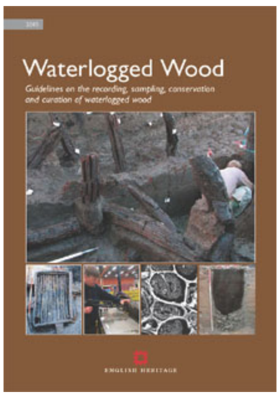
Historic England

Waterlogged Wood



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Although this document refers to English Heritage, it is still the Commission's current advice and guidance and will in due course be re-branded as Historic England.

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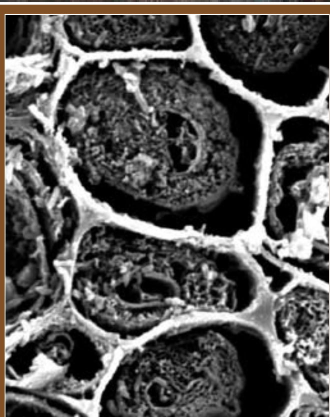
Waterlogged Wood

Guidelines on the recording, sampling, conservation and curation of waterlogged wood



ENGLISH HERITAGE

Preface

Waterlogged wood comprises a rare and significant part of the archaeological resource. It can occur in extensive wetlands or in small features, such as pits or wells, on otherwise dry sites. Its comparative rarity means that most archaeologists have little experience of dealing with the material. Waterlogged sites are usually more complex and costly to investigate than dry sites, a fact that can often put pressure on archaeological curators, contractors and consultants. It is hoped that these guidelines will help archaeologists make the best possible decisions in the face of such pressures.

The Monuments At Risk in England's Wetlands (MAREW) report demonstrated the enormous destruction of waterlogged deposits that has taken place across England, with 2020 sites lost over the last 50 years (Van De Noort *et al* 2001). The associated loss of waterlogged wood is likely to increase over the next 100 years as summers become hotter and drier (UKCP09). As this finite resource inexorably diminishes, the need for well-conducted excavation, curation and *in situ* management increases.

This document is the third edition of Waterlogged Wood Guidelines issued by English Heritage, previous editions being produced in 1990 (Coles (ed) 1990) and in 1995 (Brunning 1995). Since then some new techniques have been developed and others have been modified, although many of the most important techniques and issues remain unchanged.

Sites that produce waterlogged wood are also likely to preserve other organic materials and palaeoenvironmental remains. For such projects the English Heritage guidelines on dendrochronology (English Heritage 1998, new edition forthcoming), environmental archaeology (English Heritage 2002), leather and textile (English Heritage 2009), investigative conservation (English Heritage 2008a) and piling (English Heritage 2007) may also prove useful. Some advice on how to deal with wood from inter-tidal and sub-tidal environments is included within these guidelines, but more detailed advice and guidance for underwater archaeology is available from other sources (eg Green 1990 and Bowens 2008).

Contents

Six things to remember

Many archaeologists live busy lives and may not have time to read innumerable professional guidelines from cover to cover, no matter how useful they may be. If you go no further than this page here are six things to remember.

1 Wet site excavation justifiably costs more.
Archaeological costs rise where preservation of the record is best. Make sure this is recognised in project planning, briefs, specs, WSIs and Project Designs.

2 Get specialist advice early.
The involvement of wood specialists at an early stage will save time and money. The EH Regional Science Advisors should be able to supply contacts and provide good advice themselves.

3 Preservation *in situ* of waterlogged sites is a big risk.
Don't condemn waterlogged deposits to possible gradual unseen destruction merely as a more convenient alternative to excavation. All preservation *in situ* entails a potential risk of failure. Specialist advice should be sought through the EH Regional Science Advisors.

4 Keep temporary storage short term.
The longer waterlogged wood is kept in temporary storage the worse its condition will become and the more likely it will end up in a skip. Try and implement a rapid timetable for recording, sampling and selection for conservation.

5 Expect to conserve some wood.
Sites that produce significant quantities of waterlogged wood should expect that at least a proportion of the assemblage warrants conservation and curation.

6 Don't panic.
Many archaeologists will be unfamiliar with dealing with waterlogged wood. It is rare and important, and its appearance can cause stress to tight budgets. Get specialist advice before the fear takes hold, so that good decisions can be made.

1 Introduction

1.1 Why is waterlogged wood important?

Wooden remains are important because they provide evidence for the main raw material used for structures, artefacts and fuel throughout most of human existence. Clarke (1968) thought that a typical dry archaeological site might preserve about 15% of what was actually used by its inhabitants, but more recent estimates, based on archaeological and anthropological evidence, suggest that perishable organic materials comprise 90–95% of the potential archaeological record (eg Soffer *et al* 2001; Purdy 1988). Analysis of wooden remains provides unique and significant information about material culture, economy, industry and buildings.

Wood can be analysed in combination with other palaeoenvironmental data sources to increase understanding of the wider landscape. It gives direct evidence for the character of the local treescape and how this changed over time. It can also provide information on woodland management and on the selection of raw materials, and can be used to identify imported products.

Waterlogged wood is also valuable for scientific dating. It can provide samples for radiocarbon dating, like other organic materials, but several species can also be used for tree-ring dating

Figs 1 and 2 (above) Medieval wicker fish basket from Hicklin's Land, Hemington (Leicestershire); and basket shown partly dismantled to show internal funnels (scale rod = 1m) (© University of Leicester Archaeological Services).
Fig 3 (below left) Oak piles, woodchips and charred debris from a Bronze Age site at Must Farm, Cambridgeshire. Numerous domestic organic artefacts were also present (© Cambridge Archaeological Unit).
Fig 4 (below right) The 'God Dolly' from the early Neolithic Bell Track, Somerset. The earliest known human figurine in the UK. (© Somerset Levels Project).

(dendrochronology), which can produce extremely precise dates. The use of some imported species can also help to date more recent sites.

In the UK wood remains only normally survive in waterlogged conditions or if they are wholly or partially charred, or are associated with the corrosion products of metal objects, especially copper or copper alloy. The specific burial conditions that create such exceptional preservation also leave such sites highly vulnerable to many factors that can lead to their destruction. A recent review found only 739 prehistoric sites in England and Wales that had ever produced records of waterlogged wood (Brunning 2007a), and suggested that it may have survived on just 1–5% of sites in different areas of England.

Waterlogged wood thus represents an informative, but extremely rare resource. It is therefore imperative that archaeologists devote to it the resources and forethought that it deserves.

1.2 Who are these guidelines for?

The quality of the excavation, recording and conservation of this precious and diminishing part of the archaeological resource has been extremely variable. This is partly caused by unfamiliarity with 'wet site' excavation and an inability or unwillingness to devote appropriate financial resources and time on the recording, study and preservation of this valuable source of archaeological information. This situation is exacerbated by the inability of current methods of archaeological prospection to predict accurately the extent and nature of deeply buried archaeological sites that are the main sources of waterlogged wood.

These guidelines are designed to help overcome some of these problems for anyone involved in fieldwork that may uncover waterlogged wood. For curators, contractors and consultants they are intended to provide practical advice on the planning and running of projects involving waterlogged wood. They can also, if required, be used as a set of national standards to which fieldwork projects might be required to comply through planning conditions or grant aid systems.

Some frequently asked questions related to waterlogged wood are:

1. Do we need to excavate this waterlogged wood? *see* sections 2.4 and 5
2. How do we excavate it? see section 3
3. What do we keep and where do we put it? see sections 3.4.4 and 3.8
4. What do we sample and how? *see* sections 3.1.1 and 3.6
5. Who will help me sort this out? see section 9
6. How much will it cost? Ask the specialists.

2 Project planning and evaluation

Sites that produce waterlogged wood are significantly different from the more common 'dry' site. They will take longer to excavate, will require more specialist involvement, and will have more numerous and more lengthy post-excavation processes. The inevitable result of good waterlogged preservation is more substantial costs for archaeological fieldwork.

It is therefore crucial that the potential for these significant cost implications are identified as early as possible in planning fieldwork projects; and for commercial projects it is important that the developer is not shielded from such cost implications. Briefs and specifications must provide a level of clarity for contracting units to provide realistic tenders.

If non-planning or rescue-related fieldwork – such as academic, research, training or community projects – unexpectedly encounters waterlogged wood it should be left unexcavated. In such circumstances excavation should not be undertaken until it is certain that the necessary financial and scientific resources are in place to carry it out. As waterlogged wood is so rare, it is usually best to leave it undisturbed unless its survival is threatened.

The consultation paper on the new Planning Policy Statement for the Historic Environment (PPS5) retains the essential thrust of the existing PPG16 guidance, including desk-based assessments and field evaluations, although the terminology employed is significantly different (Department for Communities and Local Government 2009). The draft Historic Environment Planning Practice Guide (English Heritage 2009), which complements PPS5, provides further detail on the provision of desk-based assessments, field evaluations and written schemes of investigation.

2.1 Briefs, specifications, project designs and written schemes of investigation

This section will not duplicate the detail contained in ACAO 1993 or in Institute of Field Archaeology 2008. Project designs are discussed in English Heritage 1991 and the process for English Heritage-funded projects has been revised by MoRPHE (Lee 2006). This idealised framework for the management of projects is not always used in the commercial sector, so the advice given below will attempt to be realistic, rather than idealistic.

Funding in blocks associated with formal review stages and costing updates (English Heritage 1991, section 3.10) is ideal for generating accurate and precise project costings. This procedure is not always applied in commercial archaeology for several reasons. The formulation of an accurate price for projects involving waterlogged wood is often difficult at this stage, not least because waterlogged deposits are inherently more unpredictable and require greater post-excavation costs than normal sites do. Therefore there is a greater need for 'contingency money' to be included in budgets run on this basis.

Where waterlogged deposits are known to exist, the curator could choose to specify a fixed percentage ('scientific contingency') of the overall tender that could only be spent on specific tasks (eg scientific dating, palaeoenvironmental analysis, wood conservation). Such work could only be undertaken (and charged for) once the curator has approved the costing proposals generated by assessment. In this circumstance the fixed percentage should be set high, as it is far better to overestimate than to underestimate, as the money will only be spent if it is justified. If preservation is not as good as first thought, then the contingency can remain unspent. This practice would help to avoid contractors skimping on post-excavation costs to enable unrealistic tenders to be submitted.

Written schemes of investigation (WSI) and project designs (PD) should include strategies for dealing with waterlogged wood. Such strategies should include specifications for excavation, recording and sampling procedures, for the method of temporary storage and for the method of selection for conservation. The strategy should make it clear whether any assessment and discard of wooden remains will take place on site (*see* section 3.1).

Briefs and specifications can ask for work to be carried out in accordance with these guidelines and WSIs and PDs can be expected to incorporate that assurance. The wood specialist(s), dendrochronologist and conservator should all be named in these documents. It is reasonable for the curator or grant funding body to ask for confirmation of the experience of the wood specialist (eg list of published or unpublished reports), as there is no other form of accreditation. The English Heritage Regional Science Advisors may be able to suggest specialists and accredited conservators can be found on the ICON Conservation Register website (www.icon.

org.uk). The local receiving museum should be contacted as early as possible about sites where waterlogged wood will be excavated. This will make conservation and curation more likely to happen.

2.2 Desk-based assessments

Where desk-based assessments are carried out in advance of fieldwork there are some sources of information that may help to predict the presence and survival of waterlogged wood. Geological data from the British Geological Society (BGS) is useful for identifying the extent of superficial floodplain deposits (alluvium, peat etc) where waterlogged deposits should be expected to exist. Borehole data (BGS, academic and commercial) will provide more detail on stratigraphy where it exists. The results of previous excavations may hold information, not just on the presence of waterlogged deposits, but also on the condition of wooden remains and possibly information on the burial environment.

2.3 Evaluations

General guidance on field evaluations is obtainable from two documents: Hey and Lacey 2001 and Institute of Field Archaeology 2001. Archaeological evaluation of wetlands has also been the subject of a recent Planarch study (Dyson *et al* 2006). Evaluation of the extent and potential of archaeological remains in areas of deep peat, clay, silt, gravel or urban deposits, can be problematic. Aerial photography, fieldwalking and most types of geophysics have been of little use where sites are more than 1m below the ground surface (English Heritage 2008b; Gaffney *et al* 2002). Geophysical survey also encounters particular problems in waterlogged deposits.

Ground Penetrating Radar has had apparent success in identifying waterlogged wood structures (eg Clarke *et al* 1999; Utsi 2003). One ongoing project has suggested that gradiometry and resistivity can also be successful in some circumstances (Armstrong 2008). However, more work needs to be carried out before such techniques can be reliably used in evaluations. Combinations of geophysics, augering, test trenching and lidar ('light detection and ranging') have been successful in characterising floodplain burial environments and seem to be the best option for evaluating wetlands where wood is likely to occur (English Heritage 2008b; Waddington 2008).

Evaluating the archaeological potential of such deposits is more difficult and less precise than in areas of shallower stratigraphy. Therefore there is greater need for 'contingency' money to be included in budgets to cover unexpected discoveries. In addition there may be a stronger case for the developer to consider unexpected archaeological discovery insurance after the initial evaluation.

Fig 5 Excavation of the Finzel's Reach site beside the River Avon in Bristol revealed several features containing waterlogged wood. These included ditches, the base of postholes, a possible cesspit, several rainwater wells, and tanning vats. Their existence had not been identified in the evaluation because of their isolated character and relatively small size. Most of the features were fully excavated but some, below the limits of development, were left *in situ* (© Oxford Archaeology).

Techniques for evaluating sites underwater are significantly different to those employed on dry land. A summary of suitable marine techniques can be found in Oxley and O'Regan 2001.

For a proper evaluation of a site that includes waterlogged wood, It is essential that an experienced wood specialist is present on site to assess the importance and possibly the date of the wood exposed, and to take appropriate samples. Evaluation briefs, specifications and WSIs should ensure that wood samples are taken for dating purposes. Where tree-ring samples are taken, expert advice should ideally be sought from a dendrochronologist. The inherently limited character of evaluations means that the potential for successful dendrochronological dating will usually be low because of the small number of available samples. Instead, radiocarbon dating is more likely to be successful.

Fig 6 Finzel's Reach, Bristol: An early medieval square rainwater well or cesspit, which reused building and fence timbers. Tool marks of chisels, augers and several axes could be seen on the timbers, revealing wood working techniques typical of the medieval period (© Oxford Archaeology).

Where an evaluation encounters waterlogged wood, the minimum amount of wood should be exposed for the shortest possible time in order to characterise the deposit and reveal its extent. Exceptions to this rule are sites, usually prehistoric in date, where it is not absolutely conclusive whether a wood deposit is anthropogenic or natural in origin. Many natural accumulations of wood in channels, beside water bodies and in fen peat deposits can be of purely natural origin. In such locations there is a danger that broken or decayed timbers may be mistaken for evidence of deliberate woodworking. In addition, wooden structures created by beavers can sometimes appear to the untrained eye to be anthropogenic. This is further complicated by the fact that humans often re-used beaver structures and vice versa (Coles 2006). In such uncertain circumstances it is extremely important that an experienced wood specialist visits the site. The lack of such specialist involvement at this stage has led to large, costly projects being carried out on purely natural features, and probably also to anthropogenic structures being dismissed as natural features.

Misinterpretation is most likely to occur in narrow evaluation trenches where the ends of much of the wood may extend outside the trench. Cut ends often offer the most definitive proof of wood working in such circumstances. Such circumstances can even be problematic for an experienced specialist to be conclusive about. In these cases the exposure of more of the deposit during evaluation is entirely justified and is recommended.

2.4 Preservation *in situ* or excavation

National Planning Guidance (Department of the Environment 1990) emphasises the need for preservation *in situ* of nationally important archaeological remains. Because waterlogged wood is such a rare and informative part of the archaeological resource, deposits containing worked wood are inherently likely to be of national importance. The consultation paper on the new *Planning Policy Statement for the Historic Environment* (PPS5) also states that 'the local planning authorities should be guided by the principle that the more significant the heritage asset, the greater the presumption in favour of its conservation' (Department for Communities and Local Government 2009, Policy HE10.1).

