion on their underside. Not only was this shortening the life of the lead, it was encouraging specifiers and clients to turn to replacement materials, some of which were not in keeping with the character of the historic buildings. This was a major problem for conservation bodies because in many cases lead had been the only covering used for centuries, and on many complex roofs it was the ideal material. So in the late 1980s, the Building Conservation and Research Team at English Heritage commissioned a major research project to understand the causes and mechanisms of underside corrosion and find a solution.

Above right: Chronic underside corrosion, made worse with acid attack, has eaten through this Code 9 lead at Donnington Castle Gatehouse in less than 40 years. Normally this quality of lead should have lasted well over 100 years © Chris Wood

> Lead has one important weakness. It can be attacked by pure water, such as condensation

Lead has one important weakness. It can be attacked by pure water, such as condensation. When lead sheets are first laid on a roof, white staining of corrosion will appear on the top side, but gradually the lead combines with carbon dioxide in rainwater to build up a protective layer of lead carbonate. On the underside, where no carbon dioxide is present, any condensation will begin the corrosion process. This gets worse if there are acids present, coming from woods such as oak and from glues commonly used in hardboards and plywood. Industry’s solution was to change the design of the roof to accommodate a ventilated structure by lifting the plane of the slopes by 200mm, causing all manner of detailing problems on many historic roofs. What was needed therefore was a coating applied to the underside that could resist the onset of corrosion in order to maintain the existing design of the roof. >>

Above left: The Great Hall, Hampton Court, where chronic corrosion condensation meant that the lead had to be replaced within 40 years. © Chris Wood

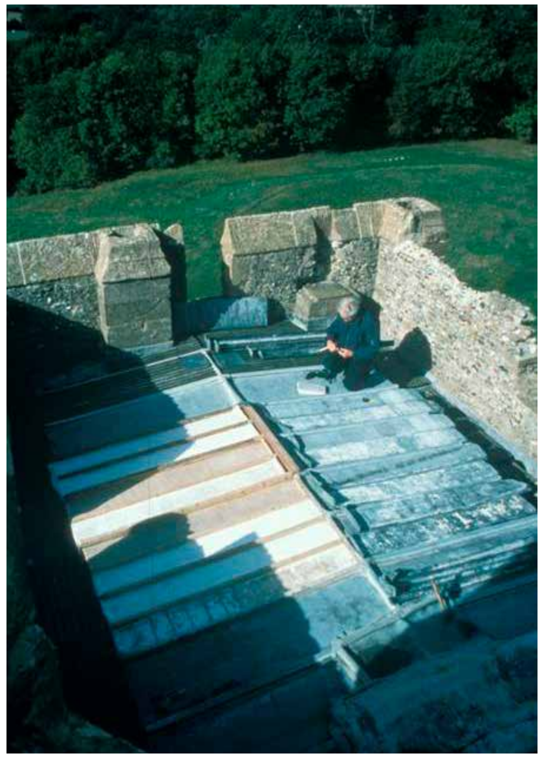
Below left: The new lead on the Great Hall roof at Hampton Court was given a coat of chalk slurry and shows no sign of underside corrosion after nearly 20 years, despite the very hostile environment. © Chris Wood

A simple mixture of chalk powder and water ('chalk slurry') painted onto the underside proved to be effective

Above right: Chalk emulsion being painted onto lead sheets before fixing onto the roof. A green dye is now applied to easily distinguish the emulsion from the corrosion product. © Chris Wood

Below right: Donnington Castle Gatehouse which proved to be an excellent testing site. Chalk emulsion has kept the lead samples free of corrosion for 15 years but the non-treated areas have been badly attacked © Chris Wood

A simple mixture of chalk powder and water ('chalk slurry') painted onto the underside proved to be effective. The carbonate ions in the chalk combined with the lead to form a protective layer of lead carbonate, which performed effectively in laboratory tests. Chalk slurry has now been used on many roof repairs. The mix was improved with the addition of a chalk-based paint which produced 'chalk emulsion', providing a far more adhesive and effective coating. Both systems have been monitored over the last twenty years on sites where the corrosion problem is particularly bad and so far they have proved effective at resisting corrosion. We will publish guidance later this year on the Historic England website. >>



Lead staining

Over the last twenty years the distinctive light-grey colour of lead roofs and statues has started to turn purple/brown, either in small patches and stripes or over the whole surface. The change is most prevalent on aspects exposed to direct sunlight, particularly in rural and coastal areas, and it affects new as well as centuries-old lead. At present it does not appear to reduce the longevity of lead; the main problem is the blotchy appearance that now afflicts many prominent cathedral and church roofs as well as valued artworks. Solutions will remain elusive until we understand how and why it is happening.

Many theories have been suggested, ranging from the greater use of fertilisers to aeroplanes discharging excess fuel. Testing to date has shown that the composition of lead was not a factor (old lead has more impurities), nor was surface topography responsible, but rainwater running over a surface appears to stimulate staining.

Historic England commissioned laboratory testing at the University of Aberdeen, which confirmed that a typical protective layer on the lead surface comprises a complex mixture of different lead compounds including plattnerite (beta lead dioxide). It is this mixture which produces the purple/brown stain. On the samples provided from various historic buildings, it was clear that this was not a corrosion product but a conversion of one existing compound to another. Why it is happening is not clear. A mild acid will remove it, so possibly today's cleaner air has reduced the amount of dilute sulphuric acid which might have removed the staining. So far it has not been possible to recreate starting conditions in the laboratory to simulate the creation of the stain, but that will have to be the next stage in unlocking this mystery ■

The author

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Chris was the Head of the Building Conservation & Research Team at English Heritage, and is now a part-time Senior Architectural Conservation Advisor with Historic England. He is retiring later this year after 26 years with English Heritage and Historic England. He has led dozens of research projects prompted by casework priorities or other urgent issues affecting historic and traditional buildings. He has also written extensively on many materials, including lead, the research on which he managed. He has worked in private practice architecture and was a conservation officer for over a decade.

