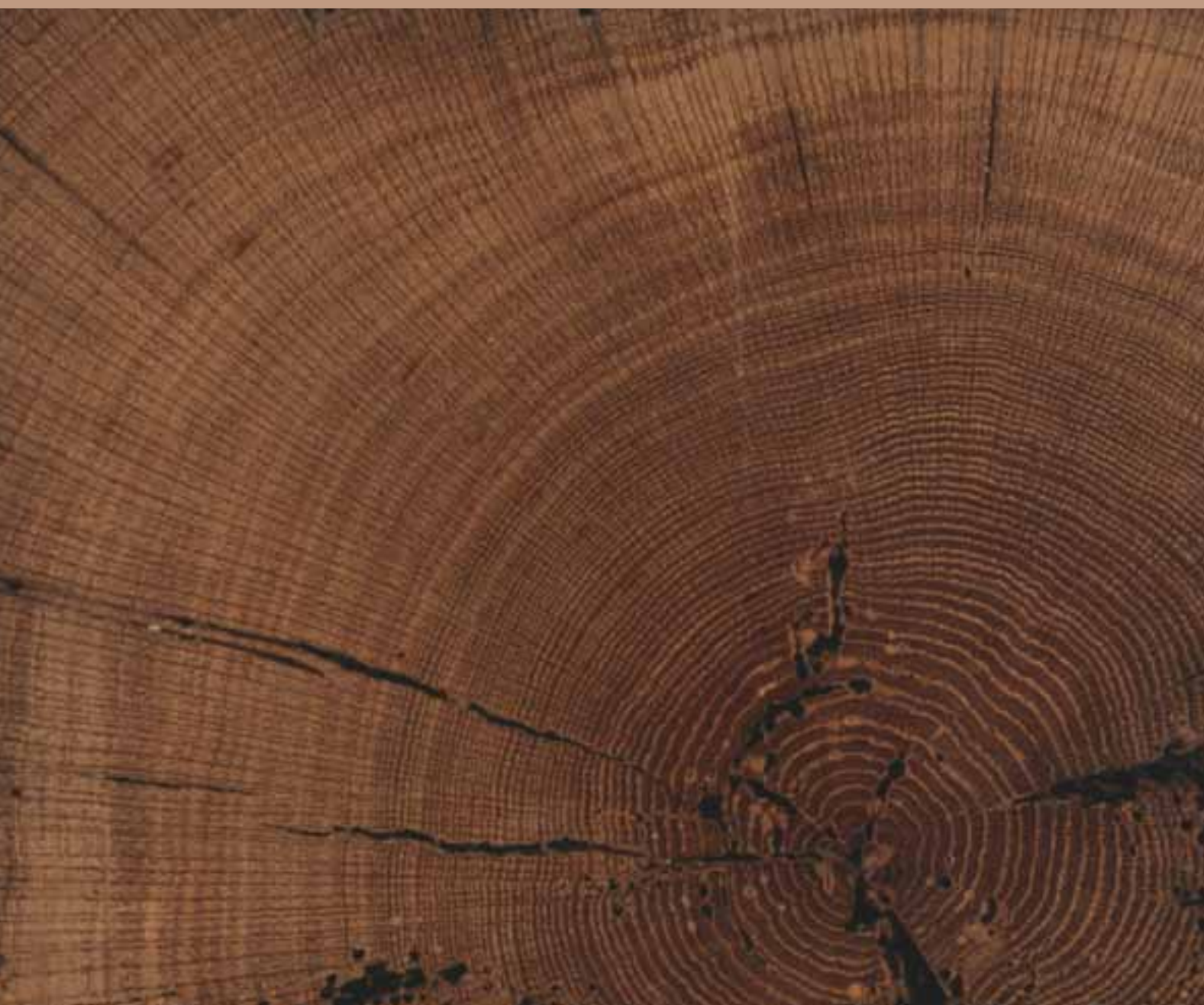


HOARSTONE FARM,  
BEWDLEY, WORCESTERSHIRE  
DENDROCHRONOLOGICAL ANALYSIS  
OF OAK TIMBERS

SCIENTIFIC DATING REPORT

Ian Tyers



**HOARSTONE FARM  
BEWDLEY  
WORCESTERSHIRE**

**DENDROCHRONOLOGICAL ANALYSIS OF OAK TIMBERS**

Ian Tyers

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## **SUMMARY**

A tree-ring dating programme was commissioned on timbers from Hoarstone Farm. The results identified that timbers in the hall, both cross-wings and the porch were datable by tree-ring dating techniques, with these areas using timbers felled during the early seventeenth century. This dating programme was commissioned on this Building At Risk during renovation works. This report archives the dendrochronological results.

## **CONTRIBUTORS**

Ian Tyers

## **ACKNOWLEDGEMENTS**

The sampling and analysis of timbers at Hoarstone Farm was funded by English Heritage (EH). Practical help and valuable discussions were provided by Nicholas Molyneux, Historic Buildings Inspector West Midlands Region (EH), and Stephen Price who also kindly provided descriptive text and the plan used here. Becky and Nick Norton kindly facilitated access, and provided useful discussion and coffee.

## **ARCHIVE LOCATION**

Historic Environment Record  
Worcestershire Historic Environment and Archaeology Service  
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## **DATE OF INVESTIGATION**

2008

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# CONTENTS

Introduction .....	1
Methodology .....	1
Results .....	3
Discussion.....	4
Central range .....	4
Eastern cross-wing .....	5
Western cross-wing .....	6
Porch.....	6
Stone block.....	7
References.....	8
Figures .....	9
Tables .....	13
Appendix I .....	16

## INTRODUCTION

This document is a technical archive report on the tree-ring analysis of oak timbers from Hoarstone Farm, Worcestershire. It is beyond the dendrochronological brief to describe the building in detail or to undertake the production of detailed drawings. Elements of this report may be combined with detailed descriptions, drawings, and other technical reports at some point in the future to form either a comprehensive publication or an archive deposition on the building.

Hoarstone Farm stands in rolling countryside *c* 3.5km west of Kidderminster, and *c* 2km north of Bewdley (NGR SO 7938 7680) within the county of Worcestershire (Fig 1). It is an H-shaped Grade II\* timber-framed house, facing south, refronted in brick. There are later wings on the north side, one of which has a stone-built ground floor, and a timber-framed upper storey and roof. The house contains a pair of fine carved overmantels, allegedly from nearby Tickenhill Palace.

## METHODOLOGY

Tree-ring dating employs the patterns of tree-growth to determine the calendar dates for the period during which the sampled trees were alive. The amount of wood laid down in any one year by most trees is determined by the climate and other environmental factors. Trees over relatively wide geographical areas can exhibit similar patterns of growth, and this enables dendrochronologists to assign dates to some samples by matching the growth pattern with other ring-sequences that have already been linked together to form reference chronologies.

The building was visited in March 2008. An assessment of the dendrochronological potential of timbers in several areas of the structure had been requested by Nicholas Molyneux. This assessment aimed to identify whether oak timbers with sufficient numbers of rings for analysis existed in any part of these structures. This assessment concluded that the timbers in the two cross-wings and central range of the H-shaped building, along with the very small porch all contained suitable material whilst the stone blocks structural timbers were of fairly marginal potential. The overmantels were considered unsuitable for sampling and analysis.