The draft *Historic Environment Planning Practice Guide*, which complements PPS5, states that the knowledge acquired through archaeological investigation is not a substitute for the heritage asset itself (English Heritage 2009, Policy HE13, paragraph 58). When considering preservation *in situ*, the archaeological advisors to the planning authority have to contrast the loss of some knowledge through excavation against the potential loss of knowledge that may occur to the unexcavated part of the asset.

Unfortunately, waterlogged burial environments are inherently complex. The factors affecting the decay of wooden remains have been subject to much recent analysis (eg Björdal 2001; Björdal *et al* 1999; Klaassen (ed) 2005) but are still not completely understood. Therefore it is extremely difficult to be certain that preservation *in situ* will work in the medium term (beyond 10 years). The current predictions for climate change (Murphy *et al* 2009) indicate that summers are very likely to become significantly drier and hotter, and that a greater strain will be placed on natural aquifers. This suggests that the rate of loss through peat wastage and agricultural attrition may also increase. These trends suggest that future preservation *in situ* of waterlogged deposits will become even more difficult during the present century.

To ensure that an attempt at preservation *in situ* stands a good chance of success, a considerable body of evidence is required. This will include quantifiable baseline information on the condition of the waterlogged wood (*see* section 5.1) and detailed analysis of the burial environment (*see* section 5.4). As there is usually considerable seasonal variation, a minimum of one year's monitoring will normally be required to characterise the burial environment.

Even where such robust evidence exists, preservation *in situ* will always run a risk of turning into destruction *in situ*. In almost all burial environments some degradation of wooden remains will occur (Klaassen (ed) 2005; Palma and Gregory 2004). The only uncertainty is the speed of the degradation. Some significant parts of the resource, such as sapwood on timbers that could be dated dendrochonologically, are extremely vulnerable to changes in burial conditions. Ongoing monitoring may be able to detect the early signs of changing conditions that might lead to rapid decay.

In development control cases it is usually unrealistic to expect effective mitigation in response to such changes years after development has ceased, especially if preservation is threatened by changes outside of the development area. It is therefore entirely justifiable to attempt to obtain significant archaeological information from such deposits by partial excavation even where preservation *in situ* is attempted. Such intrusion may slightly increase the risk of future degradation to the remaining unexcavated material, but this is preferable to the possible complete unrecorded loss of the resource.

If waterlogged deposits are left *in situ* as development goes on around them, without the scientific evidence to prove they will be preserved, this should be seen as 'abandonment *in situ'*, reflecting the possibility that unseen destruction of the resource will occur in the short term. The mere existence of waterlogged deposits on a site must not be taken as an indication that they can be successfully preserved *in situ* if they are just covered up. Where there is a 'reasonable' (in planning terms) choice between abandonment *in situ*, preservation *in situ* and excavation, abandonment should never be chosen, and

Fig 7 Finzel's Reach, Bristol: Several barrel wells of mid-13th- to 15th-century date were excavated (© Oxford Archaeology).

Fig 8 Finzel's Reach, Bristol: Number markings were preserved on some of the barrel staves (© Oxford Archaeology).

preservation *in situ* attempted only where there is robust evidence that it will work in the medium term.

For underwater marine sites the scientific basis for preservation *in situ* is far more certain, although the reality is not always easy to achieve. Where wooden remains lie permanently buried at depths greater than 0.6m they should be safe from attack by wood-borers and from fungal and bacterial decay (Gregory 2004). In areas of strong or shifting currents, or where the seabed is dynamic and experiences periods of erosion, preservation is far less likely to be successful. Structures can be created on the seabed to encourage the deposition of sediment over wrecks, but such schemes require consistent monitoring to check and confirm their ongoing effectiveness.

Any wooden remains exposed on the seabed around the UK will suffer degradation from bacterial and fungal decay, and attack by wood-boring molluscs and crustaceans. The shipworm (*Teredo navallis*) can cause extremely rapid destruction to exposed timbers. As sea temperatures rise an even more aggressive marine borer (*Lyrodus pedicellatus*) is spreading into UK waters (Palma 2008).

2.5 Unexpected discovery

Waterlogged wood should be expected on peat and alluvial floodplain deposits, but it also frequently occurs in cut features such as pits, wells and ditches that form isolated waterlogged environments in otherwise 'dry' sites. The biggest problems occur where wood is unexpectedly found during an excavation, with significant cost implications for the project. The first reaction is often to try to determine if preservation *in situ* is possible. Such action is subject to significant risk (*see* section 2.4) and should not be undertaken without robust scientific evidence to prove that it will work. If an appropriate evaluation had failed to identify the potential of significant waterlogged features, English Heritage could be approached to provide financial assistance for excavation, analysis and curation.

3 Excavation, recording, sampling and temporary storage

3.1 Excavation

3.1.1 Excavation strategies

There are two significantly different strategies for excavating waterlogged wood. **Method 1:** Minimal recording and total retention. This is more commonly used where a wood specialist is only available intermittently or hardly at all.

Planning check list

Briefs and specifications

- Consider asking for all work to be carried out in accordance with these guidelines.
- Consider if contingency provision/ scientific contingency is required.

Fieldwork planning

Ensure that the WSI/PD includes the following:

- named wood specialist, dendrochronologist, conservator
- methodology for excavation and recording and sampling strategy
- provision of temporary storage facilities for any retained wood
- procedure for contacting receiving museum for conserved wood

Evaluation

- minimum exposure of wood to characterise feature
- sampling and lifting of wood for dating and condition assessment only
- presence of wood specialist essential for good interpretation
- don't leave doubt if wood feature is natural or anthropogenic

Excavate or leave *in situ*?

- Is there robust proof that preservation *in situ* will work?
- Where there is a reasonable choice, never abandon *in situ* and be very cautious attempting preservation *in situ*.

Excavation

Two different strategies for excavation: 1 All excavated wood is removed from site for later recording, sampling and discard or retention selection; or 2 Significant recording, sampling and selection for retention takes place on site.

Fieldwork with total removal

- A wood specialist is present periodically and ensure site staff have adequate training for excavating, site recording and lifting.
- Information on orientation, inclination and relationships with other timbers need to be recorded before removal.
- Excavation reviews to include the curator or grant giving representative, project manager, wood specialist and consultant (if there is one).
- Samples taken for radiocarbon or dendrochronological 'spot dating', or both, on site.
- Site visits arranged for dendrochronologist, museum curator and conservator.

Fieldwork with on-site recording, sampling and discard

- Wood technologist must be on site and oversee wood recording, sampling and selection for retention.
- Sampling of unretained wood: take samples of all wood for species identification and tree-ring counting, except for large numbers of small roundwood and woodchips, for which only selective sampling is needed.
- Dendrochronologist (or nominated individual) present to take samples.
- Site visits arranged for dendrochronologist, museum curator and conservator.
- Selection and retention reviews to include the curator or grant-giving representative, the project manager, the wood specialist and the consultant (if there is one).
- Consider options for reburial or experimental research for the portion of the wood assemblage that is not to be retained.

Post-excavation recording and analysis

- Formulate timetable for wood in temporary storage.
- Consider 'fast track' option for special items for conservation.
- Complete wood recording (if not done on site).
- Make selection for photography and illustration.
- Prepare proposals for sampling and analysis for species ID, for woodland management, and for radiocarbon and dendrochronological dating following rapid assessment.
- Analysis to include: wood technology, species ID, woodland management, dendrochronology (where appropriate samples have been analysed) and conservation assessment.
- Make final selection of wood for conservation.
- Consider options for reburial or experimental research for the portion of the wood assemblage which is not to be retained.

Dissemination

- conservation of wood selected
- disposal or reburial of unconserved wood
- curation, archiving and display

The advantages of this methodology are that wood can be cleaned properly before recording and sampling; and that there is a break to allow a reasoned strategy for sampling, analysis and selection for conservation to de developed, informed by assessment of the whole assemblage and some dating evidence. The main disadvantages are that temporary storage facilities are required for all the wooden assemblage; and that the wood specialist does not see all the material in the ground.

Method 2: Recording and sampling on site. This strategy is sometimes adopted where very large quantities of wood are being excavated and a wood specialist is on site most of the time, working with a team familiar with waterlogged wood. The advantages of this strategy are that a significant part of recording and sampling is done during excavation; and the quantity of wood entering temporary storage is much reduced. This can significantly reduce the time spent on post-excavation work. The main drawbacks of this method are that sampling, retention and discard strategies are worked out in advance on less than perfect prior information, and have to be updated as excavation progresses; also that cleaning and recording of material also has to be done on site in less than perfect conditions.

Any decision to undertake assessment and selection for retention during fieldwork should be decided at the planning stage. In some circumstances it may be necessary to make such a decision during fieldwork, but this should also be done only under the conditions outlined above. Any discard policy must also be formulated with regard to the views of the eventual recipient of the archive and the legal owners of the material (English Heritage 1991, section A.4.3.2).

Where assessment during excavation is carried out it is important that more sampling than normal should be undertaken for identification, woodland management studies and dendrochronological and radiocarbon dating. It should be remembered that different selection criteria apply to radiocarbon and dendrochronology samples.

Ideally every piece should be sampled for species identification and woodland management in such cases. In addition, a greater amount of the assemblage should be retained for possible conservation and detailed analysis. This is because the importance of an individual timber may only become apparent during post-excavation analysis. All possible artefacts should be kept intact and not sampled on site.

Figs 9, 10, 11 At Testwood Lakes, Hampshire, the timbers of Bronze Age bridges were sprayed with water and wrapped in polythene to prevent desiccation during excavation. Much wood recording took place in situ but the timbers were removed from site for post excavation analysis (© Wessex Archaeology).

3.1.2 Excavation techniques

Sharp edged metal tools such as trowels and spades cause damage to waterlogged wood and should not be used for uncovering wood in deposits such as peat, where wooden or plastic spatulas and bare hands are a practical alternative. In most clay and gravel sites the use of metal tools is inevitable but especial care should be taken in their use as even solid oak timbers can be badly damaged. Thorough cleaning of delicate wood surfaces *in situ* should not normally be attempted unless with particular care. Water sprays can be used in some deposits to help excavate and clean around wooden structures.

The first exposure of wood during an excavation may cause damage to the surface of the piece or pieces. Any such damage should be marked and recorded to avoid later confusion. Marking can

be achieved using stainless steel or brass pins with heads of a particular colour that will be recognised as signifying excavation damage when the wood is being recorded at a later stage. In many deposits, for example clays, it may prove hard to keep bark attached to the outside of the wood. In such cases it is important that the presence of bark is recorded as early as possible, as it can be important in woodworking studies and dendrochronological analysis. The protection of sapwood immediately after exposure is essential for the same reason. Surface features may hold other important evidence, such as paint, pitch or food remains.

Throughout the period between exposure and lifting, wet wood will begin to desiccate, split and decay unless positive action is taken. For this reason the minimum possible area of wood should be exposed at any one time, taking into account the size of the excavation team and the need to understand, plan and photograph the deposits.

Maintaining a high moisture content on site for long periods can be very difficult. Wholly enclosed shelters with high humidity and moderate temperatures may produce good conditions for working on structural wood and may also help prevent flooding by rainwater. In some cases the temperature inside such shelters can become unpleasantly high for both the wood and for the excavators, and such environments can have health and safety implications.

Where large areas of wood are going to be exposed on site for some time a garden sprinkler or 'leaky hose' system may prove useful. In other circumstances, when wood is not being planned or photographed, it should be protected with water-soaked polyether foam, then covered with thin, preferably black, plastic sheeting and the foam regularly sprayed with water. Clingfilm may also prove useful to wrap directly around wood to retain humidity. Care is needed to avoid damage to upstanding remains when covering them with plastic sheeting. Additional advice can be found in Watkinson and Neal 2001.

3.2 Recording *in situ*

Much of the recording of wood *in situ* should follow normal archaeological practice. Plans of structural wood should normally be drawn at 1:20 and elevations of front, back and sides (if relevant) at 1:10. Wattle panels may need to be drawn at a larger scale, however. Presentation of the wood surfaces on these plans should be kept to clear outlines, and include major structural features (holes, notches, joints) and areas of damage. Photogrammetry for whole structures may be found useful.

In addition to the normal context numbering, each excavated piece of wood should be given a site wood number. The exceptions to this are groups of wood such as *in situ* wattle work or collections of brushwood or woodchips that are going to be described and sampled as a group rather than individually. A general site policy for such group numbering should have been developed before the start of the excavation.

The labelling of wood is probably best achieved using waterproof labels (eg Tyvek), clearly marked with waterproof black ink, and attached with stainless, corrosion resistant pins. The staining of labels in water can sometimes make them illegible, however, so sealing them in polythene bags is often a wise precaution. Labels must be securely held in place as their loss can entail huge problems in post-excavation analysis.

Numbering and labelling is probably best done immediately before planning (the wood numbers should of course be recorded on all plans and elevations) to

Fig 12 At a development site at Huntgate, near the River Foss in York, a trench was excavated to characterise the deposits, which were more than 3m deep (©York Archaeological Trust).
Fig 13 (above right) Huntgate, York: Part of a sunken-floored building was revealed with walls made of oak uprights and reused boat planks. Dendrochronological analysis of 10 timbers showed that the building was built in the late 960s AD and that the boat had been made in southern or eastern England at most 12 years earlier (©York Archaeological Trust).

Fig 14 Huntgate, York: The timbers were carefully removed for further recording and conservation by freeze-drying (©York Archaeological Trust).

reduce the impact of loosing labels, unless they are needed before this for inclusion in context descriptions. It is suggested that publication photographs are taken before numbering, as once assigned, the labels should not be removed.

Once a wood number has been given, a Wood Recording Sheet (WRS), or a digital equivalent, should be started for the individual piece or groups of wood (if wattle work etc). The full range of information to be presented on such a sheet is given in section 3.5.2, but the information that must be recorded before lifting should include the following:

- relevant context, plan and photography numbers
- setting (horizontal, vertical etc), orientation and inclination
- surface condition, and areas of excavation and pre-excavation damage or breakage (clearly distinguished)
- visible fitting details (joints, nails, pegs etc), with sketch guide for easy identification
- relationship to other timbers

3.3 Lifting, packaging and transportation

The lifting of waterlogged wood requires careful handling techniques. Lifting of very delicate objects should be done under the direction of a conservator. Advice from a conservator will also be required for those not experienced in handling and transporting waterlogged wood. Additional advice can be found in Watkinson and Neal 2001.

The main point to remember is that waterlogged wood does not have the same strengths as modern wood does, so, for example, if two people pick up a prehistoric plank from either end it will usually immediately break in the middle. The strength of waterlogged wood varies enormously depending on species and preservation. Oak heartwood is generally quite hard and strong, but it is also heavy and may have cracking and decay that is not readily apparent on the surface. It can still split and be dented and any sapwood that survives will be especially vulnerable. All other species, with the exception of yew, usually have little inherent strength and will bruise and break quite easily no matter how sound they appear on the surface.

As much of the deposit surrounding the wood as possible should be excavated before lifting, and fragile sapwood and bark may first need to be secured in place with bandages or pins. Wood should be lifted directly onto a surface that can be used to support the piece for its transportation

Figs 15 and 16 Lifting of the huge late 11th-century bridge timbers from the Hemington aggregate extraction site, Leicestershire (Fig 15 © University of Leicester Archaeological Services).

Fig 17 After being recorded, the timbers were conserved for eventual display, initially using the sugar replacement treatment, with the help of more than 40 tons of free sugar from British Sugar (© University of Leicester Archaeological Services).

to the temporary storage area. To prevent breakage, this surface should be capable of supporting any irregularities in the piece.

Long, thin items are less likely to break if lifted vertically rather than horizontally. Several people, or mechanical means, may be required for lifting long or heavy timbers. Ideally long timbers should not be sawn into shorter pieces, as they are often hard to put back together after conservation. Where timbers are sawn into segments, markers should be left on both sides of the cut to enable correct realignment. Sawing roundwood items at a slight angle will enable the join to be correctly realigned at a later stage.