Further reading

English Heritage 2013 *Practical Building Conservation: Roofing*. Farnham, Ashgate Publishing, 417-443

Teutonico, J M 1998 **'**Metals**'.** English Heritage Research Transactions **1,** 21-72

Solutions to the blotchy appearance of many cathedral and church roofs will remain elusive until we understand how and why it is happening

Opposite right:
Lead staining on SW elevation of the Archer Pavilion at Wrest Park which was markedly worse than in 2002. Some bays though are not affected and all date from 1956.

Simulation models and energy efficiency in historic buildings

Are building simulation models a good predictor for understanding the real energy-efficiency performance of traditional buildings?

There is a widely held view that traditional buildings are inherently energy intensive and require significant improvement to reduce their energy use and carbon emissions. The assumption of poor performance is, however, largely based upon the use of predictive modelling tools whose reliability in assessing the real performance of traditional buildings can vary widely depending on the information used for the simulations. Common simulation software are designed to calculate energy consumption and thermal performance and use hygrothermal assessment, a technique which analyses heat, air and moisture transfer through materials, to evaluate the potential of long-term risk from moisture accumulation after retrofit.

Simulation models – false but useful?

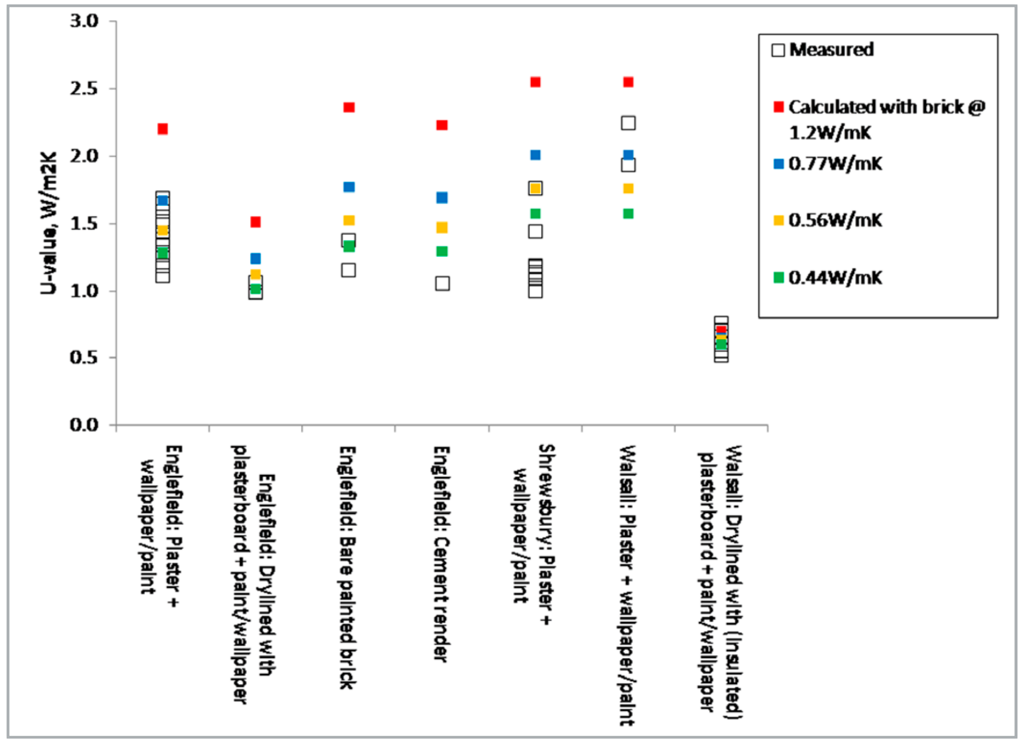
Certainly the ability to be able to predict performance is helpful as it can guide policy makers and building professionals in their decision-making. It is often used as a relatively quick, cost-effective method of understanding the impacts of any interventions on buildings, unlike real-time monitoring which takes time and is resource intensive. However concerns about the usefulness of modelling are well known as all models are abstracts of complex real-world situations and the predictions will be as accurate as the data used when modelling.

The question is, is modelling useful even though it is often a false representation of what is actually happening? And how can we improve its accuracy? Is it a simple fact that all models are both false and useful, and, if so, how can that be? These are the some of the questions that we have been trying to answer in our research into understanding the actual energy efficiency, thermal performance and hygrothermal behaviour of traditional buildings.

Problems with using standardised data for traditional buildings

The Reduced data Standard Assessment Procedure (RdSAP) is the most well-known but problematic model used to assess the energy performance of traditional buildings as it is the basis of Energy Performance Certificates (EPCs). EPCs are used by the Government to drive energy-efficiency policy but it is not a model that is based on energy performance: rather, it is a model based on energy costs.

The question is, is modelling useful even though it is often a false representation of what is actually happening?



Left: A comparison of modelled U-values using a range of default thermal conductivities with eighteen measured in-situ U-values, showing that the default values underestimated the real average U-value by one third. © Historic England

The model frequently underestimates the energy efficiency of traditional buildings and makes recommendations for work that may be neither necessary nor appropriate. The workings of EPCs are substantially based on assumptions, relying on standardisation of data which are not reflective of a building's actual energy and thermal performance, the context or occupancy behaviour. This inaccuracy skews any analysis of the overall performance of traditional buildings and it could potentially lead to flawed decisions, to the detriment of the traditional fabric. Our study into the in-situ U-values (a measurement of heat loss used in EPC's) of traditionally constructed solid walls has indicated that their actual thermal performance has often been underestimated by as much as a third, and that accurate calculations are very much dependent on the quality of the input data. If in-situ values are used for EPC's, care should be taken that the measurements are gathered under suitable conditions, for sufficient duration, and with an understanding of the walls' construction.