The sampling took place during May 2008. The selected timbers were sampled using a 15mm diameter corer attached to an electric drill. The cores were taken as closely as possible along the radius of the timbers so that the maximum number of rings could be obtained for subsequent analysis. The ring sequences in the cores were revealed by sanding.

This preparation revealed the width of each successive annual tree ring. Each prepared sample could then be accurately assessed for the number of rings it contained, and at this stage it was also possible to determine whether the sequence of ring widths within it could be reliably resolved. Dendrochronological samples need to be free of aberrant

anatomical features, such as those caused by physical damage to the tree, which may prevent or significantly reduce the chances of successful dating.

Standard dendrochronological analysis methods (see eg English Heritage 1998) were applied to each suitable sample. The complete sequence of the annual growth rings in the suitable samples were measured to an accuracy of 0.01mm using a micro-computer based travelling stage. The sequence of ring widths were then plotted onto semi-log graph paper to enable visual comparisons to be made between sequences. In addition, cross-correlation algorithms (eg Baillie and Pilcher 1973) were employed to search for positions where the ring sequences were highly correlated (Tyers 2004). Highly correlated positions were checked using the graphs and, if any of these were satisfactory, new composite sequences were constructed from the synchronised sequences. Any *t*-values reported below were derived from the original CROS algorithm (Baillie and Pilcher 1973). A *t*-value of 3.5 or over is usually indicative of a good match, although this is with the proviso that high *t*-values at the same relative or absolute position need to have been obtained from a range of independent sequences, and that these positions were supported by satisfactory visual matching.

Not every tree can be correlated by the statistical tools or the visual examination of the graphs. There are thought to be a number of reasons for this: genetic variations; site-specific issues (for example, a tree growing in a stream bed will be less responsive to rainfall); or some traumatic experience in the tree's lifetime, such as injury by pollarding, defoliation events by caterpillars, or similar. These could each produce a sequence dominated by a non-climatic signal. Experimental work with modern trees shows that 5–20% of all oak trees cannot be reliably cross-matched, even when enough rings are obtained.

Converting the date obtained for a tree-ring sequence into a useful date requires a record of the nature of the outermost rings of the sample. If bark or bark-edge survives, a felling date precise to the year or season can be obtained. If no sapwood survives, the date obtained from the sample gives a *terminus post quem* for its use. If some sapwood survives, an estimate for the number of missing rings can be applied to the end-date of the heartwood. This estimate is quite broad and varies by region. This report uses a minimum of 10 rings and a maximum of 46 rings as a sapwood estimate (see eg English Heritage 1998, 10–11).

Where bark-edge or bark survives, the season of felling can be determined by examining the completeness or otherwise of the terminal ring lying directly under the bark. Complete material can be divided into three major categories:

- 'early spring', where only the initial cells of the new growth have begun – this is equivalent to a period in March/April, when the oaks begin leaf-bud formation;

- 'later spring/summer' where the early wood is evidently complete but the late wood is evidently incomplete, which is equivalent to May-through-September of a normal year, and
- 'winter' where the latewood is evidently complete and this is roughly equivalent to September-to-March (of the following year) since the tree is dormant throughout this period and there is no additional growth put on the trunk.

These categories can overlap as, for example, not all oaks simultaneously initiate leaf-bud formation. It should also be noted that slow growing or compressed material cannot always be safely categorised.

Timber technology studies demonstrate that many of the tool marks recorded on ancient timbers can only have been done on green timber. There is little evidence for long-term storage of timber or of widespread use of seasoned, rather than green, timber in the medieval period (see eg English Heritage 1998, 11–12).

Reused timbers can only provide tree-ring dates for the original usage date, not their reuse. Identifying reused timbers requires careful timber recording which notes the presence of features that are not functional in the structure. It is always possible that some timbers exhibit no evidence of earlier usage, and are thus 'hidden reused' timbers. The dendrochronological impact of this problem is particularly acute where only single timbers have been dated from a structure.

The analysis may highlight potential same-tree identifications if two or more tree-ring sequences are obtained that are exceptionally highly correlated. Such pairs, or sometimes more, are then used as a same-tree group and each can be given the interpreted date of the most complete of the samples. They are most useful where several timbers date but only one has any sapwood or where same-tree identifications yield linkages between different areas.

## RESULTS

In May 2008, 29 timbers of five separate areas of the building were cored; these cores were labelled 1–29 inclusive. Five timbers were sampled in the eastern cross-wing, eleven from the central range, although this included several purlins that may have been part of the modifications necessary to integrate the stone block roof, six from the western cross-wing, four from the stone block, and three from the porch (Figures 2–4). Each sample was assessed for the wood type, the number of rings it contained, and whether the sequence of ring widths could be reliably resolved. This assessment confirmed that all the sampled timbers were oak (*Quercus* spp.) and that 25 were suitable for dendrochronological analysis. The four exceptions were samples 6 and 10, which are purlins in the central area, sample 26 from the stone block, and sample 29 from the porch, all of which had either too few rings for analysis or had fragmented badly during sampling. There was very good

survival of sapwood in all of the targeted areas, and bark-edge survival was extremely good. The details of these samples are provided in Table 1.

The samples were prepared for analysis, measured and the resultant ring series were compared with each other. The nine suitable samples from the central range roof were found to cross-match each other well (Table 2), all five of the eastern cross-wing roof samples cross-matched (Table 3), the six samples from the western cross-wing cross-matched (Table 4), and the two suitable samples from the porch cross-matched (Table 5). Each cross-matched group was then combined into a single composite data set. These were then compared with each other, the composite series from all four areas were found to form an internally consistent group (Table 6). These four groups were then combined into a final site composite which was then compared with medieval and later tree-ring data from throughout England and Wales. The composite sequence was found to cross-match very strongly against data from sites in the West Midlands and South-West regions (Table 7). This cross-matching provided consistent calendar dates for the sequence. A summary of the results for the component samples of this chronology are provided in Table 1 and Figure 5.

The individual series from the stone block were not found to form a consistent group, and the individual series were compared with English, European, and other reference data, as well as the other undated sequences. These series have failed to provide any consistent dating evidence.

The measurement data for all the measured samples are listed in Appendix 1.

## DISCUSSION

The dated samples are derived from four different parts of the building, each of a slightly different date. These parts are discussed in their date order below. The stone block is assumed to be of later date and the observations about this material are discussed at the end. All the datable material matches strongly with other local reference data and it is likely that these timbers were derived from the general vicinity of Hoarstone.

### Central range

The central range roof comprises two trusses (T4 and T5, Figures 2–4). The eastern truss, T5, has a doorway through it. These simple A-trusses have diminished principal rafters, and interrupted collars to allow for access. T4 has clasped purlins, and there are straight wind-braces. Both T4 and T5 have their upper face to the east. There is no evidence the central range originally had end-trusses.