The method of packaging of wood on site depends on the type of temporary storage available and on how far the wood will have to travel to reach it. Where a cold store is being used, wood can be heat-sealed in polythene tubing or bags, with the site and wood numbers recorded both on the inside and on the outside of the bags. Waterproof pens should be used for the outside and waterproof labels inside. As little air as possible should be left in the bags before sealing.

If the wood is to be temporarily stored in water such packaging is not always appropriate, but can protect wood underwater and keep fragments and labels together. In such circumstances a few small slits in the polythene are needed to let in the water. Large timbers may need no packaging if they are entering such a store, but smaller items will need to be held in some sort of netting – such as 'netlon' tubing – which will allow the free flow of water but will keep individual items separate.

Where the temporary storage facility is some distance from the excavation, the delay of many hours or days between lifting and immersion in the storage area means that some sort of wrapping is needed, as described above, for wood destined for cold stores. Wood stored in water-filled tanks needs checking on a weekly basis against leaks and infection. Tanks should preferable be under cover, or if outside, covered with lids to protect against the elements and wind-born debris.

Transportation of wood in water-filled containers is likely to cause damage to the wood as it slops around and should not be attempted. Wood must be kept damp and well-supported during moving. Depending on the size of the assemblage and on the type of transportation used, stacked storage containers may or may not be useful. To provide support for wood and to help prevent breakages layers of material such as saturated poly-ether foam sheet and bubble wrap can be used. If bubble wrap is used the bubble side must not be in contact with the wood or it will cause pock marking. If the wood is being transported from the excavations to a water store and the journey time is short, the wood need not be individually wrapped, but can simply be sprayed with water and then covered over with sheets of saturated foam and plastic sheet to reduce evaporation.

3.4 Assessment

3.4.1 Planning for assessment

The main area for supplementary data collection associated with a waterlogged wood assemblage will normally be in the assessment of dendrochronological potential. Species identification of parts of the wood assemblage will also be required to provide an accurate assessment of the potential for non-oak dendrochronology.

Before samples are removed for dendrochronological analysis, species identification or conservation assessment, it is necessary for the relevant pieces to be recorded by a wood technologist and usually also photographed and drawn, to publication standard if appropriate. In some cases it is possible to remove samples before photography and drawing with no significant detrimental effect.

3.4.2 Assessment

A waterlogged wood assemblage should normally be assessed for the archaeological potential of wood technology, species identification, woodland reconstruction, dendrochronological dating and decay analysis studies (English Heritage 1991, section 6.2). In addition it is necessary for a conservator to make a 'condition assessment' of the assemblage to establish viable conservation regimes for the material and its storage needs (English Heritage 1991, section 6.11). Wooden artefacts should be identified at an early stage and fast-tracked through the post-excavation process to prevent damage before conservation.

Assessment of potential for wood technology and woodland reconstruction studies normally involve a rapid scanning of the assemblage and the paper record, while the need for species identifications and decay analysis should be apparent without any further work. Samples will have to be taken for analysis for the assessment of dendrochronological potential (*see* section 2.4.5).

3.4.3 Spot dating

Initial artefact dating will often be necessary before detailed assessment (English Heritage 1991, section 6.8). Dendrochronological 'spot dates' are often required to provide such dating evidence. Small groups of timbers can sometimes be assessed and analysed by a dendrochronologist in a short period of about four to six weeks after the receipt of samples, as no detailed report is required at this stage.

In extreme cases, where there is no other dating evidence, the bulk of tree-ring analysis may be in the form of spot dates. If spot dates are carried out during the fieldwork stage there is a danger that timbers with poor dendrochronological potential will be selected (*see* section 2.4.5).

3.4.4 Selection for curation and discard

The Society of Museum Archaeologists has produced guidelines on the selection, retention and dispersal of archaeological collections (Society of Museum Archaeologists 1993), which should be consulted to help form a plan for conservation and discard. General recommendations on the long-term conservation and storage requirements of a wood assemblage should be made by agreement between the project manager, the wood technologist, the conservator and the museum curator. The material for eventual display should be identified at this stage, as its selection will influence the sampling policy. The curator and grant-giving body will need to be involved in the selection process also.

It will usually not be possible to select precisely all the individual pieces of wood for conservation at this stage, as the selection will be greatly influenced by the analysis of the assemblage for woodworking information. It should, however, be possible to produce an estimate of the likely conservation costs at this stage.

The material selected for conservation should be in a condition that is viable for long-term preservation and perceived as of value for future analysis owing to its intrinsic academic interest. Retention of whole timbers rather than of cut sections is recommended. Where a large quantity of wood is involved it may only be possible to select a larger number of cut sections from big timbers to preserve discrete areas of tool marks, carpenters marks or joints.

Where wood is desired for a museum display it may be necessary to conserve more wood than could be justified solely on the grounds of wood technology in order to preserve the overall integrity of a structure.

A representative sample from each of the following categories should be selected for retention and conservation (Society of Museum Archaeologists1993, section 4.3.7):

Function: examples of functional types (wall post, rafter etc); examples of joint types and fittings (best example of each joint-type occurring in each structure); examples of re-use
Technology: examples of felling and woodworking methods (eg hewn, sawn, split, weave of hurdle etc); moulding and other ornamental treatment; examples of specific surface treatments (eg pitch, paint); pieces showing evidence of tool marks, tool signatures, tally marks, carpenter's marks or graffiti; examples of woodworking debris
Natural features: examples of specific woodland management practices
Other: any other pieces identified by the excavator and wood specialists as particularly significant to the interpretation of the site or of the nature and use of wood; cores or sections taken from timbers left *in situ*; samples selected for dendrochronological and other scientific studies

The amount of material selected from these categories will vary according to the period and type of structure excavated and its relative rarity. The most relevant source of information is a review of waterlogged wood excavated between 1968 and 1987 that details the numbers of excavated and conserved structures by period and structural type (Nayling 1989). This survey has not been updated, however, and is not detailed enough to provide information on the different types of joints and woodworking that have been conserved. Early conservation methods may also have produced a poor-quality result, which would diminish their academic value.

Very little prehistoric, and especially Iron Age, wood has been conserved, therefore such material should usually be considered to be potentially of national significance. Any worked Mesolithic or earlier wood should definitely be reserved for conservation, as should any prehistoric timbers with evidence of joints. Some wood should be conserved for its regional, as opposed to its national, significance.

3.4.5 Post excavation proposals/updated project design

Wherever possible there should be a continuity of staff between the fieldwork and the assessment and analysis stages. For example, if a wood technologist was employed during fieldwork, that same person should be employed for the analysis.

When formulating a timetable for analysis it must be borne in mind that some forms of analysis will have to be done in sequence. In particular, the study of the assemblage for information about wood technology must be carried out before samples are removed for other forms of analysis.

The updated project design must include a timetable for the wood in temporary storage, giving details about when the various forms of analysis will be completed, when the final decision concerning retention or dispersal will be made and when the wood for retention is to be sent to the designated conservation facility. Any significant deviations from this timetable should be explained.

York Archaeological Trust Wood Record Sheet	Site Code/ Accession No:	Timber or SF No:
Site Name:	Context No:	Area:

On Site Recording: Context Information

Co Ordinates		Reduced Levels:		8	
E	N	1		9	
		2		10	
		3		11	
		4		12	
		5		13	
		6		14	
		7		15	

Orientation:

Drawings and Images	Overall dimensions m/mm
Plan Nos:	Length:
Section/Elevation Nos:	Width:
Photo Reference Nos:	Thickness:
	Diameter:

On Site Recording: Interpretation.

Stratigraphic Position:

this context is

Physical Associations:

Dating/Phasing:

Function as Found:

Ancient or Recent Damage:

Special Reasons for Recovery:

Method and Conditions of Recovery:

Completed By:	Date:	Checked By	Date:

Fig 18 and 19 Wood recording sheets for use on site and for post-excavation (© York Archaeological Trust).

York Archaeological Trust Post Excavation Wood Record Sheet

York Archaeological Trust Post Excavation Wood Record Sheet	Site Code/ Accession No:	Timber or SF No:
Site Name:	Context No:	Area:

Type:	Cross Section:
Condition:	

OA Dimensions m/mm:

Length

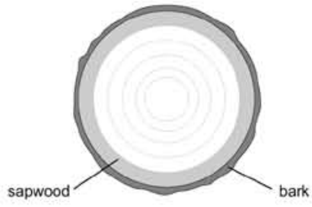
Width

Thickness

Diameter

Cross Section Sketch:

	Yes	No
Bark	☐	☐
Sapwood	☐	☐
Knotty	☐	☐
Straight Grained	☐	☐



Further Research Potential:

	Yes	No
Dendrochronology	☐	☐
Tree ring Study	☐	☐
^{14}C	☐	☐
Display	☐	☐

Species Identification:	Conversion:

Woodworking technology:

Tool Marks ______________________________

Joints ______________________________

Fixings and Fittings ______________________________

Intentional Marks ______________________________

Surface Treatment ______________________________

Other ______________________________

Reused: Y ☐ N ☐ Not Known ☐

Recommendation: Discard? ☐ Discard after further research/sampling? ☐ Retain and Conserve ☐

Checked:

Date:

Measured Sketch:

3.5 Recording after lifting

3.5.1 Cleaning

Before recording, the wood must be cleaned. Ideally this will be carried out by a wood specialist, or under his/her supervision, where this is a practical option. Sponges, soft brushes and liberal amounts of flowing water may be used, depending on the nature of the deposit from which the wood the wood was retrieved. In the case of delicate objects, or of surface features such as paint, a conservator should do the cleaning. Cleaning is sometimes best done outside, because it can be a wet and messy process and because the light is usually better than it is inside buildings.

3.5.2 Wood Records

Recording after lifting should mainly be done on Wood Record Sheets (WRS) or on dogital equivalent (*see* section 3.2). These must be designed by a wood specialist before the fieldwork stage. No single design or format is promoted in this guide, as each WRS should be tailor-made for the type of site under investigation, a complex urban waterfront structure, for example, having many different requirements from a brushwood trackway. Where a computer recording system is used during fieldwork or during post-excavation work the WRS should be designed to be compatible with the data handling system employed. With wood assemblages of several hundred pieces it may prove useful to put some of the basic attributes and storage information onto a computer database.

The questions asked and the information demanded on the WRS should follow the standards set out below. With the exceptions of the dimensions and the basic site stratigraphic information, the recording on a WRS should be carried out by a wood technologist or other suitably trained and experienced staff.

For recording woodworking information, drawings and sketches are usually much more important than written descriptions. Several existing works provide details of woodworking terminology (eg Crone and Barber 1981; Hewett 1980; Milne (ed) 1992).

The information on a WRS should include the following:

Basic site information
- context and associations
- planning and photography numbers
- setting (horizontal, vertical, angled etc)
- orientation and inclination (in degrees)

Appearance
- size and shape (dimensions and sketch)
- damage, breakages and number of pieces (pre and post excavation)
- surface condition (from fresh to weathered)
- surface features, wear, charring, paint, and presence of bark, bark edge or sapwood

Functional interpretation
- artefact purpose within structure or context
- details of fitting (joints, nails, pegs etc, and sketch)
- possibility of timber having been re-used or modified from original purpose

Natural features
- species identification (always by microscopic analysis, except in the case of oaks identified by wood specialist or other trained person)
- natural growth features, growth pattern and timber quality
- features of induced growth, coppiced heels etc
- evidence of insect, fungal or plant damage

Technological evidence
- evidence of felling and cutting of log to length
- conversion type and method, including sketched cross-section. (In long timbers where the cross-sections vary, several sections should be drawn at intervals along the length of the timber. Unless the piece is being retained for conservation it will often be necessary to saw it up to enable these sections to be drawn.)
- evidence for shaping and finishing of timbers, including measurement of selected tool marks and recording of stop lines, jam curves and tool signatures
- traces of wear

3.5.3 Illustrations

Only a proportion of the wood assemblage from a site will require post-excavation illustration. Detailed advice on illustrating wooden artefacts is available in Allen 1994, and most of the principles outlined will also apply to structural timbers. The scale of the drawing should vary according to the size of the piece, from 1:1 to 1:20. When the larger scales are used it may be necessary to draw some details, such as joints, at a smaller scale. Illustration of wood should show the following:

- size, shape, direction of grain and growth, and position of branches or knots
- areas of bark, sapwood and exposed heartwood

