1.0 TREE-RING SERVICES (TRS) - METHOD STATEMENTS

Methods employed by TRS in general are those described in English Heritage guidelines (English Heritage 1998). Tree-ring analysis and graphics are achieved via a dendrochronological programme suite developed by Ian Tyers of Sheffield University (Tyers 1999). Alcock's (1996) timber-framed building nomenclature is generally adopted to facilitate regional comparisons.

TRS ensures that all work is carried out in accordance with its Health and Safety Policies, to standards defined in The Health and Safety at Work etc. Act 1974. At the outset of the fieldwork Risk Assessments are undertaken to ensure that potential hazards have been identified and mitigation or control measures will be implemented. TRS operators are insured. Further details of the methods generally employed by TRS are described in individual reports and below.

Dendrochronological Assessment of Buildings

Where possible, buildings are inspected with a building historian to help clarify possible different phases of construction and to identify reused and later inserted timbers. Solid oak timbers with more than 50 rings, traces of sapwood or bark, and good accessibility are the main criteria for a positive assessment. Where less that 10 timbers per phase of interest pass these four criteria, a degree of professional judgment needs to be applied to identify whether sampling is likely to be worthwhile. For example a single sample of 120 rings may be datable whereas one with 50 rings might not. Where very few suitable samples can be identified, the location and period of a building are additional factors in an assessment. An area with a high density of local reference chronologies typically increases the chances of successful dating. In some instances the need for dating evidence to guide the decision making process will lead to 'Spot dating', and dendrochronological samples may be taken for spot dates. At the end of the assessment if the conclusion is that the timbers, as far as can be judged, do not have sufficient rings in them for dendrochronology sampling, the client is advised against further work in order to save unwarranted expense.

Sampling and Preparation

Whenever possible, timbers with more than 50 annual growth rings are selected for sampling. This is necessary to help provide a pattern of rings of sufficient length to be unique to the period of time when the parent tree was growing. Timbers are sampled using purpose-made 12mm diameter corers attached to an electric drill. Sampling is located as discreetly as possible in what appear to be original timbers and is orientated in the most suitable direction to maximize the numbers of rings for subsequent analysis. Extracted core samples are immediately taped and glued onto wooden laths on site and then labelled, ready for subsequent analysis.

Tree-ring series are revealed through sanding with progressively finer grits to a 600 abrasive grit finish to produce results suitable for measuring. When required, for example where bands of narrow rings occur, further preparation is performed manually. Where requested, extraction holes are "made good", employing pine dowelling, wood-glue, sawdust and wood stains to restore the timbers to their original appearance.

Measuring and Cross-matching

Tree-ring series are measured under a ×20 stereo microscope to an accuracy of 0.01mm using a microcomputer-based travelling stage. All samples are measured from the

centremost ring to the outermost. Any samples considered unsuitable for dating purposes are then rejected. These include samples with disturbed ring series which cannot be measured due to knots or bands of extremely narrow rings, and those samples with fewer than 40 rings.

Samples of fewer than 50 rings are sometimes rejected from dendrochronological analysis because their ring patterns may not be unique. Although this is certainly true of all ring series of fewer than 30 rings, which should not be used in dating, samples with 30 to 50 rings may be dated in some circumstances (English Heritage 1998). It has been felt wise to maximize the recorded amount of data, and so series of 30–50 rings are included in analysis and considered for dating, usually when they match well with a number of other series. Samples are measured twice and the two sets of measurements cross-matched and plotted visually as a check. Where series match satisfactorily they are averaged and the resulting series are used in subsequent analysis. Series containing fewer than 50 rings are suffixed '-S', and series from managed trees '-M' to help indicate that additional caution must be exercised in dating.