The eleven samples from this area comprised two of the four principal rafters, three posts, three collars, and three purlins. Two of the purlins were unsuitable for analysis but the other nine samples were found to cross-match, the composite sequence was found



to date, and thus there are tree-ring dates for all nine of these structural elements. The 262-year central range composite sequence was found to strongly match composite sequences obtained from the surrounding regions at AD 1300 to AD 1611 inclusive. This material comprised slow-growing and long-lived oaks.

The tree-ring analysis dates the rings present in the cores. The correct interpretation of those dates relies upon the characteristics of the final rings in them. Bark-edge survived on three of these timbers, significant amounts of sapwood on another two, and a small amount on a third, and the heartwood/sapwood boundaries were present on the remaining three. Making allowances for minimum and maximum likely amounts of missing sapwood provides individual felling dates, or felling date ranges, for each of the datable timbers. Figure 5 and Table 1 include the felling date or interpreted felling date ranges for each of the datable samples.

The interpretation of this material is straightforward. The three samples complete to bark edge each retain a complete ring for AD 1611. These three timbers were therefore felled in the winter of AD 1611 or early spring of AD 1612. The calculated felling date ranges for the remaining six samples indicates this material was either precisely or broadly contemporaneous. The three precisely dated timbers comprise a door post from the east truss and a post and a collar from the west truss. There is no suggestion any of this material is either reused or secondary.

### **Eastern cross-wing**

This roof comprises three trusses, two forming the end dormers. These simple A-trusses are all but identical to those of the central range, with diminished principal rafters, although here the end trusses (T6 and T8, Fig 2) use tenoned purlins, and the intermediate truss (T7) uses clasped purlins. The five samples were obtained from two principal rafters, a purlin, a brace, and a collar. All five were suitable for analysis and all five were cross-matched and dated. The 262-year eastern cross-wing composite sequence was found to strongly match to the material from the central range, as well as to other composite sequences obtained from the vicinity. There is no significant difference between this material and that found in the central range, with this material also comprising slow-growing and long-lived oaks. Remarkably, both groups yield a composite chronology of 262 annual rings, with both dated AD 1350 to AD 1611 inclusive.

Bark-edge survived on all five of these timbers. No allowance needs to be made for missing sapwood; instead, individual felling dates can be assigned to each of the datable timbers. Figure 5 and Table 1 include the felling date for each of these datable samples.

The interpretation of this material is straightforward. Three of the samples complete to bark edge retain a complete ring for AD 1611. These three timbers were therefore felled in the winter of AD 1611 or early spring of AD 1612. The other two exhibit the onset of growth for AD 1612, so these two (a purlin and a principal rafter) were felled in the early

spring of AD 1612. It seems highly likely that all of this material was felled over a limited number of days or weeks in the early spring of AD 1612. Given the structural integrity of this cross-wing and the central range, it is reasonable to conclude both areas were constructed during a single building campaign, with the framing of the central range built just before the framing for the eastern cross-wing.

### **Western cross-wing**

This cross-wing is slightly larger than the eastern range, but it exhibits the same constructional details. For example, the central A-truss (T2) again uses clasped purlins, contrasting with tenoned purlins in the end trusses (T1 and T3, Fig 2). The six samples were obtained from two principal rafters (both those from T2), a purlin, a collar and a common rafter. All six were suitable for analysis and all six were cross-matched and dated. The 216-year western cross-wing composite sequence was found to strongly match other data from Hoarstone, as well as composite sequences obtained from the vicinity. There is no significant difference between this material and that found in the central and eastern ranges, with this material likewise comprising slow-growing and long-lived oaks. The western cross-wing composite chronology was dated AD 1398 to AD 1613 inclusive.

Bark-edge survived on one of these timbers, sapwood on another two, and the heartwood/sapwood boundaries were present on the remaining three. Making allowances for minimum and maximum likely amounts of missing sapwood provides individual felling dates, or felling date ranges, for each of the datable timbers. Figure 5 and Table 1 include the felling date or interpreted felling date ranges for each of the datable samples.

The interpretation of this material is straightforward. The sample complete to bark edge retains a complete ring for AD 1613, and the onset of growth for AD 1614. This timber was therefore felled in the early spring of AD 1614. The calculated felling date ranges for the remaining four samples indicate that this material was either precisely or broadly contemporaneous. Given the slight differences in size of this range and this slightly later felling date, it is reasonable to conclude this area was completed a short time after the central range and eastern cross-wing were completed. It is possible that an earlier house was on this part of the plot (Nicholas Molyneux pers comm), and the other part of the building had to be completed and occupied before it could be demolished.

### **Porch**

The porch stands at the corner of the central range and eastern cross-wing (Fig 2). It contains relatively few accessible timbers. The two corner posts at the very top, tiebeam/wall plate level, were found to exhibit evidence for surviving sapwood. Both these and an exposed length of wall plate were cored, the latter unfortunately not producing a usable core. Both the corner posts were cross-matched and dated. The 167-

year composite sequence was found to strongly match the other sequences from Hoarstone, as well as sequences obtained from the vicinity. Although the composite is shorter, there are no significant differences in the character of this material and that found in the central range, or the eastern and western cross-wings, with this material again comprising slow-growing and long-lived oaks. This composite chronology was dated AD 1451 to AD 1617 inclusive.

No bark-edge survived on these timbers, but significant amounts of sapwood survived on both. Making allowances for minimum and maximum likely amounts of missing sapwood provides felling date ranges for both of the datable timbers. Figure 5 and Table 1 include the interpreted felling date ranges for both samples.

The interpretation of this material is relatively straightforward. One of the samples retains an outermost sapwood ring for AD 1617, and the other for AD 1611. Combining the calculated felling date ranges for both dated samples suggests this material was felled after AD 1617 and before *c* AD 1628. The mathematical combination of estimated sapwood distributions is statistically complex, and to achieve a tighter interpretation would require reliable sapwood data for the area, period, and the specific character of these oaks. Such data are not presently available. It is clear, however, that this porch utilises timbers felled shortly after those used in the ranges of the H-shaped farmhouse. It is reasonable to conclude, therefore, that the porch was a later addition to the original structure. It was evidently built only a short time after the rest of the house was completed. This addition may relate to a need to improve access routes, only identified after the house was occupied, or perhaps after earlier structures were demolished (Nicholas Molyneux pers comm).

## Stone block

The stone block is timber-framed above first-floor level. Structural details from T10 suggest it is secondary to the rest of the structure (Nicholas Molyneux pers comm). The visible faces of the oak timber used in this range suggested it was completely different in character. The grain was much more distorted, the growth rates appeared higher, and the trees appear much younger. Sampling the best of this material yielded four cores, one of which contained insufficient rings for analysis. The remaining three each yielded a short sequence, although all three were complete to bark-edge. However, there is no identifiable cross-matching between these series. Each exhibits wildly varying growth rates, and they exhibit no visual similarity. This suggests these timbers were obtained from differing sources, each undergoing different exploitation patterns. They were certainly obtained from a quite different type of woodland than the trees which produced the rest of the Hoarstone Farm timbers.