Even where good quality data are available, in-situ U-values have their limitations as they give only steady-state mean values and therefore can only be seen as a broad representation of the heat loss from a wall. They do not reflect dynamic real-life conditions. The values will be affected by many factors, from the moisture content of the walls to the climate on the day, the orientation, and the condition of the building. Traditional walls are variable as they are heterogeneous constructions, hence results will vary across one wall.

Understanding heat and moisture in historic buildings

Understanding the hygrothermal performance of traditional buildings is one of the most important steps in creating durable and healthy energy-efficient buildings. The use of hygrothermal simulation tools has increased in response to the growing number of reports of moisture problems after retrofit. We know that to reduce carbon >>

Right: Fixing the sensors at Chapel Street, Appleby, prior to the installation of lime hemp insulation. © Historic England

emissions we need more energy-efficient buildings. However, improved energy efficiency may result in problems if inappropriate measures are installed that interfere with the correct management of moisture.

Traditional buildings are particularly vulnerable to unwanted effects of energy retrofit measures. Their moisture behaviour is completely different to that of a modern construction. Unlike modern buildings, in which impermeable vapour barriers are employed to keep moisture from entering, traditional constructions are composed of hygroscopic and semi-permeable materials and are naturally ventilated, allowing the transfer of moisture vapour to maintain their equilibrium. However, problems can occur when they are altered, particularly by adding modern impermeable materials which produce changes in their hygrothermal behaviour.

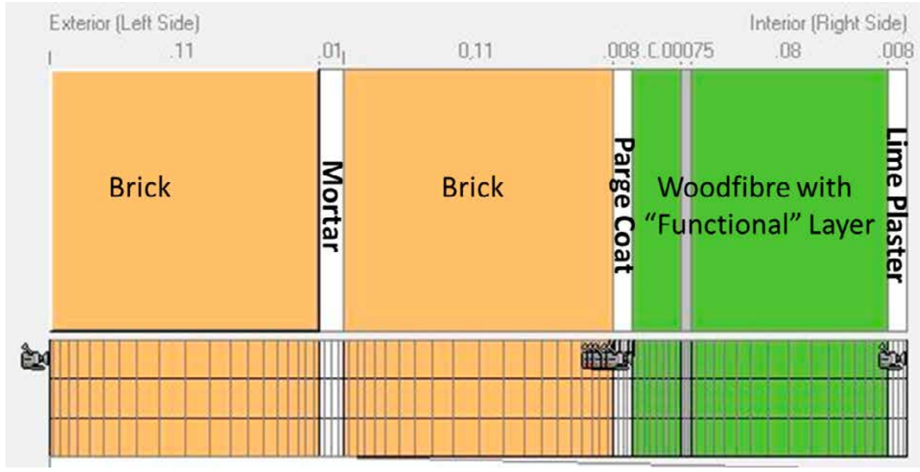
The main advantage of modelling is that, if the building fabric has been accurately characterised, the long-term hygrothermal performance of various energy retrofits can be predicted, minimising any potential damage to the fabric or to the occupants' health. Accordingly it can help to select retrofit strategies, identify risks of interstitial condensation, investigate influence of driving rain and assess the impact of flooding on the environmental conditions inside a building.

However, determining the hygrothermal behaviour of traditional constructions and any proposed interventions is complex. It requires the evaluation of heat (conduction, convection and radiation), airflows (natural and mechanical) and moisture (vapour diffusion and liquid transport) interactions. It requires detail of the geometry of the building assembly, its materials' properties and the exterior and interior boundary conditions. Orientation and the degree of shading and exposure are also significant. As these interactions occur dynamically, it can be difficult to predict with any certainty the impact of alterations and its associated technical risks from moisture.

Gaining evidence of the effects of energy retrofit

Unfortunately, very little empirical evidence exists about the long-term effects of energy retrofit on the hygrothermal balance of traditional buildings. Concerns about the risk of moisture accumulation from fabric upgrades to traditional buildings led us, in collaboration with Dr. Paul Baker from Glasgow Caledonian University, to carry out research at three sites: a brick terraced house in New Bolsover, Derbyshire; Shrewsbury Flax Mill Maltings, Shropshire; and a sandstone building in Appleby, Cumbria).

Traditional buildings are particularly vulnerable to unwanted effects of energy retrofit measures