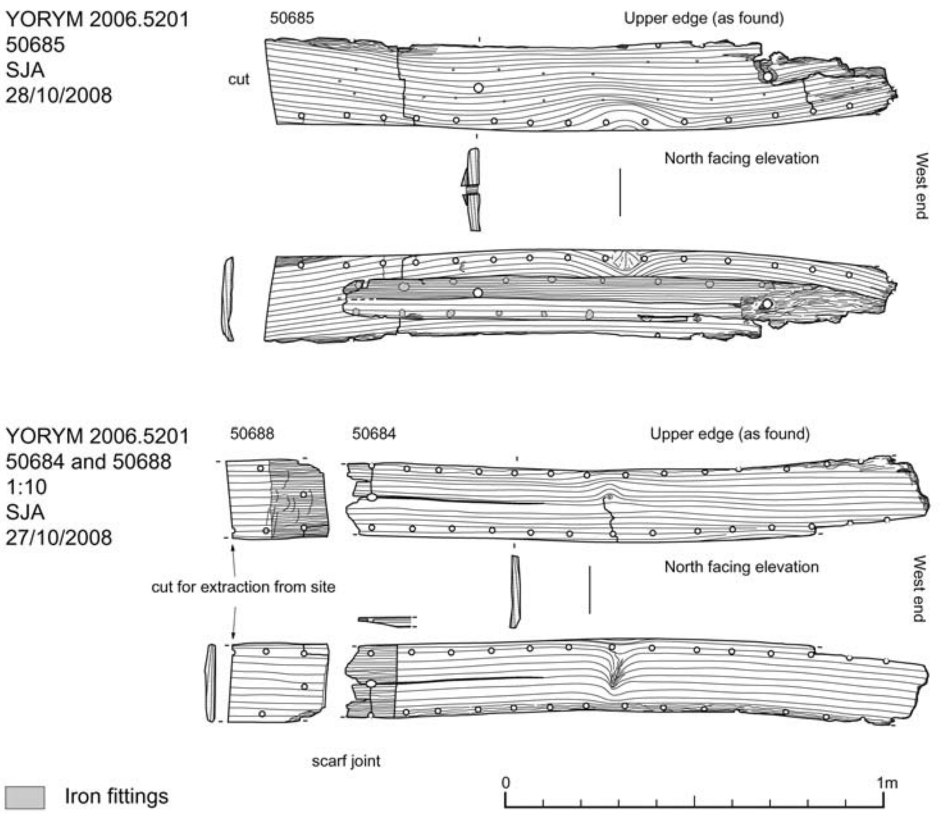
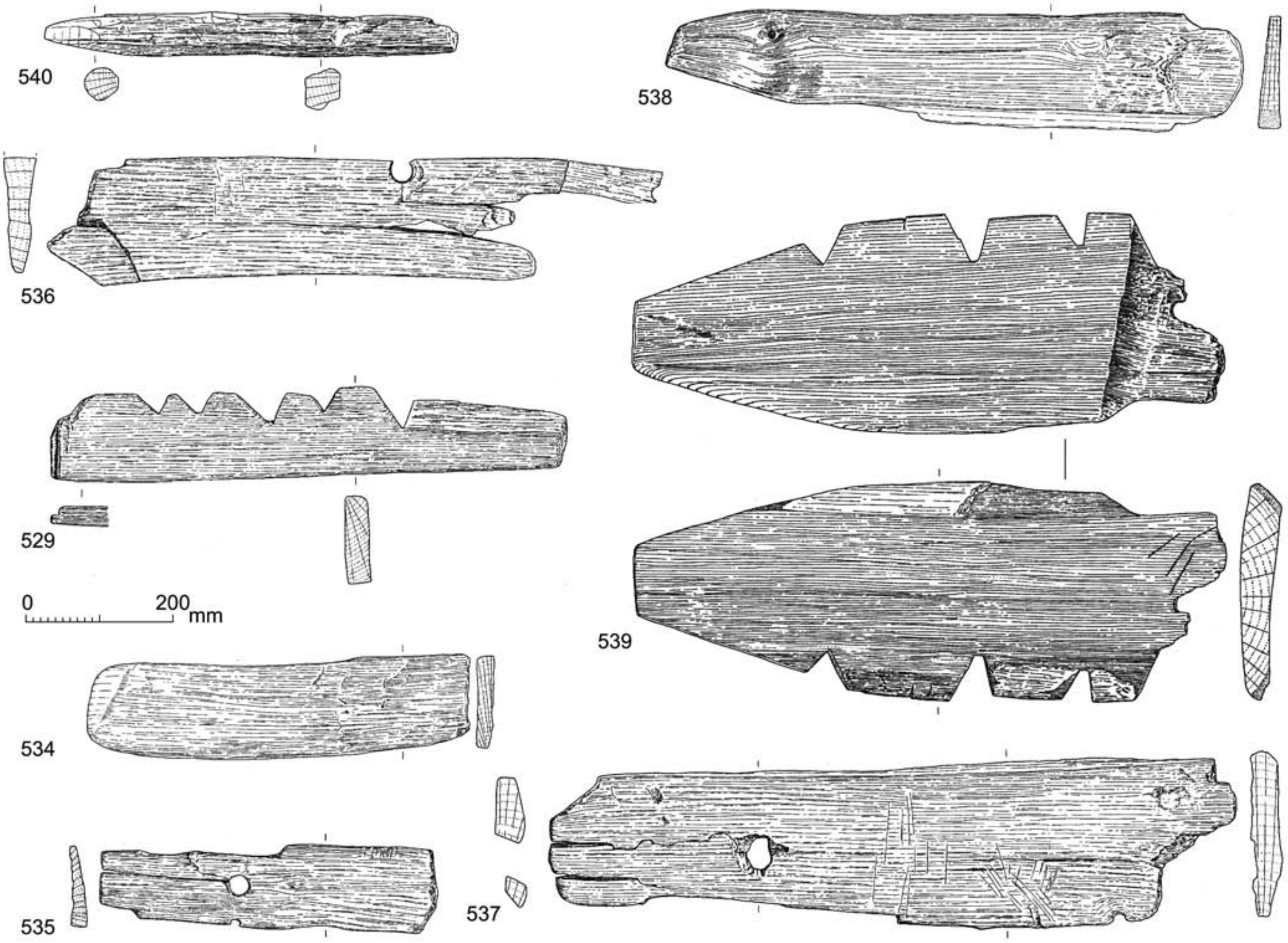
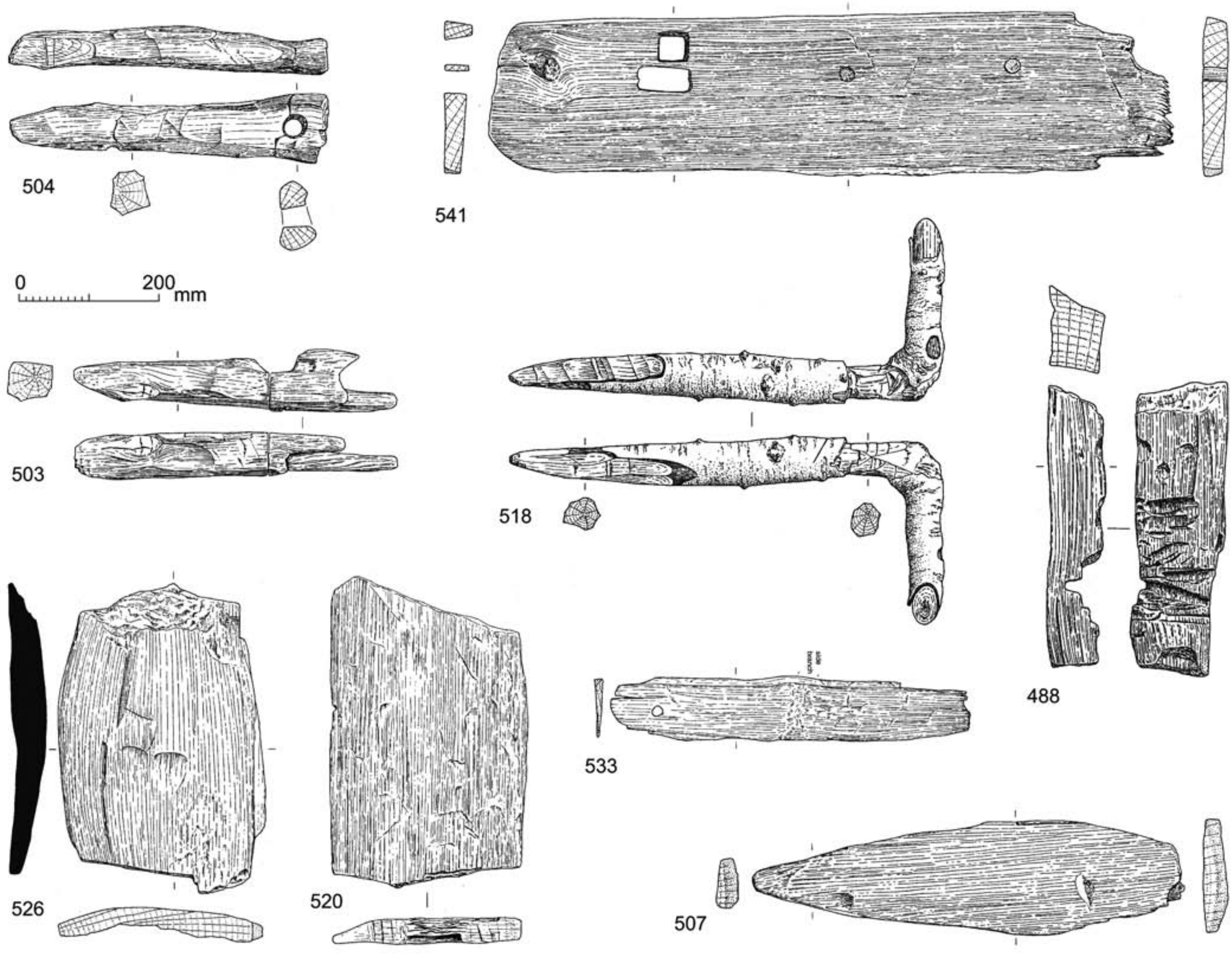


Fig 20 Drawing of 10th-century boat plank reused in a building at Hungate, York (© Steve Allen and York Archaeological Trust).



Figs 21 and 22 Drawings of wooden objects and reused timbers from Burlescombe, Devon (© Lesley Collett).



- areas of decay, damage (ancient and modern), wear and compression
- position and character of joints, holes, nails and tool marks
- at least one accurate cross-section showing relation to other drawn faces
- the location of cross-sections and of tree-ring samples

The positioning of large or delicate pieces for illustration should be done by staff familiar with the handling of wood. Illustrations should be made of several faces of converted structural timbers and artefacts, but usually only of one face of simpler material. Cross-sections should show the pith, sapwood and the ray and ring patterns, and for converted wood they must be drawn at both ends if possible. The illustrations should be checked by a wood specialist/technologist to ensure all the necessary details have been recorded.

3.5.4 Photography

Archive photography should be done with black and white print film. Digital colour photography will be useful for publications, displays, lectures and other purposes, but should be used in addition to, and not instead of, black and white print for archiving. Where digital photographs are to be archived, guidance is available in other documents (Brown 2007).

In addition to overall shots of individual timbers, photographs should be taken of joints, tool marks and areas of wear. Photography will often prove difficult and may require a large amount of space. The positioning of large or delicate pieces for photography should be done by staff familiar with the handling of wood. If this is not possible, the general advice of a conservator should be sought before the process begins. A wood technologist should be involved in photographing technological aspects to ensure that the significant features are captured.

Slightly damp wood surfaces reflect tool marks best, in combination with an angled light source. Both natural light and artificial light can be used, separately or in combination. Camera metering will pose problems and over exposure is usually required. White or very dark backgrounds should normally be avoided. Bracketed photos are highly recommended when using film. A scale should always be included in every shot, as well as the wood record number.

3.5.5 Moulding

Synthetic rubber compounds can be used for moulding, which can be done during or after fieldwork. Moulds may be useful for recording joints or tool marks, but is not an acceptable alternative to the conservation of such features. The operation should always end with a positive cast. A conservator should advise on and conduct any moulding operations, and may suggest other types of mould. If the piece being moulded may later be used for a radiocarbon date the conservator should check with the radiocarbon lab that the materials used will not affect the date. Some problems may be experienced with the long-term storage of moulds and resulting casts.

3.5.6 Laser scanning and 3D modelling

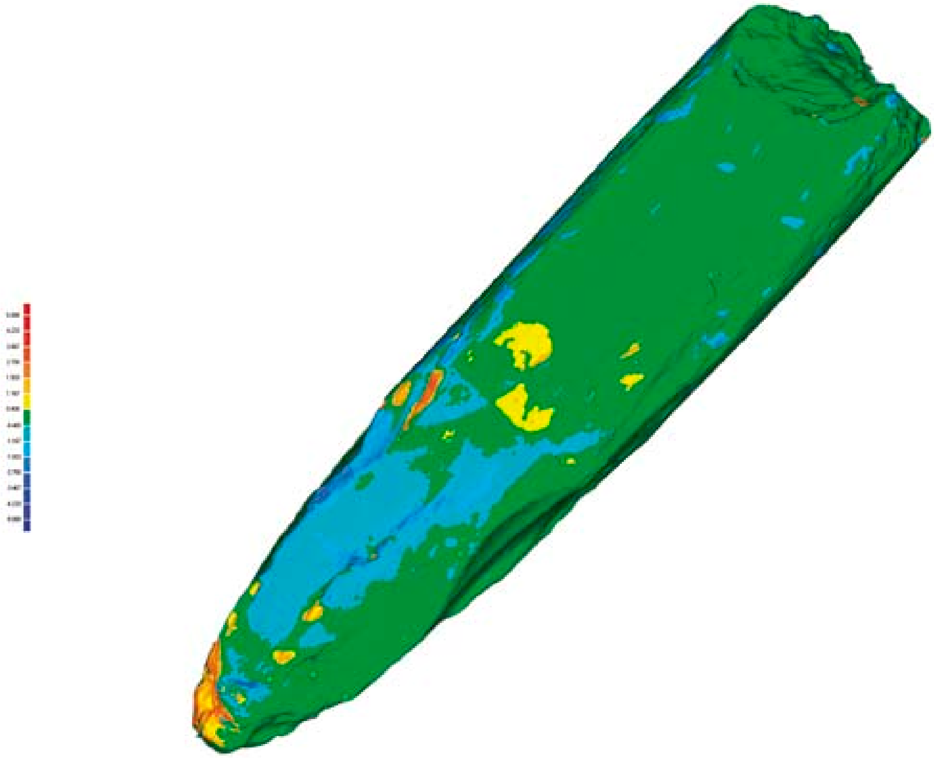
Laser scanning is becoming more widely used for recording archaeological wood (English Heritage 2007). Laser scanning produces a detailed, high- resolution, three-dimensional model, which can be manipulated to show details on artefacts that are difficult to represent in line drawings. A moveable light source reveals and highlights details such as tool signatures in greater relief for better understanding of woodworking techniques. Laser scanners currently work to a sub-millimetric resolution, with each new model working to a higher resolution and accuracy.

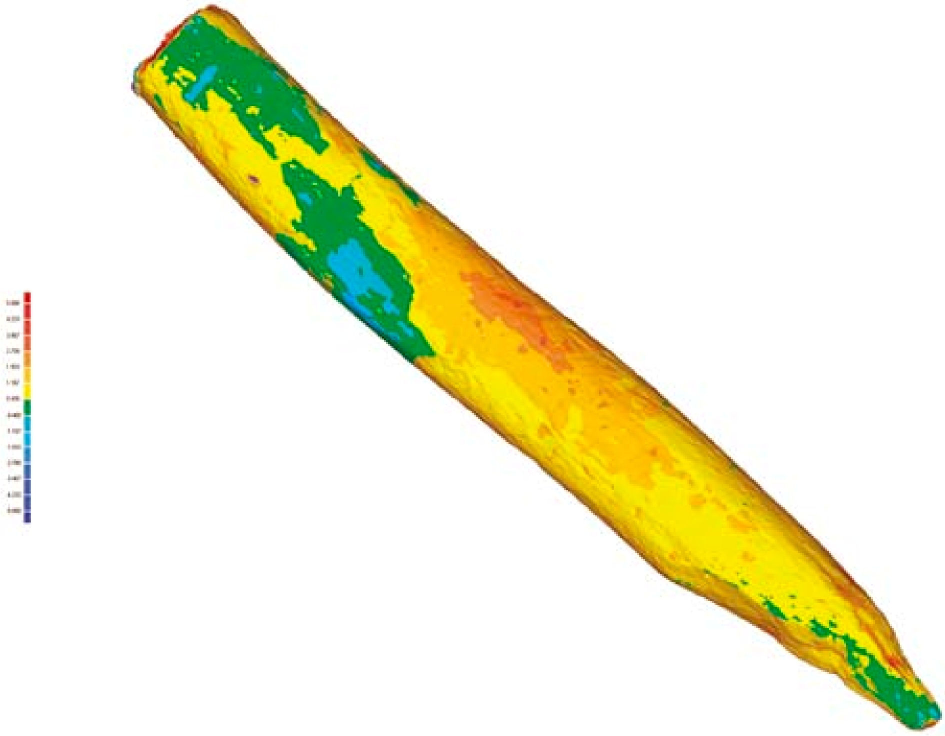
Ideally the wood should be scanned as soon as it is excavated, to preserve the maximum amount of information, as waterlogged material degenerates without conservation, and because short-term storage has been shown to lead to slight changes in wood structure. Repeated laser scanning of the same objects has the ability to detect the scale and character of such pre- and post-conservation changes.

Laser scanning is a relatively rapid process, probably faster then normal illustration. By manipulating the digital product, publication-standard images can be produced, although there is a significant difference between different pieces of scanning equipment. Laser scanning differs from illustration in that no interpretation is incorporated into the resulting image.

Laser scanning is an excellent tool for recording detailed woodworking and tool marks. Its application for tool mark analysis is likely to increase significantly and should enhance the way in which tool marks are recorded and to make it possible to record more detailed and accurate measurements of blade impressions. It should become

Fig 23 Laser-scanned image of cut wood enabling detailed comparison of tool signatures to be made (© Birmingham Archaeo-Environmental and VISTA).





Figs 24 and 25 Repeated laser scanning of wood in short-term storage has been used to show changes in wood structure over time, using a colour coded relief model (© Birmingham Archaeo-Environmental and VISTA).

possible to digitally compare striations left by inconsistencies in the cutting edge and to apply statistical levels of certainty to such techniques as same-blade matches.

Laser scanning and three-dimensional modelling of timbers is especially useful in the recording and analysis of the remains of ships and boats. A Faro Arm © device has been successfully used to digitally record ships timbers in three dimensions. To operate, users simply guide the Arm's touch-probe along the surface of the object to be measured. A computer simultaneously illustrates the three-dimensional measurements on screen and records all the data, creating a three-dimensional model of the piece. It is possible to obtain three-dimensional models of every timber and reassemble them digitally. This technique should enable the distortion created by compression in the burial environment to be removed, and thus a more accurate reconstruction of the original shape of the vessel. Such digital data can be used to produce highly accurate scale models assembled from individual, machine-produced components.

Scanning alone will not provide an adequate record of a timber, however. The examination of the original object by a wood specialist is also required. For the same reason, and because of the problems associated with digital archiving, laser scanning should not be seen as a replacement to the conservation and curation of wooden objects. Guidelines for archiving such digital data are available in English Heritage 2007 and in Brown 2007, but it is also important that paper versions of the digital data are included in the archive as far as this is possible.

3.6 Sampling

3.6.1 Sampling policy

To ensure that the maximum information is obtained from an assemblage of wood it is essential to develop, with specialist advice, a reasoned sampling policy before excavation begins. This is especially important on sites where not all the wood is retained for assessment after excavation.