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## FIGURES



*Figure 1. Location of Hoarstone Farm (circled). © Crown Copyright. All rights reserved. English Heritage 100019088. 2007*

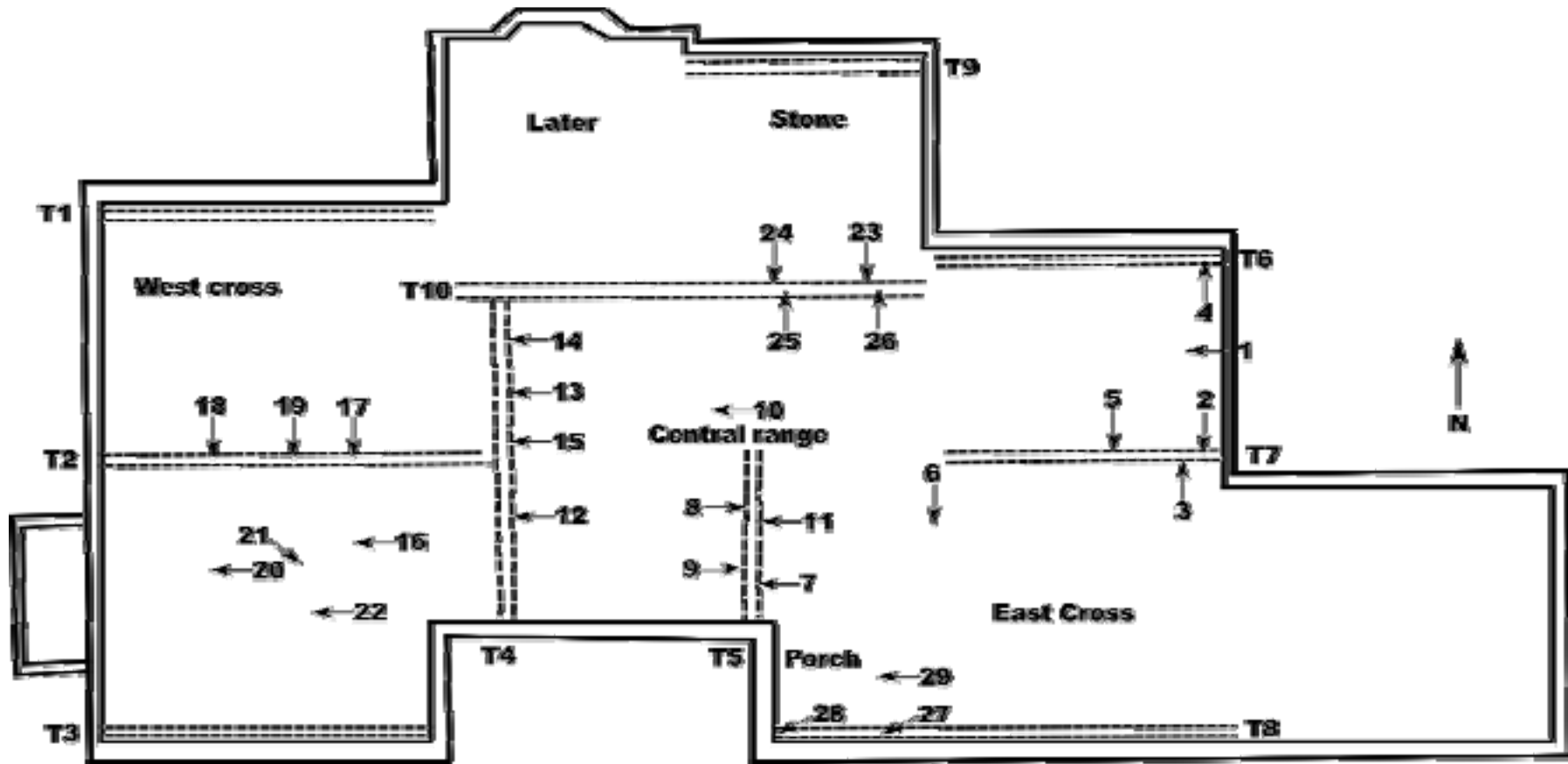
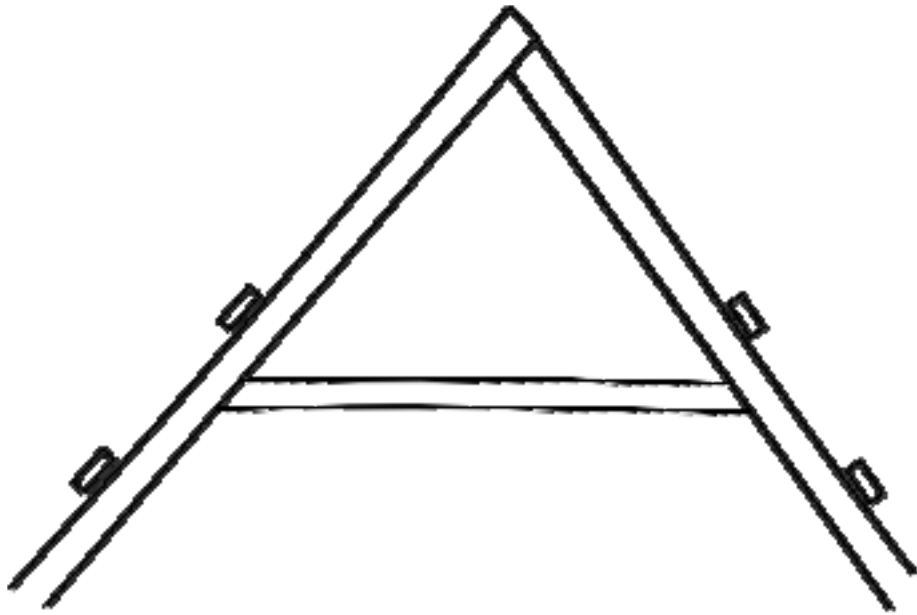
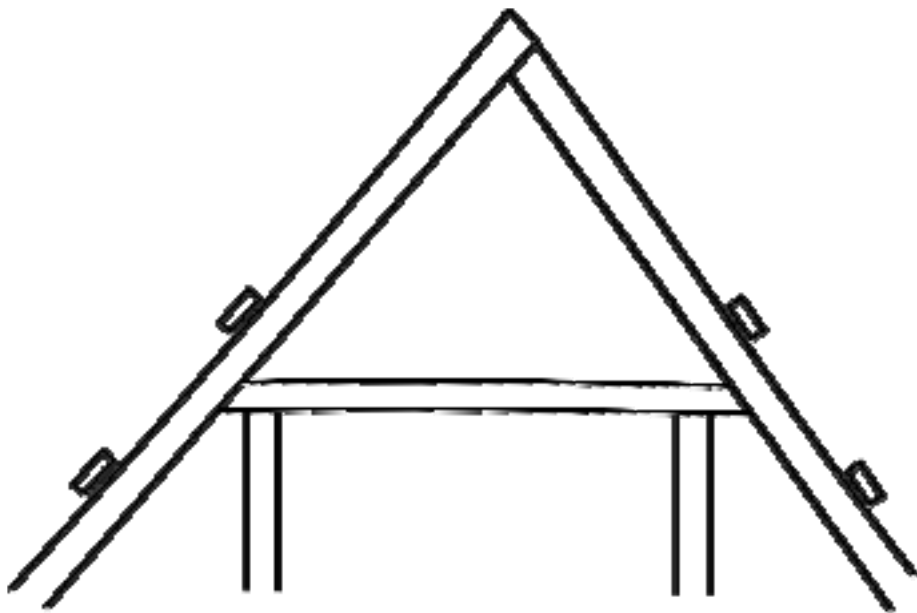