Left: Schematic diagram of WUFI model with wood fibre. © Historic England

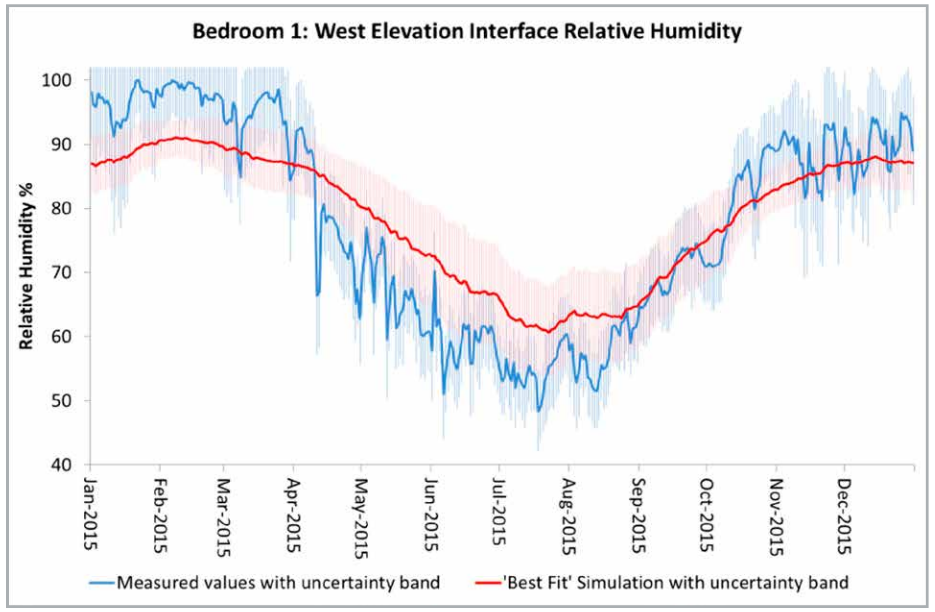
At Bolsover and Shrewsbury, we have been monitoring the moisture conditions at the wall-insulation interface or within the walls after the application of internal wall insulation, and we will be doing the same at Appleby. The results have been compared with modelling using the 1-D WUFI software – a commonly used hygrothermal modelling tool developed by Hartwig Künzel at the Fraunhofer Institut Bauphysik in Germany – to provide confidence in the gathered results. Further, we have been looking into the factors affecting the accuracy of the predictions by carrying out a sensitivity analysis to assess the relative significance of a range of input parameters and to inform best practice when modelling traditional constructions. From this we were able to analyse the reliability of the model and identify which parameters have the greatest impact on the simulations and create the greatest uncertainties.

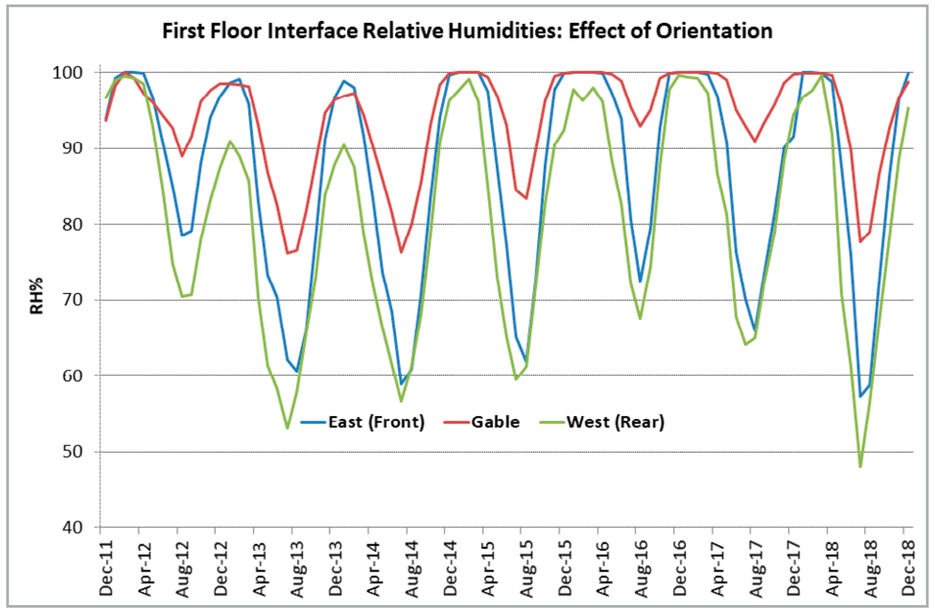
We have been comparing the performance of two types of commonly used internal wall insulation: first, hygroscopic insulation systems such as wood-fibre board sandwiched between a bonding undercoat and a top skim coat of lime plaster; and, second, an impermeable, non-hygroscopic insulation known as PIR or polyisocyanurate (a thermoset plastic rigid board) with aluminium foil on both sides finished with plasterboard. The former represents an approach which is viewed as more sympathetic for use in traditional solid-walled buildings, benefiting the absorption, transport and release of moisture; whereas the latter represents the more conventional vapour-checked solutions, as used in modern buildings. Where possible, we have been collecting local climate data and data of the inside environment and have carried out laboratory tests to characterise the traditional fabric. >>

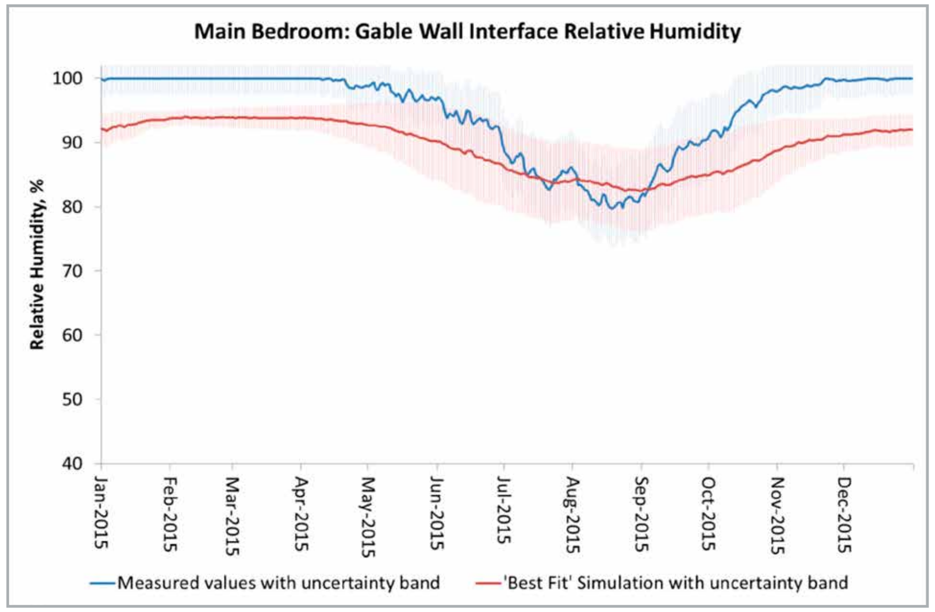
We have been comparing the performance of two types of commonly used internal wall insulation