The sampling policy should be designed to answer specific questions about the site, such as date of building, type of woodland utilised, length of occupation, nature of local environment and other relevant issues. It should also take into account national, regional and period-based research agendas if the site is of a period or type that is not well-represented in the excavated archaeological record.

If not all the wood is being retained for post-excavation assessment, then it is important to 'over sample' during excavation, ie to take more samples than are thought necessary to answer the questions posed in the sampling policy. Temporary storage of samples is rarely a large problem, and the reasoned selection of sub-samples for analysis is best accomplished once the full extent and nature of the site is understood.

All samples should be placed in sealable plastic bags with the wood number and other relevant site information (eg context) written in waterproof ink on the outside. To prevent desiccation, a small amount of water should be put in the bags before sealing. As much air as possible should be excluded from the bags. Immersing the filled sample bag almost up to the top in water before sealing is an easy way to do this.

Depending on the staffing structure of the project, it may be possible to avoid multiple sampling by only taking a single sample for several forms of analysis, such as species identification, woodland management studies and dendrochronology. Many specialists will do species identification and woodland management at the same time and this is the most cost effective way for them to do this.

Sampling from significant artefacts should be done by a conservator or by the specialist him- or herself. The latter option is preferable.

3.6.2 Wood species identification

Only oak (*Quercus*) heartwood, which has a distinctive colour, hardness, ray and pore pattern, can be identified in the field. Even this should only be undertaken by staff experienced in such identification. For all other species identifications, a small sample should be taken for identification under a microscope with the wood structure examined on the three principal planes: radial, transverse and tangential. Ideally the sample should be taken from a well-preserved, knot-free section of the wood and need only be a 20mm square cube if it is cut cleanly. If the wood is badly preserved a larger amount may be required.

Where pieces that are to go for conservation cannot readily be identified to species by surface observation, and therefore need to be sampled, it is usually acceptable for a smaller than normal sample to be removed, by a specialist from an unobtrusive spot. Sampling of artefacts is usually carried out by taking thin sections from the surfaces with razor blades, but it is not always possible to produce identifications by this method. Attempts to identify the wood in artefacts should always be made before conservation, as it is much easier at this stage, and may have implications for the treatment selection. The sample location should be marked on any archive drawing.

Ideally every piece of worked wood should be sampled for species identification, although where there are large deposits of woodworking waste, or an over abundance of small roundwood pieces (30+), a selective sample is acceptable. To avoid bias, selective sampling should be done on a random basis to ensure that it is not just the largest or best preserved pieces thar are identified. The species identification of apparently unworked pieces of wood will assist in reconstructing the local woodland habitat, and may prove useful in highlighting differences between the range of species growing near the site and those that were actually used.

3.6.3 Woodland management samples

Tree-ring samples to determine age and growth rates should be taken where information is sought on the character of the woodland that was being exploited. Such studies should form part of the analysis of all assemblages of worked wood. The proportion of the assemblage sampled will vary from site to site, however, according to the recommendations of the specialist undertaking the analysis.

It is likely that the same specialist will be able to carry out species identification and ring counting from the woodland management samples. Always check before sampling. Samples should be extracted where the largest number of annual rings is present, and in the case of roundwood a complete cross section should be taken. Knot holes and branches should be avoided.

More specific sampling may be undertaken where the morphology of roundwood suggests that coppiced or pollarded wood has been used. Long, straight, branch-free stems are the most obvious characteristic of wood from such a source, sometimes associated with the distinctive ‘coppiced heel’ at the bottom end. Wattle hurdles or fences are the most likely locations for such sampling. Taking samples for analysis may identify the growth patterns associated with such material, and plotting the age and size of the samples in conjunction with species identification should help to ascertain whether a managed woodland was being exploited. Under no account should wood be said to be from managed coppiced woodland without such studies being carried out. A specialist can sometimes do the measurement of stem diameters and ring counts at the same time as he or she does species identification.

Fig 26 The Bronze Age Eclipse Track, Somerset, made using thousands of hazel rods from coppiced woodland (© Somerset Levels Project).

Sampling to determine the possibility of such managed woodland exploitation is only a realistic option where a sample of at least 20 individual pieces is available from a discreet grouping, such as a wattle panel. In such cases every vertical and horizontal member should be sampled from the widest part of the stem and numbered separately.

3.6.4 Environmental indicators

Sampling of wood for evidence of fungal, bacterial or beetle attack can help to reconstruct the environment in which the wood was deposited and determine whether timber was stored before use. The specialist doing such analysis will probably have specific sampling requirements, but in general such samples should be taken as soon as possible and should be kept in a cold store.

The choice of sample location is very important; for example the determination of ancient water levels may require samples at intervals from vertical timbers. Beetle attack may be visually identifiable only in cross-sectional or in longitudinal section, depending on the type of infestation.

3.6.5 Dendrochronology

Sampling for dendrochronology should only be taken under the direction of a dendrochronologist or a suitably qualified and experienced individual approved by the dendrochronologist. Sampling is a different process from assessing the samples for their dateable potential.

Only a dendrochronologist should undertake the assessment of the samples, unless he or she has given approval for a named member of the fieldwork team to undertake some of this work. Under no other circumstances should sampling and assessment effectively be combined into one process. Sampling by inexperienced individuals usually results in poorly selected samples, which not only wastes time and money but also reduces the potential information that can be gained.

Samples should be 50–100mm thick and should be taken from the widest part of the timber. It should incorporate sapwood wherever it is present. The presence of sapwood, and preferably of the bark edge, on samples is essential for assigning precise felling dates. Knots should be avoided, as they distort the ring pattern. The species, number of annual rings and condition of the wood are also important factors in sampling:

species Oak is most often used for dendrochronology, but ash, pine, beech, and elm have also produced dates by the formation of a site master curve, which is tested against a relevant oak chronology (*see* section 1.3). Non-oak samples should only be taken after consultation with the dendrochronologist, and are usually only worthwhile where at least 6–10 samples with sufficient ring counts are available from a single context or structure.

ring count Dendrochronology relies on the pattern of annual rings being unique in time. To achieve this, samples should have at least 50 annual rings and preferably more than 100 rings. Samples with 30–50 rings may also be useful for dating if they have sapwood or bark, and are part of a larger group of samples from one structure or context. Ring patterns of less than 30 rings are definitely not unique and should not be used for dating purposes. On sites that only produce a single sample, dendrochronology is usually only worthwhile where a sample has at least 100 rings.

condition of wood Samples that have been broken tangentially are unusable unless the break is very clean, as the sequence of rings will not be continuous. However, a radial break (ie from the outside to the centre of the tree) does not interrupt the ring sequence.

Samples can be sawn by hand unless they are large oak timbers, when a chain saw may be required. To accord with Health and Safety regulations only trained staff wearing the designated protective clothing should undertake chainsaw work. Wood that is splitting or cracking should be bandaged before sawing and special care should be taken to preserve sapwood or bark where it survives.

Samples should be individually sealed in clear polythene bags and should be labelled inside and out. The outside should be labelled with a waterproof pen and waterproof labels should be used inside. Such labels should not be attached to the transverse surface, which will later be cleaned and measured by the dendrochronologist.

Samples can also be taken from timbers that are to be conserved. Tree-ring measurement is easier and more successful on such items before, rather than after, they are conserved. X-radiography has been used as a non-destructive sampling method, but the results have not been very successful. Cores and V-shaped wedges have also been taken from waterlogged timbers in efforts to reduce sampling damage to wood that is, or will be, conserved. Coring is not a viable option where sapwood is present.

Where coring is not possible the best method is to remove a complete slice from the timber using a sharp, narrow-bladed saw. After analysis the sample can be returned and rejoined to the rest of the timber during conservation. The dendrochronologist should be informed that this has been done so that the sample can be fast-tracked through assessment and measurement and rejoined to its parent timber during conservation. This will help to reduce any visual difference between the conserved sample and its parent timber.

Any slight disfigurement as a result of this process can be integrated into the display of the timber to help explain the importance of the sampling, and such minor damage is normally outweighed by the academic importance of the dendrochronological investigation. However, advice should be sought from the relevant conservator and museum curator about such sampling, especially whether the normal dendrochronological practice of freezing samples before measurement is appropriate. To prevent unnecessary sampling of wood that is to go for conservation it is essential that the work is undertaken by experienced staff (preferably the dendrochronologist) who can determine the best place to take the sample and whether there will be enough rings for analysis.

Full details of the samples should be sent to the dendrochronologist in company with the samples, but in a separate envelope. These details should include the following:

- context and sample number
- description of context
- function of timber
- details of associated timbers
- presence of bark
- evidence of re-use
- approximate date (Roman, Iron Age etc)
- whether the sample can be discarded after analysis
- whether the sample needs to be returned for conservation

Before samples are sent to the relevant dendrochronologist, the laboratory to which they are being sent should be contacted to ensure that sufficient storage space is available to receive them.

3.6.6 Radiocarbon dating

The criteria for sampling waterlogged wood for radiocarbon dating are different from those for dendrochronology. The most useful samples are those from very young roundwood or from the sapwood of larger trees. The amount needed varies depending on the water content of the wood and on the method of dating to be employed. The following weights should be ample in the vast majority of cases:

	radiometry	*high-precision*	*AMS*
wood (dry)	20g	150g	1g
wood (wet)	40g	1000g	2g

Ideally, material should be double-bagged in polythene with labels between the layers of plastic. Samples should be kept in the dark, preferably in a cold store. The great enemy of radiocarbon is algal growth, because of photosynthesis of modern (C^{14} enriched) carbon from the atmosphere. However, biocides should never be used.

Although fungal growth and the desiccation of samples will not cause problems for radiocarbon, they may destroy the structure of the samples and so prevent their identification. It is therefore essential that all wood samples are identified to age and species before submission for radiocarbon dating.

Although every effort must be made to avoid contamination, any possible contaminants of the radiocarbon samples should be noted on the sample form and the laboratory informed. The most common potential hazards are:

- diesel or petrol from pumps and site machinery
- sewage
- organic compounds from ground water

Where known temporal relationships exist between possible samples, for example through stratigraphy, the possibilities for using Bayesian statistics should be considered. Using such 'prior knowledge' can aid the statistics to increase the precision of multiple radiocarbon results (Bayliss and Bronk Ramsey 2004).

3.7 Maritime excavation

These guidelines will not attempt to provide detailed advice on marine and underwater excavation, and lifting of waterlogged wood from such sites. Guidance on underwater excavation techniques is available from several publications (eg Green 1990 and Bowens 2008).

The investigation of shipwreck sites obviously requires the involvement of an experienced nautical archaeologist. It is important to understand the ship type before it is recorded and sampled or excavated (Steffy 2006).

There are two main strategies for excavating boats and ships. Either the components of the vessel can be disassembled *in situ*, or the vessel can be cut into arbitary slices and removed with its components still joined together. This fundamental choice of methodology should be discussed with the maritime wood specialist, the conservator and the project manager. The choice of removal will have significant implications for the system of recording, labelling and sampling employed, also for and eventual conservation and display of any excavated timbers.

3.8 Temporary storage

The temporary storage of excavated wood should be discussed with the relevant conservator at the planning stage. Temporary storage facilities should be established and ready for use before excavation proceeds. Ideally they should be near or at the excavation site, but the continued use of storage facilities after completion of the excavations means that this is not always possible.

The three main requirements for the temporary storage of waterlogged wood are quite simple:

- ability to keep the wood wet, to prevent shrinkage and cracking
- exclusion of light to reduce algal growth
- very low (but not quite freezing) temperatures of *c* 4-8°C to reduce decay by micro-organisms

These requirements can be met in two main ways: with a cold store or with a water storage facility. In both cases it is essential to keep a precise and up-to-date record of where individual pieces are stored in the facility. The importance of this should not be underestimated if the efficiency, effectiveness and composure of those dealing with post-excavation analysis of large assemblages is to be assured. Computer databases may prove useful.

Cold stores are preferable to wet stores, but are usually only practical for small assemblages of wood. If cold storage is used, then the wood should be packaged as described above.

A variety of containers can be used for the storage of wood in water, although metal containers that will rust should be avoided. The volume of wood and the amount of storage space available will dictate what type of water tanks can be used. Plastic tanks (with lids to exclude light) are readily available in a number of forms and are often stackable if space is short. If there are many very large timbers a purpose built, reasonably priced facility can be established using a scaffold frame over which special heavy-duty plastic sheeting is laid and heat-sealed. Space to accommodate such a large tank may be a problem, however. Such tanks can be simply covered with black plastic to prevent light penetration, under which a layer of bubble-wrap or polystyrene foam floating on the water surface will help to exclude air and insulate the water.

There are five essential requirements that should be borne in mind when designing a wet store:

retrieval It should be relatively easy to find and retrieve a piece of wood from the store. For a numerically large assemblage of wood numerous small containers may therefore be preferable to using one or two bigger tanks.

water supply The water may need changing several times if the 'temporary' storage has an active lifespan beyond one month. Therefore a plug or tap at the base of the container will be useful for drainage. A water supply and drain are also obviously essential. Any stacking system of wood must be robust enough to support all the weight of the material when water is drained from the container.

location The store should be situated in the same place as, or as near as possible to, the location where it will be assessed and analysed during post-excavation if this was not already carried out on site.

temperature The store should be inside a building of some kind to prevent extremes of temperature (freezing will damage the wood structure and high temperatures will increase rates of decay) and also provide decent working conditions.

working area The store should have a workbench or similar facility where wood can be cleaned and examined under a good light source.

To reduce contamination, wood should preferably be cleaned before being placed in storage tanks. If the wood was lifted on aluminium sheeting, this should not be left in water storage for any lengthy period. To prevent the build up of fungi, bacteria and algae in a wet store, the water should be changed regularly. The frequency of water changes will vary according to the quality of the water supply used and the temperature at which the water is kept. To assist in disinfecting the water, techniques such as the exposure of it to ultra-violet light can be used. Circulation of the water within the storage tanks helps to reduce biological activity. Biological control using snails (*Physa* sp.) and certain fish species has also been tried with some success. A trained conservator's advice should be sought before using any of these techniques.

Under no circumstances should any chemical biocide be added to the water. This can be a health hazard to those who have to handle the wood at a later stage and should not be necessary. It may also interfere with C^{14} dating and conservation processes. The most common causes of the build up of fungi, bacteria and algae in water tanks are the failure to properly exclude light – so do not use clear plastic containers – and ambient temperatures that are too high.

Microbial decay of wood in store can often be detected by the presence of slime on the wood surface. In anaerobic conditions the activity of sulphate-reducing bacteria produce pungent sulphides and may also cause black discolourations. A possible health hazard to people handling wet wood may be posed by certain fungi that contain mycotoxins in their spores. Inhalation of these spores may cause serious respiratory disorders (Mouzouras 1994).

Temporary storage of wood after excavation all too frequently turns into longer-term storage while post-excavation analysis and conservation problems are debated or deferred. This may lead to the degradation of the material over a period of several years until a state is reached where the wood is in too poor a state for conservation and is therefore quietly disposed of. To prevent this, and the clogging up of storage locations for future material it is crucial to establish an agreed timetable up for work on wood in temporary storage, and that once this work has finished the pieces for conservation are dispatched immediately. The causes for any alterations to this programme should be explained in writing and a new timetable established.

4 Analysis and dating

A large range of techniques is now available for the analysis of archaeological wood and even the most seemingly uninspiring piece of excavated wood can reveal valuable information. This part of the document is designed to be an introduction to the current analytical methods, so that the potential of the resource can be better appreciated by those who are not familiar with it. In general these methods are applicable to the wood assemblages from all periods.

4.1 Woodworking information

Information concerning past woodworking is perhaps the most obvious potential of an assemblage of worked wood. When first excavated, before a specialist has been called in, there is sometimes confusion over whether an assemblage of wood has been worked or not. Trees can split naturally and break into forms that may suggest working by humans, and the marks of beaver teeth can appear similar to those of tool marks. This is especially the case where the surface of the wood is poorly preserved. Such confusion is largely, but not exclusively, confined to wood of prehistoric date, and underlines the need to get early specialist advice. Unworked wood may still be important for palaeoenvironmental reconstruction, and because it may have been collected for fuel or for use in simple brushwood structures.