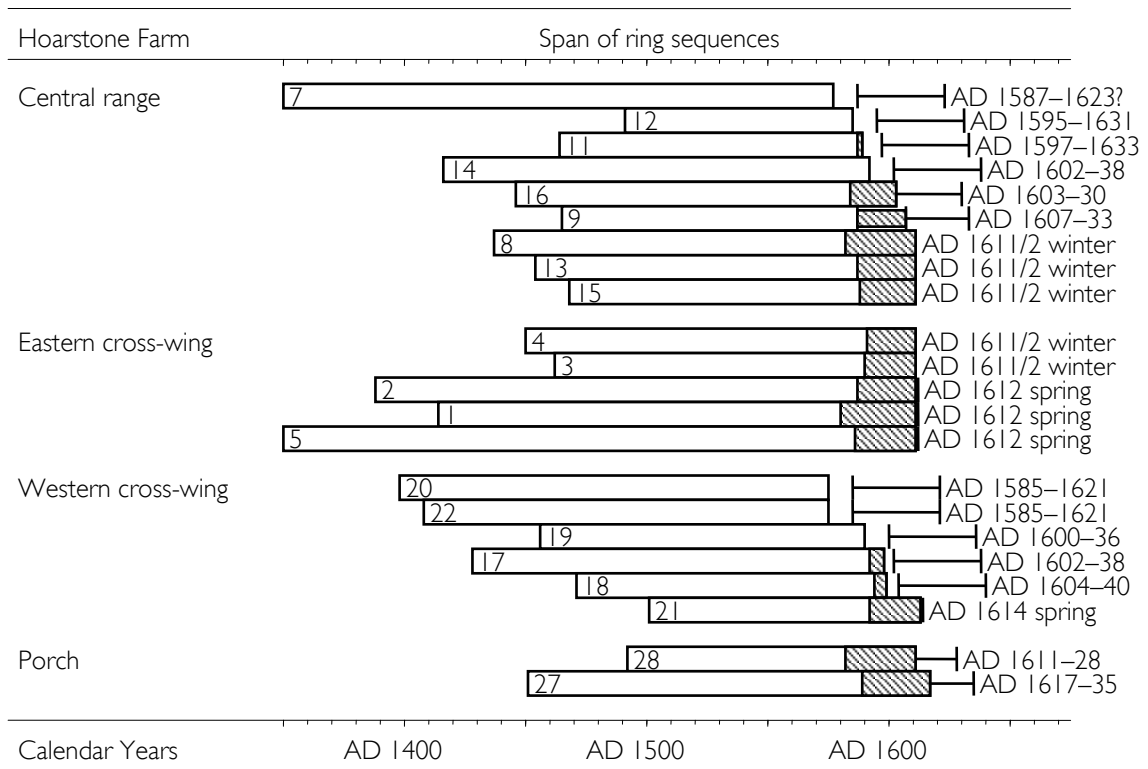
Figure 2. Plan of Hoarstone Farm showing the location of the areas discussed in this report, the truss numbering scheme followed, and the approximate location of the sampled timbers. Based on a plan supplied by Stephen Price



*Figure 3. Schematic section of main roof truss (figure supplied by English Heritage)*



*Figure 4. Schematic section of main roof truss with door (figure supplied by English Heritage)*



**Figure 5. Bar diagram showing the absolute dating positions of the 22 dated tree-ring sequences for samples from Hoarstone Farm. The interpreted felling dates are also shown for each sample.**

KEY White bars are oak heartwood, hatched bars are sapwood, the narrow bar represents unmeasured sapwood.



## TABLES

*Table 1. Details of the 29 samples from timbers from Hoarstone Farm*

Sample	Location	Rings	Sap	Date of measured sequence	Interpreted result
1	E T6 E purlin	198	31+B <sub>s</sub>	AD 1414–1611	AD 1612 spring
2	E T7 E principal	224	24+B <sub>s</sub>	AD 1388–1611	AD 1612 spring
3	E T7 E brace	150	21+B <sub>w</sub>	AD 1462–1611	AD 1611 winter
4	E T6 lower collar	162	20+B <sub>w</sub>	AD 1450–1611	AD 1611 winter
5	E T7 W principal	262	25+B <sub>s</sub>	AD 1350–1611	AD 1612 spring
6	E-C T5 S purlin	-	-	unmeasured	-
7	C T5 S principal	228	?H/S	AD 1350–1577	AD 1587–1623?
8	C T5 S door post	175	29+B <sub>w</sub>	AD 1437–1611	AD 1611 winter
9	C T5 upper collar	123	H/S+20	AD 1465–1587	AD 1607–33
10	C T5-T6 N purlin	-	-	unmeasured	-
11	C T5 S lower collar	126	2	AD 1464–1589	AD 1597–1633
12	C T4 S door post	95	H/S	AD 1491–1585	AD 1595–1631
13	C T4 N door post	158	24+B <sub>w</sub>	AD 1454–1611	AD 1611 winter
14	C T4 W principal	177	H/S	AD 1416–1592	AD 1602–38
15	C T4 upper collar	144	23+B <sub>w</sub>	AD 1468–1611	AD 1611 winter
16	C T4-W S purlin	158	19	AD 1446–1603	AD 1603–30
17	W T2 E principal	171	6	AD 1428–1598	AD 1602–38
18	W T2 W principal	129	5	AD 1471–1599	AD 1604–40
19	W T2 E upper collar	135	H/S	AD 1456–1590	AD 1600–36
20	W T2-T3 W purlin	178	H/S	AD 1398–1575	AD 1585–1621
21	W T2-T3 E rafter 3	113	21+B <sub>s</sub>	AD 1501–1613	AD 1614 spring
22	W T2-T3 E purlin	168	H/S	AD 1408–1575	AD 1585–1621
23	S T10 E door post	93	28+B <sub>w</sub>	undated	-
24	S T10 W principal	61	24+B <sub>s</sub>	undated	-
25	S T10 W tiebeam	85	35+B	undated	-
26	S T10 E principal	-	-	unmeasured	-
27	P SE post	167	28	AD 1451–1617	AD 1617–35
28	P SW post	120	29	AD 1492–1611	AD 1611–28
29	P E wall plate	-	-	unmeasured	-

KEY For locations see Figure 2. E; Eastern cross-wing roof, trusses T6–T8 from north. C; central range roof, trusses T4 and T5 from west. W; western cross-wing roof, trusses T1–T3 from north. S; the stone block roof, T9 and T10 from north. P; porch roof. N north, S south, E east, W west, H/S is heartwood/sapwood edge, B bark season indistinguishable, B<sub>w</sub> bark after complete ring, B<sub>s</sub> bark after incomplete additional annual ring, *italics* gives the estimated numbers of unmeasured rings.