Our observations so far at New Bolsover are:

- Testing has shown that the thermal upgrades have reduced the thermal performance by around 40%;
- the performance of the two insulation systems are similar with defined seasonal cycles - high relative humidities in the winter and drier in the summer;
- there are incremental increases in relative humidities year-on-year, which implies that moisture is accumulating at the wall-insulation interface, although we have not observed any signs of condensation or mould nor any reduction in thermal performance. This suggests that, if conditions at the wall-insulation interface are allowed to drop to lower relative humidities during the summer months, the insulation systems will recover sufficiently to manage the higher levels during the winter;
- there are clear influences of the climate (in particular, solar radiation), orientation, exposure and degree of shading. The west elevation which is exposed to the sun is performing better than the south elevation which is relatively sheltered;
- and when modelled, using the measured results as input data, we found broad agreement for the exposed west elevation but a less good fit for the sheltered south elevation, particularly during the colder months. >>





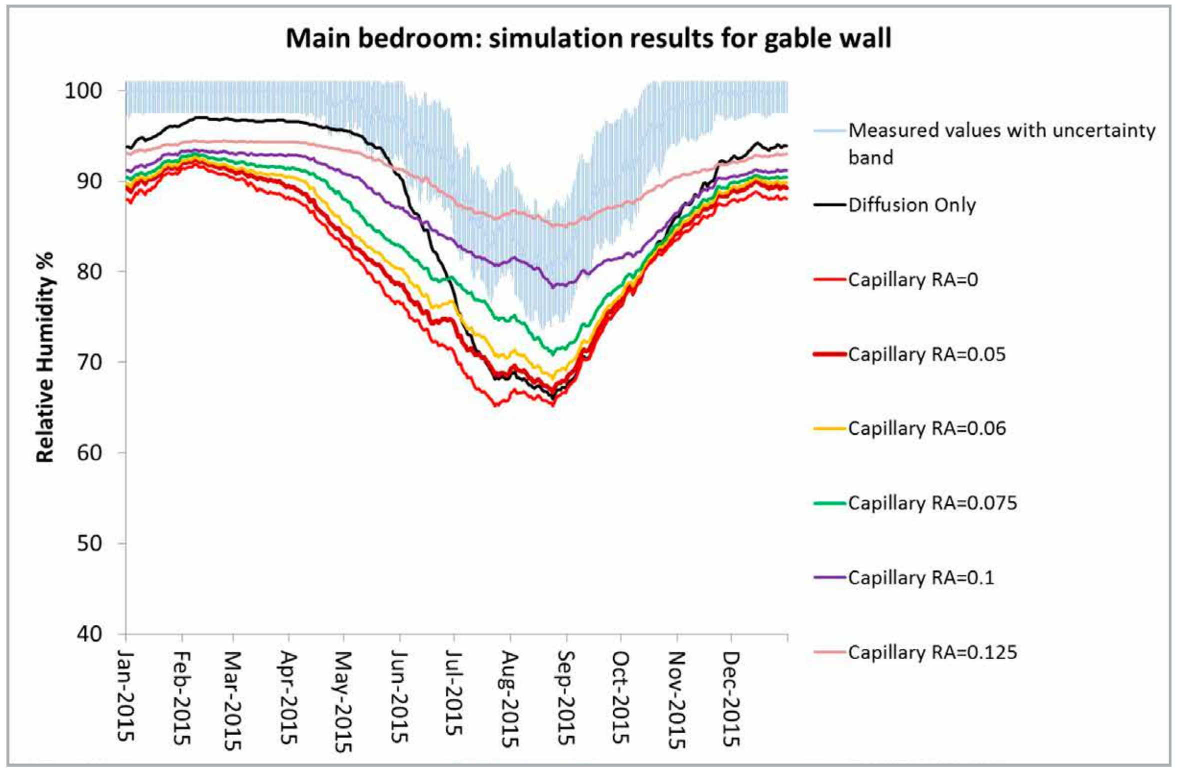


Top left: Cores were drilled into internal wall insulation systems to assess their condition. No signs of deterioration were observed in either the PIR or the wood-fibre insulation systems (shown above). © Historic England

Bottom left: New Bolsover: measured relative humidities on the first floor at the wall/wood-fibre insulation interface. The graph shows accumulated moisture over the last seven years and the effect of the seasons and orientation. © Historic England

Top right: Comparison of modelled and measured relative humidities of the exposed west elevation with wood-fibre insulation on the first floor during 2015. The graph shows reasonable agreement between the two datasets, though the simulation overestimates the moisture levels during the summer and underestimates the moisture levels during the first part of the year. © Historic England

Bottom right: Comparison of modelled and measured relative humidities of the sheltered south elevation with wood-fibre insulation on the first floor during 2015. The graph shows poor agreement between the two datasets with the exception of the summer period; for the most part, the simulation underestimates the moisture levels. © Historic England