Cross-correlation algorithms are then employed to search for the positions where tree-ring series correlate and therefore possibly match. All statistical correlations are reported as *t*-values derived from the original CROS73 algorithm (Baillie and Pilcher 1973). A value of 3.5 or over is usually indicative of a good match as it represents the value of *t* which should occur by chance only once in every 1000 mismatches (Baillie 1982), and the higher the *t*-value the closer to congruency in the cross-matching. However, due to the remaining small risk of high *t*-values being produced by chance, all indicated correlations are further checked to ensure that corroborative high results are obtained at the same relative position against a range of independent tree-ring series. Visual comparisons of series are also employed to support or reject possible cross-matches and serve as a means of identifying measuring errors.

Timber Groups

A further element of the tree-ring analysis of buildings and archaeological assemblages is the grouping of timbers within the sampled material. Inspection of *in situ* timbers may indicate that samples derive from a common timber, while common arrangements of anatomical features (knots & branching) may also indicate that samples are derived from a single tree.

Tree-ring analysis is used to support suggestions of same-tree groups between samples based on a combination of information. Timbers derived from the same tree are generally expected to have *t*-values over 10, although lower *t*-values may be produced when different radii measured from the same tree are compared. Tree-ring series producing *t*-values of 10 or above are examined to identify same-tree groups. Good comparisons of visual matching, growth rates, short and longer-term growth patterns, are combined with pith information, sapwood boundaries, bark and anatomical anomalies, to help decide whether timbers are likely to come from the same tree. Where timbers are assessed as deriving from the same tree, to avoid bias the series are averaged to produce a single tree-ring series before inclusion in the final site chronology, but inevitably some same-tree samples go undetected by dendrochronology.

Chronology Building and Cross-dating

The process of cross-matching compares all tree-ring series against one another and those found to cross-match satisfactorily together are combined to create an average series. The site mean(s) and individual ring series which remain unmatched with the site mean are then tested against a range of established reference series (reference chronologies). Significant *t*-values replicated against a range of series at the same position with satisfactory visual matching are similarly used to establish cross-matches with reference chronologies. Where cross-matching is established against dated reference chronologies, calendar dates can be assigned to the site series. The dates of the first and last rings of dated series are produced as date spans. These dates should not be confused with felling dates.

Felling Dates

Series dated by the cross-matching process provide a calendar year date for the final tree-ring present in the measured timber sample. The interpretation of these dates then relies upon the nature of the final rings in the series. Where bark survives intact on a sample a felling date is given as the date of the last ring measured on the tree-ring series. Based on the completeness of the final ring it is sometimes even possible to distinguish between spring, summer or winter fellings, corresponding to approximately March to May, June to September and October to February, respectively. Where timbers were felled in either spring or summer and the final ring is incomplete and therefore not measured, allowance has to be made for the one-year discrepancy between the end of a measured series and the actual year of felling.

Sapwood Estimates

Where bark is missing from oak samples, as long as either sapwood or the heartwood/sapwood boundary is identified, an estimated felling-date range can be calculated using the maximum and minimum number of sapwood rings that were likely to have been present. Sapwood estimates have varied over time with different data sets, geographical location and researchers. A general trend identified is that the number of sapwood rings in oak decreases from north to south and from west to east across Europe.

Sapwood estimates, appropriate to the species, area and period are used. In the case of English Medieval and modern oak 9-41, 11-41 or 12-45 rings (95% confidence limits) are used to determine estimated felling date ranges (Miles 1997). For earlier English oak material a sapwood estimate of a minimum of 10 and maximum of 46 annual rings is used (Tyers 1998).

Felling-date ranges are calculated by adding the sapwood estimate of minimum and maximum missing rings to the date of the heartwood/sapwood boundary. Felling-date ranges are refined by the presence of surviving sapwood where appropriate. Where samples ending in heartwood are dated, "felled after dates" are calculated by adding the minimum expected number of missing sapwood rings to the samples' final ring dates. These dates represent the earliest probable felling dates. However, the actual felling date of a tree may be decades later due to an unknown number of missing heartwood rings.