*Table 2. The t-values (Baillie and Pilcher 1973) between 9 sampled timbers from the central range (samples 7–16) from Hoarstone Farm. – t-value less than 3.0*

	8	9	11	12	13	14	15	16
7	-	-	-	3.52	3.88	5.43	-	-
8		4.93	-	-	5.36	4.45	4.81	4.36
9			5.75	-	4.57	3.92	3.07	4.04
11				4.06	4.10	3.80	3.46	3.00
12					3.68	3.07	-	5.19
13						8.16	7.56	5.32
14							5.54	6.76
15								4.24

*Table 3. The t-values (Baillie and Pilcher 1973) between the 5 sampled timbers from the eastern cross-wing (samples 1–5) from Hoarstone Farm. – t-value less than 3.0*

	2	3	4	5
1	3.18	3.57	-	-
2		4.74	-	5.96
3			4.95	-
4				-

*Table 4. The t-values (Baillie and Pilcher 1973) between the 6 sampled timbers from the western cross-wing (samples 17–22) from Hoarstone Farm. – t-value less than 3.0*

	18	19	20	21	22
17	7.00	5.72	4.92	5.59	3.57
18		6.30	3.49	5.69	5.01
19			-	4.07	5.57
20				3.54	3.23
21					3.81

*Table 5. The t-value (Baillie and Pilcher 1973) between 2 sampled timbers from the porch (samples 27 and 28) from Hoarstone Farm*

	28
27	5.35

**Table 6. The *t*-values (Baillie and Pilcher 1973) between the four building area composite sequences from Hoarstone Farm**

	Central	West	Porch
East	11.21	11.30	7.03
Central		10.28	9.22
West			8.10

**Table 7. Showing example *t*-values (Baillie and Pilcher 1973) between the final composite sequence constructed from Hoarstone Farm and oak reference data.**

Reference chronology	Hoarstone AD 1350–1617
Gloucestershire, Gloucester 26 Westgate Street (Howard <i>et al</i> 1998)	14.29
Herefordshire, Tupsley Lower House Farm (Tyers 1997)	10.02
Worcestershire, Bewdley Bailiffs House (Fletcher <i>et al</i> 1980)	9.09
Worcestershire, Droitwich Upwich (Groves and Hillam 1997)	12.39
Worcestershire, Hartlebury Castle (Tyers 2008)	15.12
Worcestershire, Worcester The Guildhall (Howard <i>et al</i> 2006)	9.47
Worcestershire, Wribbenhall 3 Beales Corner (Tyers 2007)	11.12
Worcestershire, Wribbenhall 12 Westbourne St (Tyers 2007)	9.39

## APPENDIX I

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95	82	56	49	59	53	78	80	84	129
98	93	82	99	121	95	112	125	129	91
116	155	102	120	104	91	85	85	84	89
114	99	94	116	101	106	76	88	92	89
89	98	122	101	129	126	118	115	121	126
82	97	120	104	120	88	106	96	99	91
94	97	86	84	80	104	99	90	82	102
92	88	79	87	70	83	85	69	63	68
90	73	95	70	65	60	69	73	67	70
78	93	60	76	87	92	68	76	61	82
63	75	81	48	78	77	75	73	86	67
76	64	79	68	93	83	53	125	90	80
75	97	103	51	53	40	55	71	44	52
62	58	54	48	45	65	52	49	45	51
51	46	54	37	48	57	47	46	47	40
39	33	41	36	38	37	33	44	42	34
41	38	34	28	29	42	38	43	31	38
43	35	46	51	49	48	40	50	38	50
49	49	65	45	52	53	55	68	84	69
65	75	94	85	105	96	89	121		

hrf2

61	65	52	87	57	44	48	37	39	47
66	72	94	88	72	98	82	94	80	55
60	83	78	61	56	66	60	74	47	43
39	51	41	55	58	76	73	55	51	59
62	40	45	58	61	58	65	76	50	59
62	68	54	41	42	43	43	34	38	52
46	41	43	45	34	41	58	51	45	51
57	48	57	54	39	56	58	38	41	40
44	53	50	49	42	54	43	51	60	38
54	68	49	54	51	68	54	78	73	64
61	52	50	49	49	53	49	43	68	50
58	63	52	52	74	52	83	88	60	79
72	94	92	95	87	121	81	109	62	75
80	108	72	89	82	74	65	54	65	59
86	55	58	76	56	66	48	67	68	57
72	56	69	66	54	57	57	61	51	50
67	69	69	76	49	76	62	78	64	66
60	66	85	74	80	67	99	69	51	51
59	88	63	69	62	69	71	74	134	148
143	122	194	106	115	84	83	121	124	163
125	123	98	93	108	114	124	125	132	122
99	95	97	103	119	138	127	85	101	125
129	109	155	154						

## hrf3

51	61	42	62	44	43	50	35	34	30
33	33	30	54	37	33	40	35	34	38
43	58	46	44	45	39	37	42	54	42
43	44	50	49	54	53	49	57	49	53
46	52	67	88	65	75	67	91	73	86
99	130	76	89	92	95	98	107	90	101
105	84	93	69	81	82	84	70	58	82
53	65	66	72	68	76	66	66	73	70
65	73	70	79	88	59	83	92	92	75
85	71	70	95	66	72	66	97	111	77
101	86	104	86	69	54	90	90	87	87
74	93	95	80	70	97	86	106	133	112
117	113	123	132	137	187	152	129	106	112
119	97	117	135	101	112	126	109	94	117
122	136	119	105	117	126	135	116	124	129

## hrf4

49	53	54	45	49	61	45	38	47	65
54	53	59	40	60	68	73	63	65	67
66	70	62	64	68	79	69	45	53	64
65	77	73	74	77	119	133	104	91	85
107	107	84	99	115	78	123	87	72	85
73	69	63	75	75	60	71	55	69	57
56	61	57	52	53	51	54	62	56	63
53	63	62	46	50	39	46	54	43	53
37	48	43	50	43	41	50	43	44	49
61	68	56	64	51	50	47	50	58	55
45	63	45	48	38	52	44	50	56	52
81	67	74	63	57	51	37	46	80	86
102	84	63	78	73	58	59	63	57	67
73	68	63	60	66	73	65	72	63	53
42	64	61	52	69	71	70	53	65	82
63	80	75	83	67	69	60	63	77	57
77	58								

## hrf5

321	229	164	174	195	176	136	151	158	157
114	107	185	153	201	124	125	133	75	66
79	59	55	66	55	60	59	65	55	45
57	54	33	36	51	41	37	56	60	61
76	76	66	46	51	43	41	52	77	76
66	66	56	82	72	69	66	51	59	71
67	69	52	56	65	60	51	42	41	54
51	61	51	54	51	52	42	37	44	34
34	48	50	52	48	72	51	62	54	46
48	39	39	43	44	53	41	47	40	41
40	43	39	38	37	36	40	49	45	46
60	48	42	43	44	31	34	33	45	40
48	34	37	32	37	40	37	45	35	39
39	47	36	39	43	42	50	45	44	36
41	41	52	39	36	39	42	37	34	41
34	31	31	36	45	43	63	44	49	56
52	47	51	42	46	49	57	55	49	52
41	50	43	38	42	34	35	32	41	28
37	34	34	30	31	33	39	33	26	33
29	33	29	28	31	32	27	29	26	27
22	24	26	30	34	32	27	29	21	28
29	37	28	38	38	30	32	34	29	34
32	37	29	35	29	30	51	53	38	55
73	49	45	45	38	79	76	108	76	86
77	77	85	96	119	84	93	76	69	62
56	60	67	80	68	69	79	78	89	104
85	99								