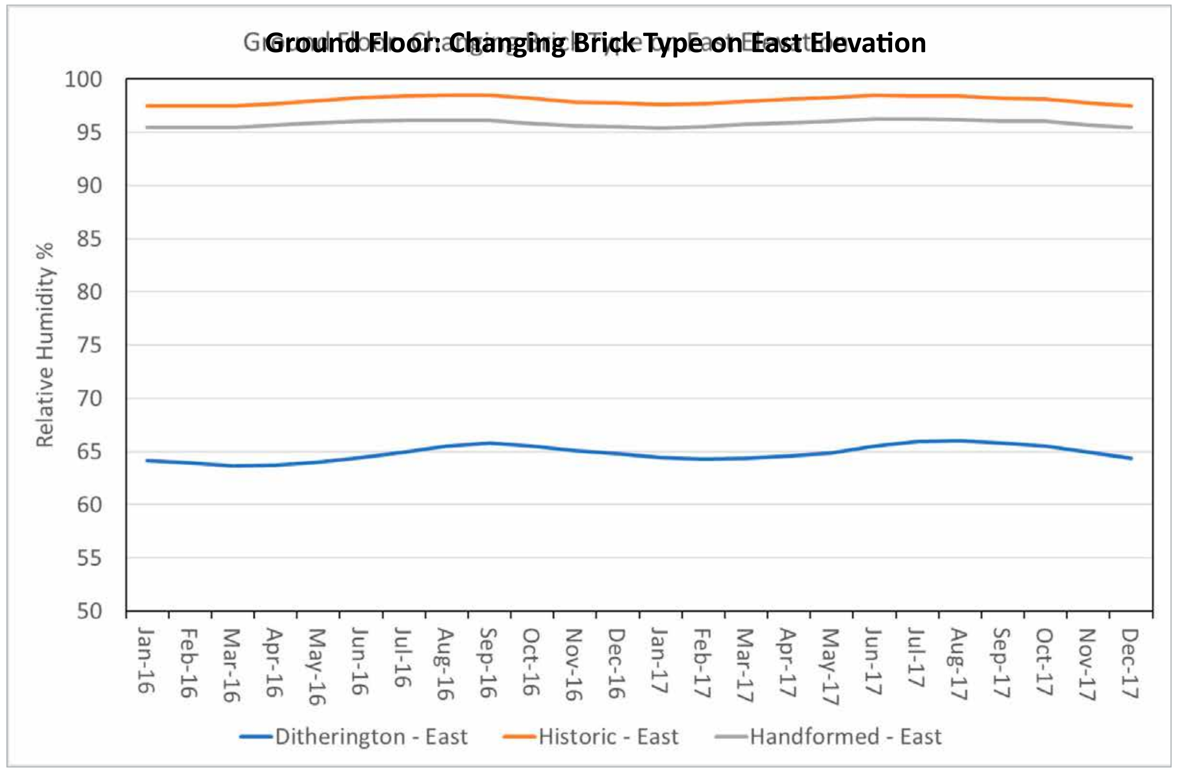


Above: A comparison of the measured and predicted interface relative humidities of the wood-fibre insulation on the south elevation on the first floor during 2015.The graph shows a range of relative humidities that can be achieved by using different rain adherence factors (RA). Generally for the RA values 0-0.075 of the simulation results, whilst tracking the dynamic behaviour of the measured data, they underestimate the latter by about 10 per cent relative humidity. © Historic England

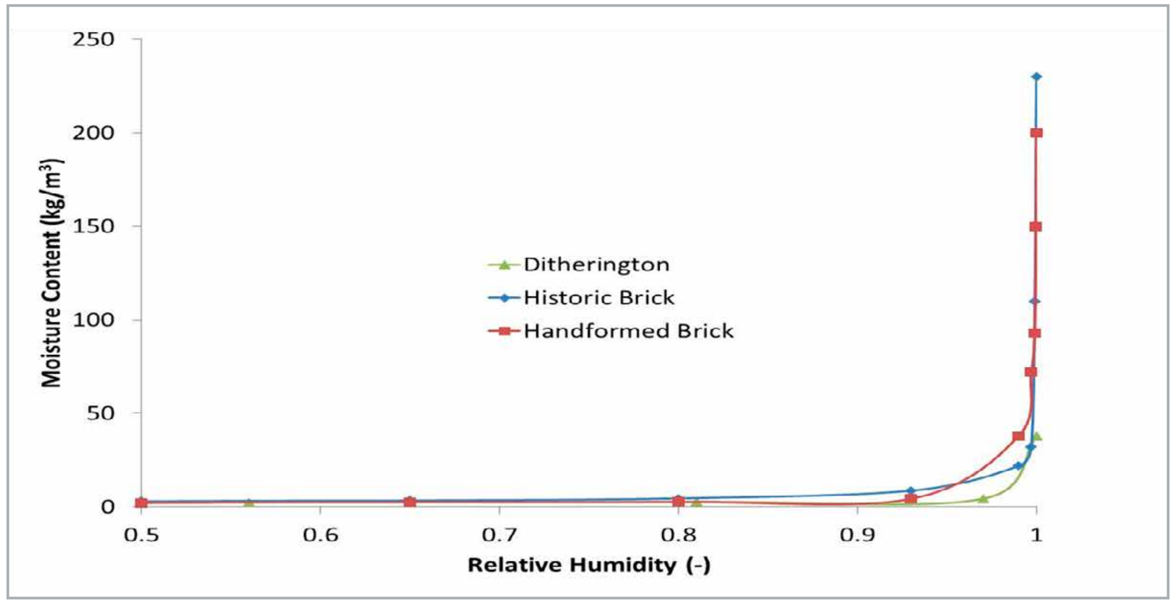
Limitations with hygrothermal modelling

The difference between the simulations and the measured data has highlighted some of the uncertainties with modelling. Modelling of conditions at both Shrewsbury Flax Mill Maltings and at New Bolsover has demonstrated the importance of accurately estimating the rain adherence fraction, which has an influence in driving rain calculations, and the amount of solar radiation and degree of shading on a wall. All have a significant effect on the accuracy of the simulations. Another limitation of modelling relates to situations where materials are not in direct contact with each other and where there is convective airflow. This was suggested by the noisier data with the PIR insulation on the south elevation at New Bolsover, where there is a service gap between the insulation and the brickwork. Airflow is a three-dimensional phenomenon and the WUFI 1-D is a one-dimensional model.