The aim of recording archaeological wood is to help the archaeologist to reach an accurate reconstruction of the whole woodworking process – from the selection of a tree to the final use of the timber in a structure. The selection of wood of different species and of specific parts of a tree is a very important part of woodworking, matching the natural properties of the wood to the required function. Species identification and a careful record of cross sections and tree morphology are required to establish whether such natural characteristics were being exploited to the full. The conversion of the log by various methods of splitting, hewing or sawing can usually be determined by examination of the ring patterns in cross section and from traces left on the timber surface. Evidence for the actual felling is more rarely preserved.

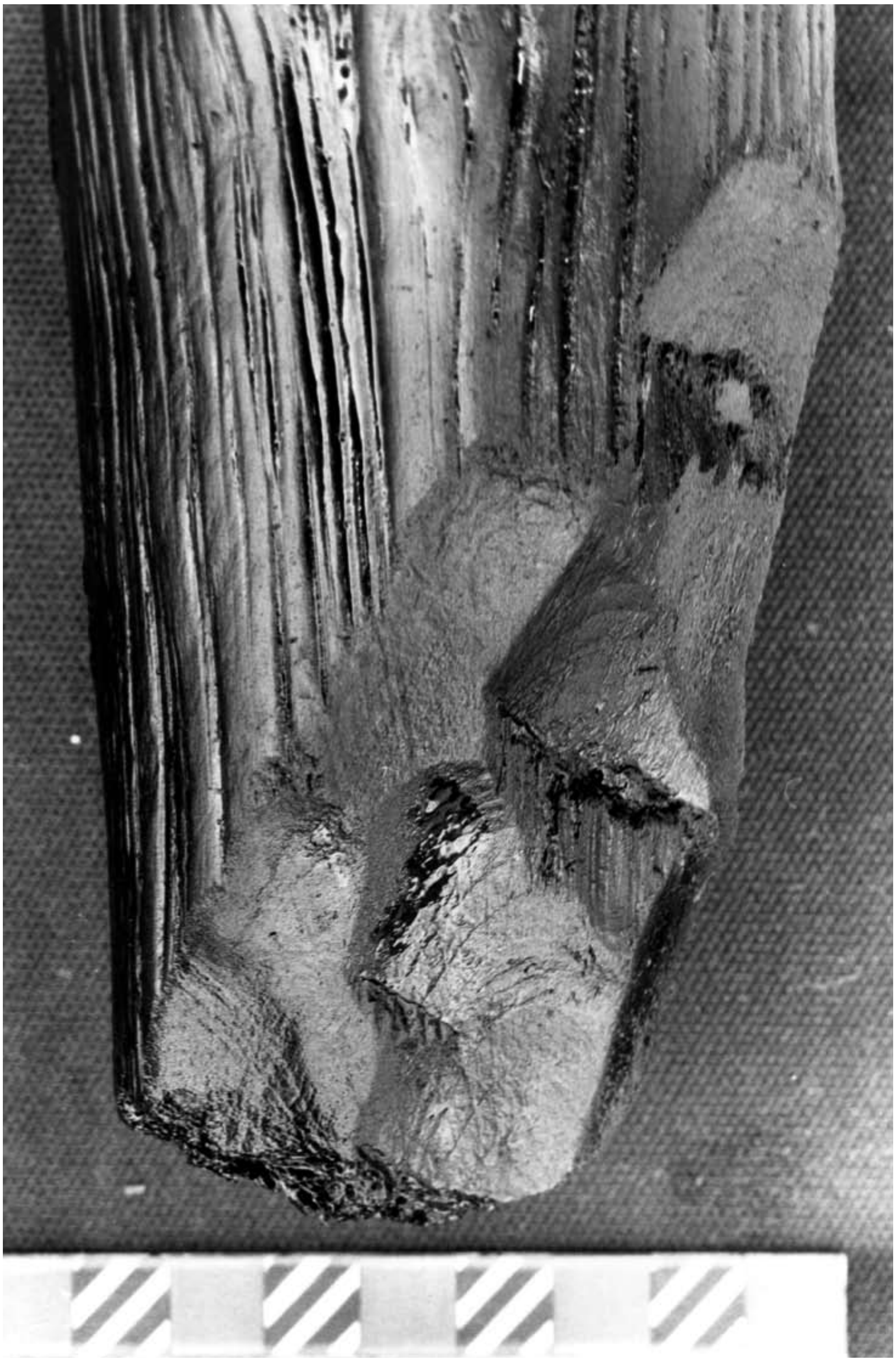


Fig 27 Facets made by a Neolithic stone axe on a timber from the Sweet Track, Somerset (Scale in cm) (© Somerset Levels Project).

Valuable information on the types of tools used in finishing timber can be gained from a study of the surviving tool marks, although it is not always possible to differentiate between some tools, such as between adzes and single-bevelled broad axes. Where a tool blade has come to a stop in the wood – producing a 'stop mark' or 'jam curve' – it may be possible to measure both the width and the profile of the tool employed (Sands 1997, 11–13; Brennand and Taylor 2003, 22–8). Where preservation is very good, the unique series of nicks and flaws in a tool blade may leave a 'signature', or set of characteristic striations, on the tool marks. With careful measuring and use of a computer it may be possible to 'match' the signatures from different timbers to show they were worked with the same tool (Sands 1997, 1–43; Brennand and Taylor 2003, 24–30). Sharpening of the blade may soon alter the signature pattern, however. Laser scanning of tool marks will probably improve the accuracy and reliability of such analyses in the near future.

The waste from woodworking is also useful because it can provide information on the type and size of tool being used and testifies to the activity in which the tool was employed. This is especially significant where the finished product of such activity is used elsewhere and hence may not be recovered in the excavation. It may also provide evidence for *in situ* woodworking. Bark fragments are also potentially significant, as bark has been used for containers, clothing, roofing material, lighting and tanning leather.

The introduction and development of different joints is one of the most important concerns in studies of past woodworking. The variety of joints employed at any one time has a large effect on the possible types of constructional techniques that can be employed. Very little evidence of above-ground wooden building techniques survives from the early medieval and previous periods. Therefore the study of the construction methods used in waterfronts, wells, boats, bridges, trackways and other waterlogged structures is an important source of information on the building methods employed on a much wider range of structures.

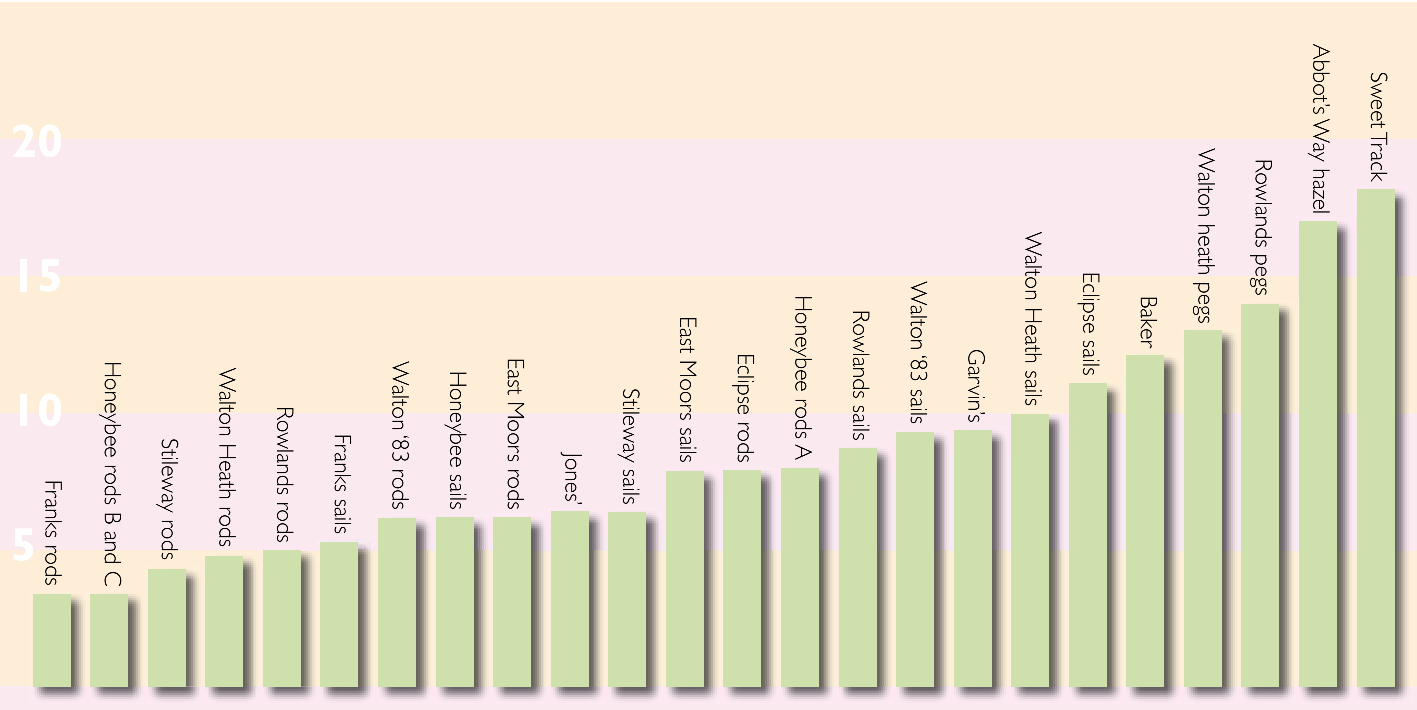
4.2 Woodland management

Trees have always formed an important part of the landscape and their usefulness to people for fuel, fodder and the raw material for artefacts and structures has meant that the control and management of this natural resource was very important. The age, species composition, growth pattern and morphology of the wood assemblage from a site can be used to help reconstruct the local woodland, but a large number of variables needs to be taken into account.

The species used on a site are often limited to those most suited to a particular task, and the proportions of different species may not directly correspond to the numbers of trees in the local woodland. Long-distance transportation of timber is well-documented from the medieval period. This is most likely to be a significant factor in urban environments, where even some small roundwood may have been brought in from a considerable distance. The re-use of timber from portable objects such as boats, wagons, crates and barrels is also unlikely to reflect local woodland composition, but may suggest trading patterns where the country of origin can be determined.

The use of local woodland may also be partly determined by physical problems of access, ownership and other socio-economic factors. Variation in timber quality on an individual site over time should also pose questions about changes in the available woodland resource, or in the status and function of the structure for which it was used.

Where pollen analysis has been undertaken the similarities and differences between the evidence for woodland from the wood remains and that from the pollen may be informative about timber selection.



Figs 28 and 29 Graph showing the average age of hazel roundwood from prehistoric structures in Somerset. The young age of the material used as rods and sails of hurdle trackways, such as the Neolithic Walton Heath Track, is a product of coppice management of the contemporary woodland (Fig 28 (above) © Richard Brunning; Fig 29 (below) © Somerset Levels Project).

Fig 30 Coppiced hazel woodland (© Richard Brunning).

Pollen and macro-plant analysis may also assist in determining whether particular elements of the wood assemblage are likely to have been derived from woodland in the immediate vicinity.

Tree-ring growth patterns and the morphology of wood may also supply information concerning woodland management. Wide growth rings and a large number of branches along the trunk are generally indicative of trees from hedgerows or pasture woodland, while trees with initial rapid growth followed by successive narrow rings prior to felling suggests competition between closely spaced 'standards' in poorly managed woodland. Many other factors, such as the influence of climate and disease, must also be taken into account, however.

Coppicing was a commonly employed method of producing long, straight stems from stools, after the main trunk had been cut back to ground level. Such stems were used for many tools and structures, such as hurdles, fences, fish traps, wattle revetments and trackways, and for fuel. Coppiced and pollarded stems can often be identified from their morphologies, from their ring patterns, and from the presence of 'heels' on the butt ends.

Coppiced wood may be produced from areas that are formally managed and cut on in rotation; or they can be harvested from naturally occurring stands that regenerate following woodland clearance. Age distribution plots of wood thought to be coppiced may help to determine whether the source is formally managed or whether it derives from 'adventitious' coppice, but a large number of other factors have a significant influence. Large timbers derived from pollarded trunks have been identified from medieval contexts in London.

Information concerning the local environment in which wooden structures were built (and decayed) can be obtained from studying attacks on the wood by beetles, fungi and bacteria. In some cases this could yield information about contemporary water levels or on the possibility of timber being stored before use.

4.3 Dendrochronology

4.3.1 Method

The most accurate and precise method of dating wood is by the study of tree rings (dendrochronology). More detailed information on dendrochronology is obtainable from the relevant English Heritage guidelines (English Heritage 1998 and new edition forthcoming).

Dendrochronology utilises the fact that in temperate regions the widths of the annual growth rings laid down by most tree species are generally determined by climatic factors. Thus trees growing at the same time will show similar patterns of wide and narrow tree rings. These ring patterns or 'curves' correspond best between trees growing in the same woodland, but the similarity of climate over much of northern Europe means that tree-ring curves can be matched with other curves derived from trees growing in other regions or countries within this area.

By matching older and older ring curves 'reference chronologies' have been built up against which new samples can be compared in the hope of getting a match. Most of these reference chronologies are formed from oak, for example the Northern Ireland oak chronology goes back to 5452 BC, while a German oak sequence extends to 8021 BC. Apart from oak, samples for dendrochronology can also be obtained from ash, pine, beech and elm. The sampling requirements are discussed further in section 3.6.5. The production of a site master curve, made up from several different trees from one site, makes a match with a reference chronology more likely, and thus increases the chance of getting a date.

It is important to remember, however, that the taking of samples for dendrochronological analysis is no guarantee that a date will be produced. The relative scarcity of sites producing prehistoric and 4th-century AD samples means that they are not as likely to date as those from other periods. However, as the number of sites producing samples increases, the chance of producing a dateable match correspondingly improves. Thus samples for which a date cannot be immediately determined may be able to be dated in the future. The establishment of a site chronology, and/or the identification of timbers derived from the same tree, can provide useful relative dating even if absolute dating is unsuccessful.

Figs 31, 32 and 33 Dendrochronological sampling of the Meare Heath (Fig 31, top) and Tinneys (Fig 32, above, © Somerset Levels Project) trackways in Somerset, produced site chronologies that cross-matched each other but did not match any absolutely dated chronology. Decades later, analysis of timbers from bridge structures at Testwood Lakes, Hampshire (Fig 33, over, page 24, © Wessex Archaeology), made possible the absolute dating of all three structures. The timbers from Meare Heath had some sapwood and were felled sometime in 1530–1503 BC. The Tinneys timbers had no sapwood and were felled sometime after 1468 BC. Some of the Hampshire timbers had sapwood and bark edge, enabling a felling date to a particular year to be assigned. That date is withheld, pending publication.

4.3.2 Precision and use

The precision of a dendrochronologically determined felling date relies on the presence of sapwood and/or bark. Where the last ring immediately below the bark is intact, a calendar date for the felling of the tree accurate to a single year or season can be obtained. Where only part of the sapwood survives the date of felling can be estimated for oaks, but if there is no sapwood only a *terminus post quem* felling date can be applied. It is important to remember that even when a felling date of a single year is obtainable this may not necessarily reflect the date of the building of a structure, as the timber may have been stored for seasoning, stockpiled, re-used from an earlier structure, or may represent a later repair.

When sapwood is present, dendrochronology can be very useful for dating structures and identifying periods of repair or rebuilding. It can also sometimes determine which timbers came from the same type of woodland and even if separate timbers were derived from the same tree.

4.3.3 Site phasing and timber provenancing

One of the most useful aspects of dendrochronological dating is that it is precise enough to enable periods of repair and rebuilding to be determined in structures. It can also isolate different phases of construction on sites and suggest the active lifespans of particular structures. On complex sites, such as lake settlements or medieval waterfronts, these attributes of dendrochronology are invaluable because the information they provide is usually unobtainable by any other means (eg Crone 2000).

Dendrochronology sometimes shows that individual timbers were derived from woodlands in different countries or regions to the place where they finally enter the archaeological record. Timber provenancing in relation to waterlogged wood is most common on portable objects such as boats, wagons, crates and barrels, which are often broken up at the ends of their active lives and re-used in structures such as waterfronts. From such information important evidence of trade routes can be derived.