## hrf7

180	189	161	181	148	126	166	181	213	173
88	103	113	122	102	116	118	194	104	151
132	154	131	116	109	107	94	114	126	140
112	116	89	104	119	68	101	78	79	68
75	83	66	48	46	34	42	67	91	87
80	78	66	89	82	79	86	82	80	84
83	76	66	66	72	71	29	42	54	43
71	90	83	103	113	117	74	87	87	67
93	91	109	91	100	117	132	76	85	79
54	62	51	53	77	74	67	84	66	85
75	76	88	75	78	68	87	80	57	72
82	85	88	87	84	74	89	77	80	81
92	82	74	69	70	115	107	90	86	86
73	103	123	128	156	128	141	131	120	105
132	110	103	100	126	98	128	112	98	76
76	74	104	82	109	88	95	100	105	110
105	104	105	114	99	80	82	79	75	98
93	78	83	66	76	65	73	73	89	71
75	92	78	77	68	96	80	66	59	70
71	92	74	67	73	59	66	50	64	54
60	73	62	48	61	58	64	58	58	63
66	72	66	61	61	50	47	44	53	66
51	55	57	67	66	69	66	74		

## hrf8

80	96	81	41	56	54	42	56	65	39
45	63	53	59	77	69	64	63	61	61
53	58	67	79	39	55	68	43	51	54
63	68	64	91	64	60	94	113	141	103
72	64	61	75	67	53	54	51	53	62
69	57	58	66	62	50	60	66	56	85
55	65	74	68	65	49	67	73	70	77
75	85	87	92	91	73	76	68	83	68
67	56	69	67	64	79	50	56	57	58
66	53	46	47	62	49	54	64	74	72
69	59	64	68	87	68	83	77	59	51
64	55	71	70	66	51	59	55	85	53
57	66	78	93	64	80	53	79	78	65
68	71	73	60	71	76	81	80	68	44
51	53	59	68	66	76	85	49	83	55
59	69	52	46	49	55	65	53	58	64
57	58	69	56	85	66	82	76	51	65
90	80	81	61	60					

## hrf9

94	92	96	119	130	142	71	103	79	114
131	90	121	95	124	158	144	107	106	138
120	93	111	97	98	105	100	79	88	91
102	130	91	93	106	89	70	84	86	92
105	140	99	99	136	102	122	130	126	98
108	88	74	87	101	92	97	101	88	86
71	103	96	98	77	80	109	90	98	96
138	121	73	80	107	105	117	88	116	91
101	97	73	92	117	94	99	74	86	76
125	67	78	80	85	119	85	123	90	127
89	81	78	94	102	95	88	86	116	116
82	97	99	72	70	104	80	113	61	78
75	88	94							

## hrfl l

81	63	71	72	87	76	81	54	94	67
83	88	87	82	96	101	123	112	131	136
153	132	131	117	89	101	115	134	100	113
104	110	134	101	92	96	78	79	84	81
108	119	106	86	87	110	90	86	103	86
67	101	77	82	89	99	98	100	92	78
77	80	81	77	76	100	71	88	76	87
63	112	102	83	89	80	82	97	96	84
90	103	90	70	78	100	95	105	84	82
78	100	86	96	76	76	122	96	99	100
96	71	56	67	68	91	69	97	93	88
100	79	78	77	85	97	103	101	98	106
104	99	114	128	128	77				

## hrf12

111	93	102	86	73	95	79	73	77	68
70	60	58	63	92	79	82	72	96	71
75	61	78	61	74	67	55	62	76	88
75	83	70	58	53	58	77	68	48	45
51	35	51	49	60	61	58	56	60	65
77	71	51	75	67	60	55	49	77	74
66	54	41	56	50	70	52	43	48	58
58	43	61	59	52	47	35	46	57	57
54	49	48	59	61	64	60	53	59	78
59	51	66	53	79					

## hrf13

144	119	155	101	114	101	113	93	105	123
76	69	75	88	107	98	99	68	78	57
75	102	72	73	68	105	80	120	97	91
82	68	61	74	65	63	77	69	55	71
58	59	72	67	56	72	58	68	62	52
60	65	56	70	58	62	58	53	49	54
50	56	54	55	58	53	49	55	58	52
33	43	42	56	54	55	46	60	45	50
45	62	53	51	42	50	47	72	42	69
65	66	54	66	59	75	70	64	52	59
52	74	50	64	64	72	101	83	79	48
80	70	46	49	50	71	50	56	53	53
56	62	54	49	43	50	62	68	40	48
72	68	57	62	52	67	55	43	58	52
70	64	57	63	69	58	56	56	64	65
73	54	77	81	81	62	80	49		

## hrf14

94	74	63	60	123	100	72	135	116	110
84	127	184	114	92	95	118	83	84	87
72	69	76	67	61	72	51	76	97	77
58	89	85	121	70	115	66	77	78	120
140	109	87	96	105	75	97	73	57	58
79	80	102	79	86	77	78	63	73	93
73	52	62	82	78	88	105	97	89	93
83	73	82	89	96	81	80	86	88	74
98	87	84	106	95	55	85	53	77	77
77	98	89	96	89	97	109	91	70	84
88	90	75	81	65	63	62	58	43	46
48	61	69	68	48	76	50	57	43	63
77	46	55	46	51	70	46	68	79	90
57	60	54	70	63	73	55	60	44	58
58	66	56	62	76	59	92	52	63	75
45	43	51	65	67	66	61	62	75	66
53	67	60	57	74	61	53	55	74	110
66	67	71	74	49	66	71			



## hrf15

68	76	56	48	47	58	67	56	53	43
54	106	81	95	76	80	75	63	55	64
78	49	74	74	55	56	55	54	57	51
53	55	51	66	45	49	46	61	44	65
70	76	78	84	68	71	52	59	54	54
52	67	45	80	69	75	46	61	51	70
70	80	44	49	45	40	40	63	56	44
54	65	63	112	68	78	89	89	70	75
70	72	75	77	43	57	48	65	56	55
49	74	64	55	54	40	59	52	43	35
47	53	47	52	48	44	53	48	37	41
40	45	50	50	47	41	43	72	56	88
74	70	65	60	67	53	84	82	55	57
53	52	35	53	39	47	40	40	49	59
64	53	58	64						