One of the biggest hurdles in modelling is the lack of historic material data from UK buildings as the WUFI ‘library’ is comprised of building materials from Germany. We have found that uncertainties of the predictions are greatly reduced when accurate material property data are used. At Shrewsbury Flax Mill Maltings, we modelled the hygrothermal performance of the south and east elevations using material property data of three different types of bricks: default data from two bricks from the WUFI ‘library’ database, referred to as a historic and a handmade brick, and real data taken from one of the bricks from the Flax Mill. Combining the specific climate effects of solar radiation and rainfall on each wall with the different material property data, we found the library bricks suggested a greater risk of moisture accumulation than the brick taken from the Mill, particularly on the east wall. One explanation for this is the different moisture capacity of each brick and its ability to absorb, transfer and release moisture; other reasons are the effect of the climate (the amount of solar radiation and rainfall on each elevation) and the degree of shading. >>



Above: A comparison of simulations on the east elevation using real material property data from Shrewsbury Flax Mill Maltings (Ditherington in the graph) and brick data from the WUFI ‘library’ historic and handmade bricks. It shows the effect of material property, orientation and weather on relative humidity of the three different types of brick and reveals that the measured data provides significantly lower moisture levels. © Historic England



Bottom: Material testing of the Shrewsbury Flax Mill brick (Ditherington in the graph) has provided lower moisture absorption at high humidities compared to the WUFI ‘library’ historic and handmade bricks. © Historic England

Powerful tools if used with caution

It is advisable to take a cautious approach when modelling as models are full of implicit assumptions. For modelling to be useful, we must question the assumptions underlying the analysis in order to understand the parameters used for the simulations. There are numerous factors that affect the performance of traditional buildings: the interactions are dynamic and are continuously changing. Further, often calculations cannot model defects and are based upon idealised homogenous walls which are in perfect condition. As everyone knows, this is never the case for traditional buildings! However, if models are used with care and an understanding of their limitations and are calibrated with real data, they can be powerful tools. Though the simulations cannot be viewed with complete confidence, it can help to inform decision-making and provide an indication of risk. As the statistician George Box once remarked, 'all models are wrong, but sometimes useful' ■

Acknowledgements

Iain McCaig, Senior Architectural Conservator, Building Conservation & Geospatial Survey, Historic England

Dr. Paul Baker, Glasgow Caledonian University

Bolsover District Council, Derbyshire

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Soki is a Building Conservation Advisor for the Building Conservation & Geospatial Survey at Historic England. In her current role, she primarily manages research projects on energy efficiency and the hygrothermal performance of historic buildings, particularly in relation to technical risks from moisture. She has published on thermal performance of traditional buildings and their elements, hygrothermal modelling, applications of infrared thermography, use of X-ray fluorescence (a non-destructive analytical technique used to determine the elemental composition of materials) on Second World War collections and environmental management of historic house libraries.

Further reading

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Baker, P 2017 ***Comparison** of WUFI simulations of the IWI systems installed at New Bolsover with measured data***. Forthcoming internal interim report for Historic England

Baker, P 2018 *A sensitivity analysis of WUFI simulations*. Forthcoming interim report for Historic England

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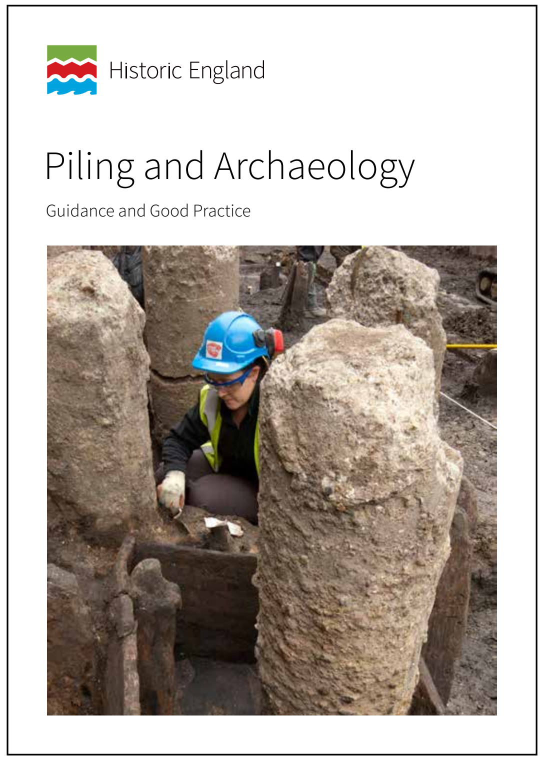
Revising Historic England guidance on

piling and archaeology

Turning research into best-practice advice.