4.3.4 Palaeoclimate reconstruction

Ring-width patterns, latewood density and stable isotope ratios can all be used to reconstruct past climate. A large number of variables have to be taken into account and there is much research still to be done on the subject. Some studies have linked the variations in patterns in dendrochronological samples and their existence to past changes in climate and possible connections to volcanic eruptions and comet strikes (eg Baillie 1999; Baillie and Brown 2002).

4.4 Other dating methods

4.4.1 Technology and typology

The type of woodworking tools used and the character of the tool marks can often be used to give a rough idea of date, such as 'Neolithic', 'Bronze Age', 'Roman' or 'post 1700'. The typology of joints or wooden artefacts can also provide dating evidence. In some instances dramatic changes in technology occurred in short time periods, and from the medieval period wood technological dating can sometimes be more accurate than dating by pottery typology.

Such techniques are especially useful for limited surveys and evaluations, as they are cheap and quick. On larger sites they are usually only useful to provide approximate dates before results from other, more accurate and precise, methods are known.

4.4.2 Radiocarbon, 'wiggle-matching' and Bayesian statistics

Wood can be used as samples for radiocarbon dating in the same way that other organic substances can be used. The high-precision radiocarbon dating of trees additionally dated by dendrochronology has provided the data for the construction of a radiocarbon calibration curve, which has enhanced the accuracy of the technique.

Owing to the fact that the proportion of radioactive carbon (^{14}C) has not been constant in the earth's atmosphere over time, radiocarbon dating of archaeological samples relies on calibration from the radiocarbon to the calendar scale.

In situations in which we have material with known age increaments – eg wood with annual tree-rings – a set of radiocarbon measurements can be obtained and the changes in the radiocarbon concentration over that period can be matched to those in the calibration curve using a method that is often referred to as 'wiggle-match dating'. Recent advance in the precision and accuarcy of AMS measurements means that small wood samples can be used for wiggle-matching' sequences of unknown date (Hamilton *et al* 2007).

Bayesian statistics can be used on groups of radiocarbon results that have known temporal relationships derived from stratigraphic evidence, or from the known spacings of annual growth rings from a wood sample. The resulting models can be used to provide much more precision in the dates than would otherwise be possible (eg Bayliss and Whittle (eds) 2007).

4.5 Other forms of analysis

Wooden objects may retain a variety of residues. Some of these may be visible on the wood surface, such as paint, salt incrustation or burnt deposits. It has been known for traces of paint to become visible after freeze-drying (D Croes pers comm). Lipids have successfully been extracted from pottery. It is possible that in the future this may also be achievable from wooden containers. All these residues can be subject to analysis with specialist advice. The English Heritage Regional Science Advisors should be able to advise on specialists to contact about such information.

5 Site monitoring and reburial

There are hardly any examples of wet sites in the UK where monitoring suggests that waterlogged wooden remains are likely to be safely preserved *in situ* over the short term (Coles 1995; Brunning *et al* 2000). Conversely there are numerous examples where monitoring has shown destruction and decay taking place (eg Van De Noort *et al* 2007; Brunning 2007b) It is wrong to automatically assume that any site can, or cannot, be preserved in the short to medium term. Any attempt at preservation *in situ* incorporates a degree of risk of failure, which must be recognised in the decision making process.

5.1 Assessing wood condition

When attempting preservation *in situ* or reburial it is essential to obtain information on the condition of the wooden remains. It is possible to assess the physical condition of waterlogged wooden remains using the techniques detailed in section 6.2. These should be helpful in determining the vulnerability of the material and in providing a baseline against which future changes can be reliably measured. In addition, the level of archaeological information contained in the material should also be assessed – ie are tool marks in a good condition; is species identification and tree-ring analysis still possible?

As far as possible the burial history of the timbers should be defined to help understand how they reached their present condition. The route by which they became buried is especially significant in this regard. For maritime sites there is a systematic model for shipwreck formation that may be useful (Ward *et al* 1999) and some experimentation is ongoing on terrestrial sites (eg Kenward *et al* 2008).

5.2 Reburial

The effects of exposing and then reburying wood are still little understood. In some cases where wood has been exposed, reburied and then re-exposed it has been found to suffer considerable loss of both surface detail and cell structure (eg Van De Noort *et al* 2007). In another case wood exposed for some time before reburial has been shown to have survived for over a century (Brunning 2007b). If a waterlogged site has begun to dry out, the chemistry of the burial environment will have altered. If rewetting occurs this may not necessarily re-establish the previous beneficial conditions and can sometimes produce changes in the burial environment that could damage other components of the archaeological record.

On terrestial sites reburial of lifted material will always entail a significant risk of failure, but must be considered a better alternative to simply dumping or destroying the material after the selection

Figs 34 and 35 The longest evidence of successful reburial in England comes from the Iron Age Glastonbury Lake Village site in Somerset. Timbers uncovered during excavations by Bulleid and Gray in 1897 and then buried under backfill were found still intact in 2003, 106 years later (© Somerset County Council).

of pieces for conservation. Reburial should not be seen as an adequate alternative to conservation and curation of the appropriate parts of a wood assemblage.

Reburial of waterlogged timbers is a more commonly used and more reliable technique for marine sites. In some cases wrecks have been excavated and recorded before apparently successful reburial near by (Grenier *et al* (eds) 2007). A detailed monitoring programme at another site has suggested that reburial at 0.5m depth can achieve minimal rates of deterioration (Gregory *et al* 2008). Some areas of the seabed may be too dynamic for such reburial to be done. Where the seabed is not dynamic, burial of timbers at a depth of 0.6m or greater should be enough to prevent degradation in the medium to long term.

5.3 Site monitoring

The techniques for the monitoring of waterlogged sites are constantly being re-evaluated and modified. Expert advice is essential when site monitoring is being contemplated. Site monitoring should examine the factors that are likely to affect the degradation rate of wooden remains. Where a previously anaerobic burial environment becomes aerobic rapid decay is likely to result from attack by soft-rot fungi, algae, nematodes, mites, bacteria and insects.

In anaerobic conditions erosion bacteria will be present, but it appears that they will only be actively degrading the remains if there is a water flux in the wood (Klassen (ed) 2005). The flow of water through wooden remains will be affected by the preservation condition of the material and varies according to the tree species.

To examine the aerobic or anaerobic character of the burial environment monitoring projects in northwest Europe have usually focused on the same parameters: water table, precipitation, dissolved oxygen content, temperature, redox potential (Eh) and hydrogen-ion concentration (pH) (Caple 1992; Jordan 2001; Matthiesen *et al* 2001; Heeringen *et al* 2002, 2004a, 2004b; Klassen (ed) 2005; Smit *et al* 2006; Holden *et al* 2006; Brunning 2007b). Other chemical parameters are also often analysed where they can affect deterioration directly (chloride, sulphate), where they serve as nutrients for micro-organisms (ammonium, nitrate, phosphate) or where they show redox conditions (sulphate, sulphide, nitrate, iron, manganese). The hydraulic conductivity of the burial environment is also a significant factor in the speed of degradation. In some urban and rural areas it is possible to have a perched water table maintaining waterlogged conditions significantly above the underlying water table (eg Holden *et al* 2006 and 2009). Sites that produce waterlogged wood also often contain many other types of archaeologically important material. The condition of these materials should also be assessed, not only to provide baseline data on their condition, but also because they are likely to be vulnerable to different factors affecting degradation (eg Kars *et al* 2001; Kenward and Hall 2001; Jones *et al* 2007).

Figs 36 and 37 Shinewater Park: During the construction of a new amenity park near Eastbourne the remains of a Late Bronze Age trackway and associated platform were discovered, including a wealth of artefactual information. In areas of concentrated wood remains, excavation was conducted from raised planks. A small part of the structures was excavated with the remainder preserved in situ in the new park. Hydrological monitoring of the burial environment, since 1997, suggests that in situ preservation of the waterlogged structures is being achieved (© University College London Field Archaeology Unit / Christopher Greatorex).

6 Conservation, curation and display

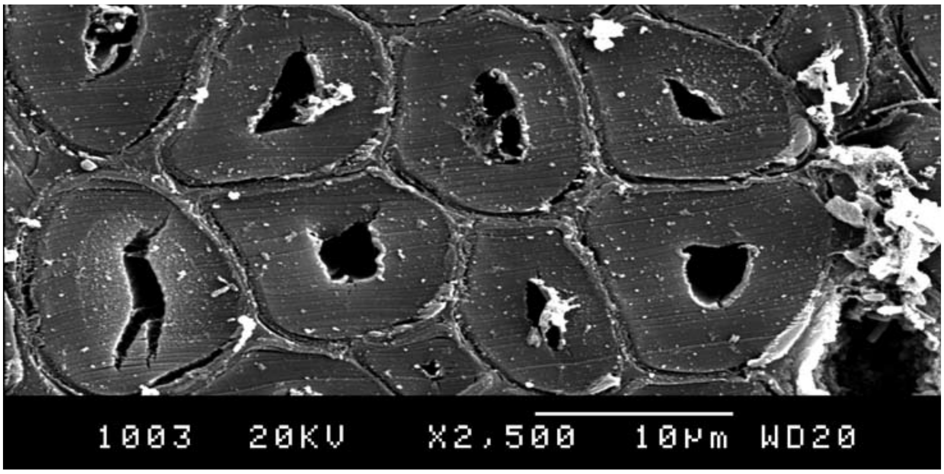
Despite its obvious significance in past cultures, wood is poorly represented in museum collections. As worked waterlogged wood is both a rare and informative resource, there is ample justification for its conservation and curation. There is therefore a clear need for more archaeological wood to be retained in regional and national museums, both for study and for display.

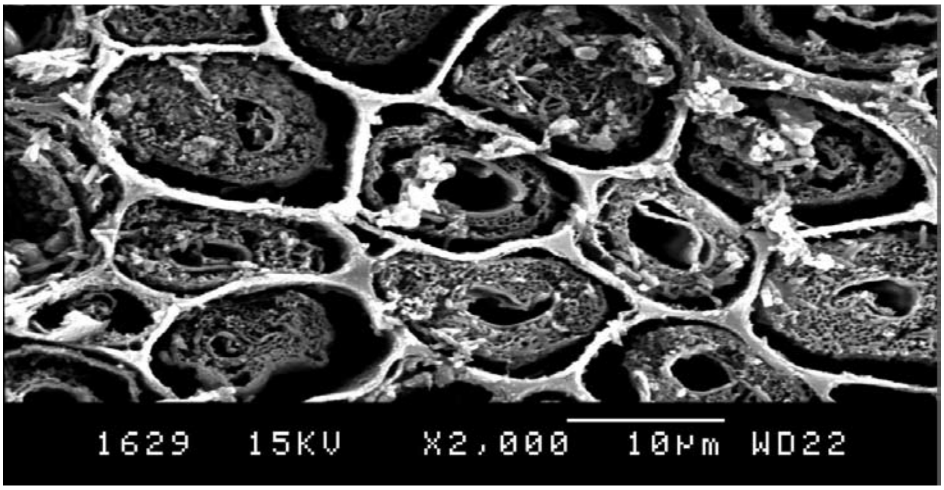
To implement such a practice, it is important for museums to become involved at the earliest possible time in projects that may generate suitable collections of worked wood. In this way the estimated costs of conservation and retention can be identified at an early stage and more time can be gained to plan areas for display or storage. The criteria to be used for selecting items for conservation and curation are discussed in section 3.44.

The conservation, curation and display of waterlogged wooden remains have been successfully carried out for many decades in the UK. Present conservation techniques produce a stable product that should be able to be successfully curated by most receiving museums.

One of the main advantages of displays of wooden structures, ships, barrels etc is that they are normally easy for the general public to comprehend and can be used to give context to other objects in a gallery. The detailed, precise and unusual information that wood yields can be used to great effect to enhance displays.

The size of some wooden structures can also be used to great visual effect. Museum displays centred around conserved wooden structures have proved to be some of the most popular national exhibits. The Mary Rose (Portsmouth) and the Jorvik Viking Centre (York) are only two of the more high-profile displays of archaeological wood in England.





Figs 38 and 39 Scanning Electron micrographs (SEM) of oak in various conditions: (38) well-preserved; (39) degraded (© Mary Rose Trust).

6.1 Condition assessment

Although there are few conservation options for large structural pieces of waterlogged wood, in order to design a conservation programme it is essential to establish the condition of all the wooden elements, as well as to factor in the limitations imposed by the scale of the project and by its intended display or storage environment. A combination of these assessment techniques can also be used to monitor wood that has been preserved by re-burial or to check on the efficacy of *in situ* preservation management schemes.

Conservators around the world use one or more of the following assessment techniques to decide which course of treatment is most appropriate for a particular wooden item, including identifying the wood species, along with its water content and specific gravity using little in the way of specialist equipment.

Other techniques that require access to specific equipment – such as Fourier Transform Infra Red spectrometry (FTIR), Sibert drill, X-radiography and Nuclear Magnetic Resonance (NMR) – are also used. In addition to assessing the wood's condition, it is also important to take into account the presence of iron salts due to corroding ironwork or bacteria in anoxic environments, as in both instances the iron salts that are formed can cause long-term problems in the treated wood.

A summary of the biological agents that can contribute to the decay of wood can be seen in the table below.

The condition of waterlogged wood found in archaeological contexts can be divided into three categories:

Class A	Well-preserved material dominates
Class B	Roughly equal proportions of well-preserved and degraded material
Class C	Degraded material dominates

Biological agents that contribute to the decay of waterlogged wood

organism	*environment*	*effects*
bacteria	Wet conditions. Aerobic bacteria also require oxygen.	Loss of cell wall material.
	Anaerobic bacteria in anoxic conditions.	Deposition of iron sulphides in the wood cells and can lead to the disintegration of lignin.
fungi	Require oxygen and a wood water content in excess of 18%.	Loss of cell wall material and discolouration, leading to a loss of strength and slow disintegration.
insects	Require oxygen and can survive in wood of only 8% moisture content.	Holes and cavities, followed by rapid disintegration.

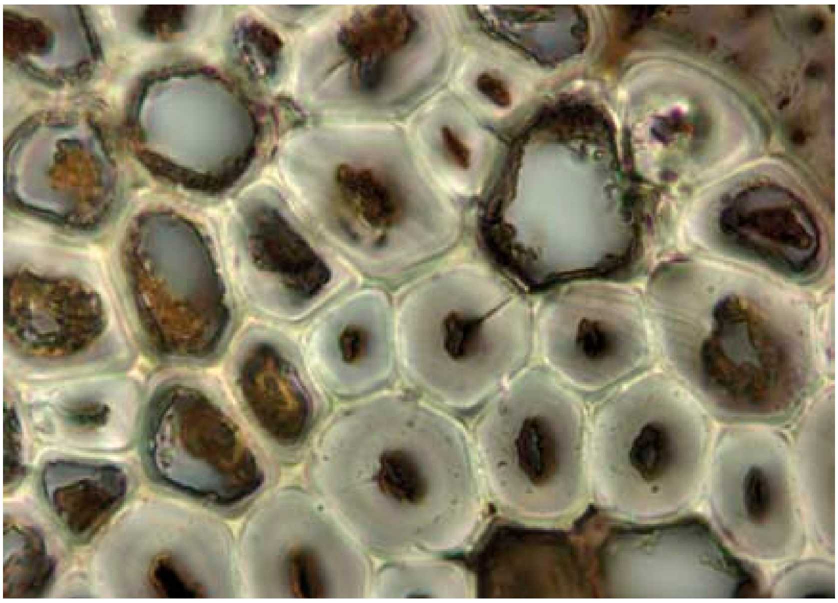


Fig 40 Thin section of oak with well-preserved cells surrounded by degraded ones (© Mary Rose Trust).