Felling Groups

It is common to find that timbers used in the construction or repair of smaller buildings, or identifiable parts of larger buildings, date into groups whose felling dates occur within a narrow range of years. These groups are called associated fellings. Where they are identified the average heartwood/sapwood boundary of the component timbers is used to calculate an overall estimated period of felling. Close location association and a short (21 years at most) range of heartwood-sapwood boundary dates are normally used to define these groups. The estimates do not assume that trees within a group were felled at the same time. However, evidence published by the Nottingham University Tree-Ring Dating Laboratory indicates that the range estimate encompasses the possible different individual felling dates (English Heritage 2001). Where bark is present within a group of timbers and other evidence does not dispute the date, it is assumed that all the trees within a felling group were felled in the same year.

Date of Construction

It is vitally important to understand that dendrochronological analysis provides dates for when trees were felled and not necessarily when their timbers were used. Green or freshly felled wood is, however, far easier to work, and it is standard practice to assume that medieval timbers were felled as required and used green (Rackham 1990; Miles 1997). Nevertheless, the use of previously felled timbers in vernacular construction was not uncommon, with short-term stockpiling of usually not more than 1 to 2 years (Miles 1997), and the use of leftovers or re-used timbers may certainly give rise to differences between felling dates and the date of construction where samples are analysed in isolation. A number of samples having a close range of felling dates are required from different elements of a building either to strongly indicate a single date of construction or to identify separate phases of construction.

Archiving procedures

After reporting, all core samples are labelled with the name and address of the site and the year of analysis before storage at our Forest of Dean laboratory & field centre. In the case of sections, the laboratory code used in the report is labelled on each individual sample. The sections are grouped together into a suitable storage container, with the name and address of the site, and the year of analysis labelled on the container. Sections are held for 1 year before either return or disposal

2.0 TREE-RING SERVICES (TRS) – INSURANCE INFORMATION

A. K. Moir trading as Tree-Ring Services is insured through Talisman Speciality. The policy number is ACS-BDWBT00075. The limit of the indemnity for public liability is £10,000,000.

3.0 TREE-RING SERVICES (TRS): TECHNICAL/PROFESSIONAL ABILITY INFORMATION

Profile of Andy Moir (Sole trader & Director of TRS)

Between 1990 - 1997 while employed as a Geography Technician at London Guildhall University, I undertook my training in Dendrochronology at the Dendrochronology Laboratory in the Geography Department, under the guidance of Dr Martin Bridge Alongside working for London Guildhall University, in 1996 I completed a degree in

Geography. My degree involved a research project into the dendrochronology of yew at Hampton Court Palace, which was subsequently published (Moir 1999). Due to the closure in of the Dendrochronology department at London Guildhall University, I set up Tree-Ring Services in 2001 , through which to date I have successfully undertaken the dendrochronological analysis of more than 650 standing buildings in England, (As published in Vernacular Architecture and listed on the Vernacular Architecture Group Dendrochronology Database).

In 2008 I completed a Ph.D. on: The dendroclimatology of Modern and Neolithic Scots pine (*Pinus sylvestris* L.) in the peatlands of northern Scotland, at Brunel University. Since completing my doctorate I have been a post-doctoral research fellow in the Institute of the Environment at Brunel University and I have had over 20 studies on dendrochronology published in peer reviewed journals.

Tools /Equipment available
For sampling, TRS uses 24v cordless drills and battery lights. Our 12mm corers for electric drills have a maximum length of 60 centimetres. Our range of increment tree cores (sometimes suitable for sampling waterlogged timbers) extends up to 120 centimetres in length.

Technical Facilities
The main TRS dendrochronology laboratory is located in the Forest of Dean, and fully equipped for most sampling, measuring and computer requirements. Computer files are back-up and stored both on and off site. The Institute for the Environment at Brunel University has totally separate dendrochronological facilities, which are also available.

Quality
A major tenet of TRS quality co-ordination and assurance is to ensure continuous quality improvement through planning, operational tools and feedback. Application of new software /technologies, risk management, on-going training and data verification methods are a few of the important measures TRS use to ensure continuous quality improvement. All ring series are double measured and visually compared with each other. Draft reports are checked and edited by a professional proof reader. Furthermore, TRS enables independent verification of all its analysis, by routinely providing both individual series and mean series ring-data in its publicly available reports.

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