Most buildings require foundations to keep them upright. In certain ground conditions and for larger buildings, piles are often the preferred type of foundation. Where construction takes place in historic towns and cities, there is a risk that new piling could damage below-ground archaeological deposits. To explain how harm from new foundations can be reduced, Historic England has been working to update our guidance on this subject: https://historicengland.org.uk/images-books/publications/piling-and-archaeology/ >>

Where construction takes place in historic towns and cities, there is a risk that new piling could damage below-ground archaeological deposits



Above: The new guidance document. © Historic England

Above: Installing sections of a preformed concrete pile. © Roger Bullivant Limited the developer is required to demonstrate how their piling design will avoid harming the significance of any archaeological remains present on the site

Why we are revising the guidance

The original guidance document, published in 2004, was based on many years of previous research and observations of past piling impacts on archaeological remains. Since then, we have commissioned further research to look at the damage caused by previous foundation schemes, collated examples of pile impacts from across Europe, and been involved with additional laboratory scale-model analysis.

This research has helped to refine sections of the guidance on the impact of a range of different pile types. The other major area of revision has reflected the changes to Government planning guidance over the past few years. This has led to a shift in emphasis in our advice away from keeping damage to below a fixed proportion, to one where the developer is required to demonstrate how their piling design will avoid harming the significance of any archaeological remains present on the site.

Collaborative authoring across the professions

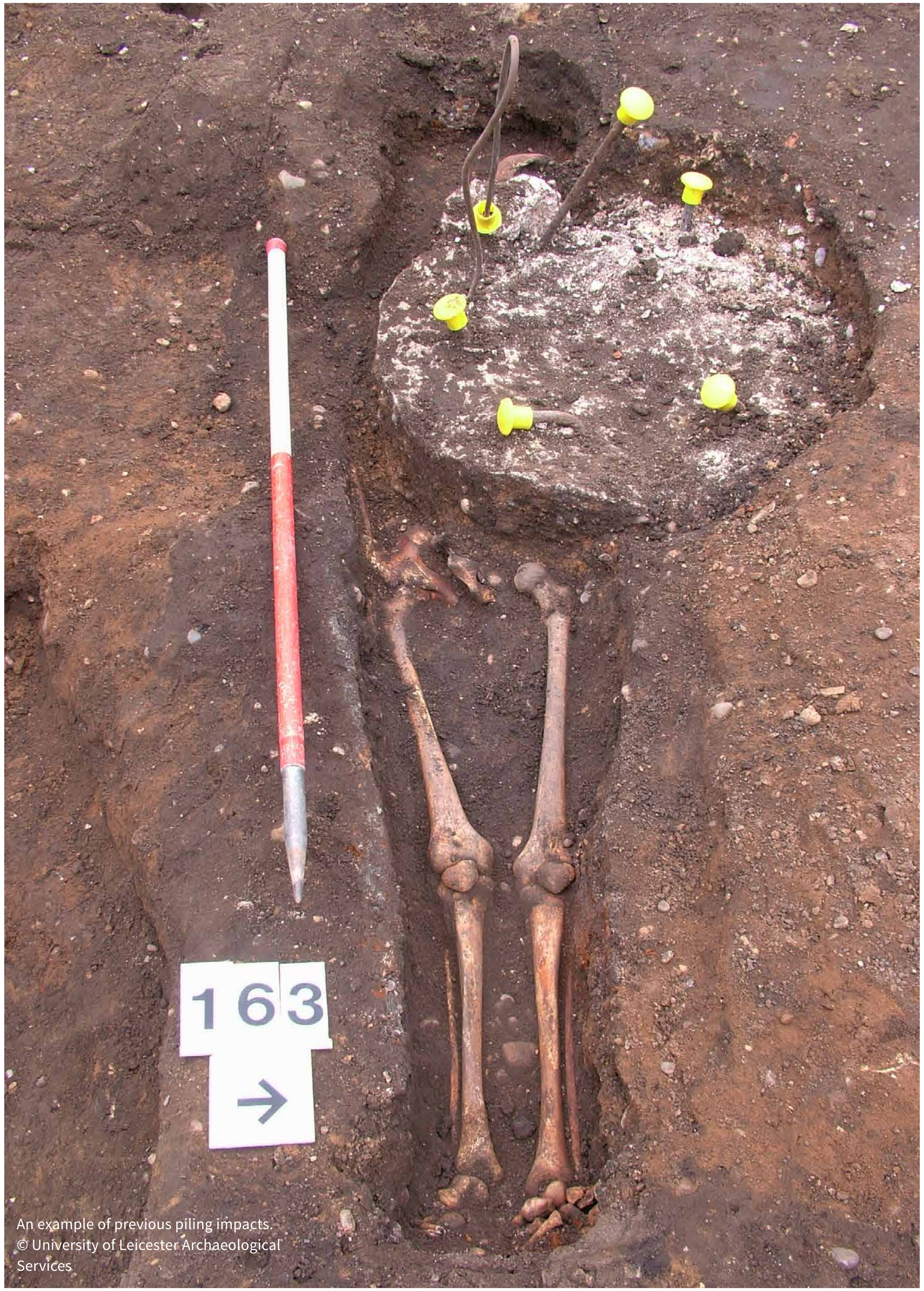
We have also changed the way we have written this guidance document, and bought in a group of engineers, local authority archaeologists and archaeological contractors to form a collaborative authoring team. This enabled us to blend our new research findings with real-life practical experiences from across different specialist areas ■

The author

Jim Williams, PhD, MCIfA
Senior Science Advisor with Historic England.

Jim has coordinated the updating of the piling guidance and is the lead author of the guidance on Preserving Archaeological Remains. He is responsible for managing nine science advisors based across England who provide archaeological science advice to Historic England Inspectors of Ancient Monuments and local planning archaeologists. He currently gives archaeological science advice to HS2, the high-speed rail route to the Midlands and north of England.

engineers, local authority archaeologists and archaeological contractors have joined with Historic England to produce the new guidance



An example of previous piling impacts. © University of Leicester Archaeological Services