6.1.1 Physical structure

Thin sections are often taken using a double-sided razor blade and mounted on glass slides to identify the wood species by transmitted light microscopy (Hather 2000). By examining the wood under these conditions it is also possible to get a basic idea of the condition of the wood, how intact the physical structure remains and the presence of fungal hyphae or deposits blocking the main arterial vessels. A much clearer picture of the state of the wood cells can be obtained using a Scanning Electron Microscope (SEM), but the samples have to be carefully prepared first. The images obtained using this microscope make it possible to identify the different types of decay to which the wood has been exposed, as well as the extent of the damage.

6.1.2 Water content

The water content of a piece of waterlogged wood is determined by first weighing a sample of the wood when totally saturated with water and then weighing it again after the same sample has been oven dried. These measurements can then be used to determine the water content as a proportion of the saturated wood or as the amount of water in relation to the dried wood (known as the U max figure):

a. water in wet sample =

$$100 \times \frac{\text{W water}}{\text{wet wt}} = < 100\%$$

b. U max =

$$100 \times \frac{(\text{W wet wood} - \text{W dry wood})}{\text{W dry wood}} = > 100\%$$

The Umax figure is most commonly used for conservation purposes, and the water content of well-preserved and degraded wood varies with different wood species (McConnachie *et al* 2008):

	well-preserved	*degraded*
oak	≥ 150%	> 150%
poplar	≤ 400%	> 400%
Scots pine	≤ 250%	> 250%

6.1.3 Density

The density or specific gravity of the waterlogged wood can be used instead of water content. It is an indicator of the residual wood tissue and can be expressed as the loss of wood substance (LWS) and is calculated using the following formula:

c. LWS (%) =

$$100 \times \frac{(\text{Rgn} - \text{Rg})}{\text{Rg}}$$

Where Rgn is the normal density of the wood and Rg is the actual density of the wood. This measurement gives a value for the degradation of the wood that is independent of the wood species, even though the density of fresh wood varies by species (eg oak is 600kgm^3; birch is 450kgm^3; and pine is 350kgm^3).

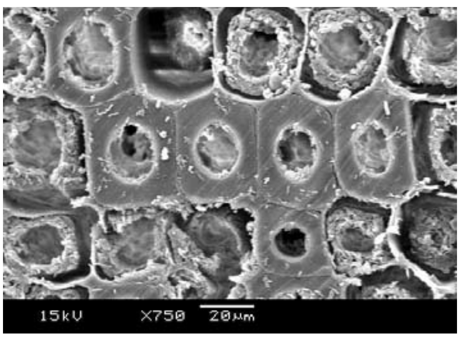


Fig 41 SEM of pine with both well preserved and degraded cells in close proximity (© Mary Rose Trust).

6.1.4 Fourier transform infrared spectroscopy (FTIR)

This technique is mainly used for the analysis of organic materials by passing a beam of light either through, or reflected from, a sample. The bonds between the different atoms can be distinguished as they absorb different regions of the infrared spectra. The samples can be mounted in potassium bromide as pellets for examination, although many recent models of spectrometers can be used to analyse powdered samples directly or to analyse small slivers of wood; and others have a microscope facility to analyse small areas or to produce compound maps of sections.

In wood it is used to obtain a spectral signature that identifies and gives an indication of the quantity of the separate chemical components, lignin, cellulose and hemi-cellulose. These values can be used as an indication of the wood condition (MacLeod and Richards 1996). Such spectral signatures can also be used to monitor the condition and degradation of wood in various environments as part of re-burial or *in situ* preservation management schemes.

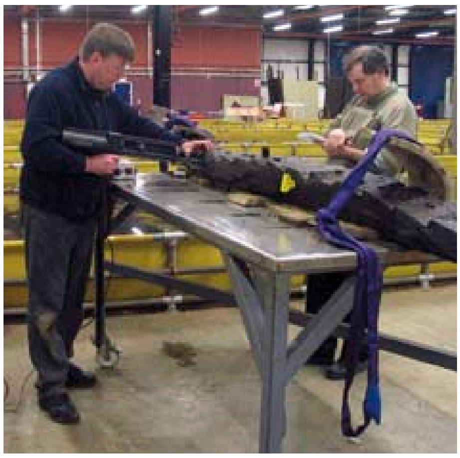


Fig 42 Using the Sibert drill to assess the condition of timbers from the Newport Ship (© Newport Ship project).

6.1.5 Sibert Drill or Decay Detecting Drill (Panter and Spriggs 1996)

The Sibert decay detecting drill is a handheld probe that produces a graphic representation of the rate of penetration into wood by a high-speed probe, by recording the resistance it meets. It can be used to assess the condition of waterlogged wood as the closely spaced bands represent well-preserved wood and the widely spaced ones are the degraded areas. This technique can be used as a quick and clear guide to the condition of the wood, without the need to take samples for laboratory analysis, and is extremely useful for assessing the condition of large and complex structures.

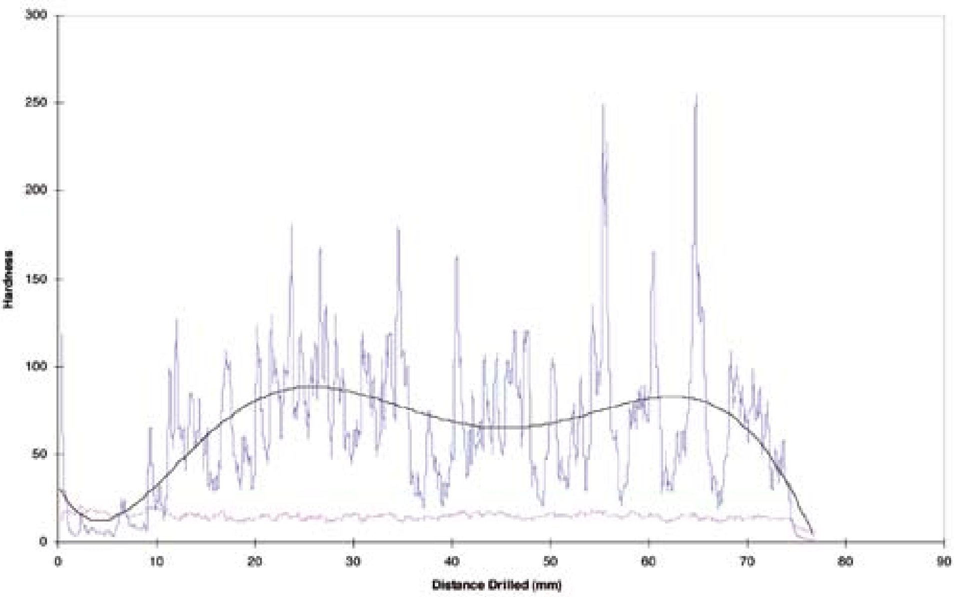


Fig 43 Example of the decay profile produced by the Sibert drill: blue line – soundness of timber under investigation; black line – overall trend; pink line – pressure required to push the probe into the wood; x-axis = distance drilled; and y-axis = 'hardness' (ie indicates how sound the wood is – the harder the wood, the less decay it has suffered).

6.1.6 X-radiography

Many wood-boring beetles and molluscs give little outside appearance of the damage they have done to the underlying wood except for the odd telltale exit-holes of the mature adults, so X-raying pieces of wood can give the true extent of the damage.

X-radiography can also be used to record joints in composite objects such as solid wheels with hidden loose-tongue joints, stitching and compartments inside basketry such as fish traps.

6.1.7 Nuclear Magnetic Resonance

NMR is a very expensive method of chemical analysis of wooden remains. It provides information about the loss of wood components as well as the chemical transformation of the residual components (Palma 2004). A sample of *c* 75mm × 30mm × 25mm is required, and the sample is destroyed in the analysis.

6.1.8 Presence of iron salts and sulphides

Iron nails and other attachments used in some wooden structures actively corrode in the waterlogged environments that preserve organic materials, and the salts that are produced migrate into the adjacent wood and accelerate the degradation of some of the cell components. Anaerobic bacteria also contribute to the presence of iron sulphides within the wood structure by breaking down abundant iron minerals in the soil and utilising sulphur from decaying vegetation.

The salts that are produced can include various forms of ferrous and ferric compounds, usually hydroxides, oxides, sulphates and sulphides. Many of these compounds are unstable in the presence of oxygen and release sulphuric acid that continues to attack the wood components and produces crystals that grow and exert physical damage to the cells they form inside. Iron salts have also been found to increase the hydrolysis of the lignin component of wood cells, which can have implications to the outcome of conservation.

In some cases it has been possible to neutralise the effects of these acidic compounds by treating the wood with sodium bicarbonate, ammonium citrate or disodium ethylene di-amine tetra-acetic acid (EDTA) while still wet. In other cases the sodium bicarbonate can be added polyethylene glycol (PEG) to seal the wood surface and neutralise any residual acids. If left untreated, however, iron sulphides will continue to oxidise, releasing more sulphuric acid, which in turn reacts with the wood. (For example the *WASA* is exhibiting these problems (Sandström *et al* 2002, 2003, 2005).

6.2 Conservation methods

(for large-scale wooden structures)
Most conservation laboratories can effectively treat small wooden objects with excellent results, but on scaling up, the same methods to preserve large wooden structures requires an approach more focused on the logistical and financial implications of the project. This means that when faced with the conservation of boats, bridges and other such large structures, one has only a narrow choice of methods from which to select a treatment that can be tailored to address the condition of the wood and the conditions in which it will be displayed or stored once dry.
The methods that have been used fall into three categories:

- controlled drying
- replacing the water in the wood with a consolidant
- freeze-drying

Freeze-drying is by far the most common method currently used in the UK. The advantage of this technique is that it produces a lightweight product with a natural colour and good retention of surface detail. It is also less time-consuming than the other methods, which all have

Figs 44 and 45 Wooden pike shaft from an Elizabethan shipwreck, which in the top image appears to be in a sound condition, while the X-ray image reveals the extent of the mollusc damage at one end and the high concentration of iron salts from the iron socket at the other end. © University College London.

significant drawbacks and can be just as costly, or even more so. The selection and implementation of wood conservation treatments should only be undertaken by a suitably experienced conservator.

6.2.1 Controlled air-drying

In cases where the waterlogged structure is preserved in a slightly degraded condition it is sometimes possible to air-dry the wood by controlling the humidity around it. This has been accomplished in various ways, from erecting polythene tents over the structure and using de-humidifiers to control the drying rate, to drying sections of boats in lumber drying kilns (Rice and O'Guiness Carlson 1996). More degraded wood can also be dried in this way if PEG is used to consolidate degraded areas by local application before drying begins. The drying of wood under these conditions can often take several years, before it can be stored or displayed in a normal environment, and will require continuous monitoring because the dry wood will continue to react to changes in humidity, which might cause it to develop serious cracks. Controlled air-drying is a high-risk approach, as areas of sapwood are usually lost and there can be a significant amount of warping, shrinkage and splitting of heartwood.

Fig 46 Large vacuum freeze-dryer.

6.2.2 Water replacement with PEG or sugars

In highly degraded wood, water provides the main structural support for the wood cells and cannot be dried without replacing the water with another chemical that will prevent the cells shrinking and the timbers from warping out of shape.

Various grades of the water-soluble polymer polyethylene glycol (PEG) have been used, either by immersing the individual timbers in solutions of this compound, as in the case of the Coppergate buildings in York (Spriggs 1981); or by spraying the same solutions over boat hulls, such as with the *Mary Rose* (Jones 2003) or with the the Hasholme log-boat (Foxon 1996). It takes many years to effectively replace enough of the water with the wax before the drying phase can begin, and in the case of spraying large boats decades are a more realistic timescale.

In some countries PEG is not easily available and sugar has been used instead to consolidate the wood structure. Large quantities of sucrose solution can sometimes be obtained from sugar producers and the wood immersed in this liquid. Once impregnated with the sugar, the timber is left to air-dry naturally or under controlled conditions. This method was used to conserve the Poole log-boat (Hutchings and Spriggs 2009). The use of sucrose should normally be seen as a method of last resort for timbers or wood structures that are too large for freeze-drying.

6.2.3 Freeze-drying

Vacuum freeze-drying is commonly used for small wooden objects, after first impregnating the waterlogged wood with polyethylene glycol or a sugar solution, and then removing the residual water as a frozen vapour to retain the integrity of the object (Cook and Grattan 1990). When scaling up the process to deal with large structures there are limited facilities for vacuum freeze-drying large items, so the structures have to be dismantled or cut into sections small enough to fit in a freeze-drying chamber and then be reassembled after drying, as in the case of the Dover Boat (Clark 2004). Alternatively the object can be moved to a place where the climatic conditions support exterior freeze-drying, as in Canada (Grattan and McCawley 1978); or a chamber can be built around the structure and dry, cold air passed over it to freeze-dry it at atmospheric pressures, as was used on *La Bourse* in Marseille (Amoigen and Larrat 1984).

6.3 Storage and display

Waterlogged wood, once conserved by any of the above methods is much easier to handle, store and display than it is in its wet form, but it still needs to be kept in controlled conditions so that it is not exposed to extremes of temperature or fluctuations in humidity.

For long-term storage it is recommended that individual pieces are packaged in individual containers with absorbent materials that buffer any external fluctuations in humidity, to keep the wood in an environment of 45–60% RH, and at temperatures of *c* 10–25°C. Do not seal it in polythene without some breathable material between the conserved wood and the plastic.

The conditions in which conserved wood is displayed must have tight controls of temperature, humidity and light levels, usually cited as 18°C ± 2°C, 55% ± 2%RH and light levels below 200lux. As these are conditions very difficult and costly to achieve and maintain in an open gallery, it is normal to exhibit the wooden structures in environmentally controlled cases within an air-conditioned gallery space.

7 Final report and archiving

General guidelines on the production of archive and publication reports are already available (Brown 2007, English Heritage 2008c). The archive report must include details of the wood sampling policy that was employed on the site and of the level of assessment and recording that was

Fig 47 Conserved Bronze Age timbers from 'Seahenge' on display in environmentally controlled display cases at the Lynn Museum (© Norfolk Museums and Archaeology).

carried out on site rather than during post-excavation analysis. If any wood was not recorded adequately, the reasons for this should be clearly explained.

For all analytical studies the methodology employed should be made clear and should wherever possible be intelligible to the layman as well as to the specialist. The archive report should include details of the condition assessment and conservation methods that are to be employed. Once the results of the conservation process are apparent a conservation report should be added to the archive. Studies of wood degradation made before conservation should also be included in the archive.

It is recommended that the publication report should include details of the sampling policy and of the chosen conservation process, and there should be full incorporation of the specialist reports. Detailed advice on the composition of dendrochronological reports is available in English Heritage (1998) and in English Heritage forthcoming. Where dendrochronological results are used in publication reports it must be made clear that the method dates the rings in the timber, and that the date spans produced for these rings should not be confused with felling dates or with the lifespans of the structures in which they were used.

The final reports sent to the appropriate Historic Environment Record should include all the wood related specialist reports. It should also be made clear where the paper archive and any conserved wood are deposited.

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Where to get advice

Advice on the excavation, analysis, conservation and preservation in situ of waterlogged archaeological remains is available from the English Heritage staff listed below. The Regional Science Advisors may also be able to provide contact details for waterlogged wood specialists.

1 English Heritage Regional Science Advisors, listed below with their regional offices:

North West
(Cheshire, Manchester, former Merseyside, Lancashire and Cumbria)
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Yorkshire and Humber
(Yorkshire and former Humberside)
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West Midlands
(Herefordshire, Worcestershire, Shropshire, Staffordshire, former west Midlands and Warwickshire)
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East Midlands
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East of England
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East of England and London
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South West
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Up to date information is available from the following websites:
1. HELM: www.helm.org.uk/Managing and Protecting/Delivering advice/Regional science advisors
2. English Heritage: www.english-heritage.org.uk/Research and Conservation/Archaeology and Buildings/Scientific techniques/RSA home

2 English Heritage, Archaeological Science teams:

Archaeological Conservation and Technology
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Environmental Science
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Scientific Dating
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3 The Conservation Register of the Institute of Conservation.
This is a register of privately practising conservators who are accredited by the Institute and are required to work to professional standards set out by the Institute. The register is free to use and it is possible to search for a conservator by location and specialism:
www.conservationregister.org.uk
info@conservationregister.org.uk

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