## hrf16

42	51	62	53	42	64	53	51	104	70
80	65	69	70	86	70	66	64	49	54
58	62	84	73	69	65	59	67	54	76
67	79	78	106	81	112	84	74	81	89
79	59	82	81	83	94	83	86	112	74
103	90	71	86	76	86	81	61	73	94
101	105	81	78	73	86	79	101	80	76
51	65	69	106	74	107	93	91	82	68
109	106	92	79	78	105	64	72	78	105
94	70	78	77	79	112	83	92	108	78
72	73	84	112	95	98	66	85	58	87
87	91	64	73	112	84	101	77	68	75
45	48	67	74	78	81	66	78	77	86
63	58	58	68	99	68	78	86	101	124
136	128	122	113	65	108	110	119	103	119
108	107	103	115	91	114	106	108		

## hrf17

132	122	113	108	151	83	89	84	92	96
113	90	75	75	83	87	126	88	79	92
119	87	104	115	95	108	158	131	147	127
126	147	128	95	108	119	67	70	100	87
97	123	93	83	79	98	108	108	76	78
72	111	105	126	110	111	124	94	82	83
70	66	86	100	66	108	97	82	90	74
82	96	101	78	77	65	79	65	66	116
97	150	123	105	101	123	102	96	82	106
111	120	88	89	99	66	59	51	80	80
101	68	63	71	59	61	68	84	76	53
74	71	88	96	62	89	71	67	47	55
63	67	76	71	47	68	55	72	55	59
71	62	79	77	72	50	63	58	47	43
53	63	72	61	55	58	76	69	66	59
54	55	75	59	53	64	63	73	75	72
88	88	60	74	83	89	125	113	143	100
133									

## hrf18

102	128	102	130	114	90	66	53	86	104
107	101	84	98	88	86	103	95	96	86
114	88	84	83	65	90	69	88	68	70
49	44	54	59	68	69	64	72	76	62
73	61	85	84	88	65	100	97	116	104
122	128	101	85	61	81	68	84	63	57
95	98	74	67	81	93	77	78	70	81
81	63	60	47	53	51	44	52	63	72
81	57	75	55	81	74	57	63	60	78
59	88	70	90	92	79	67	78	86	84
81	69	84	116	72	89	112	114	108	135
90	92	109	110	128	121	140	148	119	62
93	83	133	207	189	174	168	159	163	

## hrf19

125	101	106	84	91	66	77	65	48	66
74	84	75	85	79	66	79	62	79	99
82	77	77	109	122	137	102	97	84	73
62	67	68	69	69	84	67	49	58	59
72	66	43	68	51	51	58	46	51	66
65	70	67	80	59	65	72	59	47	63
57	76	87	72	66	71	97	71	63	50
69	67	61	56	45	62	47	52	36	63
56	40	43	57	61	65	53	56	52	45
45	39	45	47	50	50	42	47	35	46
47	51	56	44	67	58	76	60	54	54
52	52	63	58	49	54	56	50	74	57
53	65	53	55	100	67	64	64	62	69
62	79	81	61	60					

## hrf20

97	97	117	102	75	110	79	92	94	57
103	128	98	86	95	76	92	85	64	47
79	71	74	103	101	107	114	89	96	107
120	98	86	86	85	51	59	60	54	54
55	60	62	50	58	69	81	99	64	76
77	131	145	179	156	169	246	212	200	145
166	143	154	123	108	93	83	87	102	107
94	103	85	54	69	74	75	99	66	76
62	73	54	69	69	63	59	65	67	71
57	65	48	38	54	69	65	63	86	76
68	67	72	68	58	68	99	101	82	90
95	103	90	87	88	77	89	79	92	57
71	82	64	76	75	67	75	56	65	83
97	88	82	107	100	113	99	108	97	97
87	88	103	123	89	98	96	96	94	70
91	107	115	92	54	71	65	83	68	61
64	75	77	92	75	62	75	64	62	52
69	77	69	64	49	69	65	59		

## hrf21

41	66	68	73	65	65	70	55	73	61
87	59	72	73	77	53	65	72	81	77
74	91	51	58	50	61	67	59	56	62
82	70	65	55	63	67	71	66	64	82
85	65	69	84	70	62	52	77	76	93
79	73	67	50	73	65	47	48	45	68
73	100	81	81	65	55	49	64	69	70
68	65	84	99	107	87	75	61	95	121
116	100	105	106	135	139	121	112	114	51
73	91	82	93	77	68	80	79	98	65
78	88	104	83	84	85	81	67	73	76
73	89	80							

## hrf22

93	81	83	83	80	66	60	46	44	43
49	69	61	78	75	84	89	69	77	73
105	95	77	89	78	68	63	63	54	59
72	49	55	51	47	50	77	65	52	60
92	139	138	134	96	76	76	83	62	72
56	58	83	79	65	67	49	59	75	86
102	93	102	75	74	85	87	93	69	62
53	54	88	74	59	69	79	82	60	77
49	55	47	68	54	59	59	63	56	64
51	60	55	47	55	46	56	68	67	41
59	65	40	61	66	55	63	54	41	63
54	51	62	58	81	49	72	59	71	72
81	76	69	79	81	95	75	110	101	97
90	80	99	104	96	99	105	86	78	89
84	102	83	76	69	83	72	94	90	78
78	74	91	89	113	101	92	98	78	77
102	100	99	100	93	111	94	93		

## hrf23

275	265	149	147	193	274	222	196	296	439
175	245	254	239	394	362	526	431	120	83
86	87	91	164	119	170	198	363	445	79
69	71	94	118	234	191	225	293	401	368
306	107	54	95	94	96	116	160	156	167
177	224	354	347	149	355	384	548	409	80
55	46	99	90	92	52	47	43	64	63
102	109	162	128	52	54	47	58	63	102
95	101	113	87	114	193	238	145	138	231
129	100	105							

## hrf24

106	94	162	153	185	238	404	205	184	170
80	55	54	59	61	85	133	255	250	230
248	214	173	227	188	189	152	118	192	454
384	340	106	70	42	56	72	119	204	85
86	54	98	90	105	128	134	176	155	155
192	215	286	229	257	241	143	112	75	84
106									

## hrf25

220	180	185	284	299	287	434	263	231	175
231	229	235	256	343	325	223	237	248	144
102	92	91	101	120	129	156	166	188	215
241	228	182	173	112	251	285	273	203	158
115	97	130	149	149	162	154	194	180	142
298	256	169	128	99	129	96	113	75	49
46	48	51	61	49	71	64	46	58	53
59	40	36	31	30	29	29	32	26	31
31	34	38	36	42					

## hrf27

117	90	102	138	112	119	91	131	85	124
88	103	98	68	105	93	114	111	112	108
90	64	67	74	105	92	93	84	98	83
109	83	98	94	98	78	99	79	88	80
105	76	95	99	74	108	86	87	103	86
104	72	83	83	77	73	73	76	108	81
84	100	98	110	80	81	78	82	93	66
76	95	61	59	50	61	39	45	51	44
60	47	49	50	81	61	56	48	54	43
66	34	40	48	40	44	33	40	42	38
46	40	47	53	54	49	59	64	62	72
75	65	48	63	50	45	40	42	73	63
60	76	74	92	72	74	69	75	63	65
66	53	80	98	107	100	100	89	83	68
83	96	101	121	127	120	94	114	105	109
107	140	150	125	106	120	132	139	107	135
123	96	162	167	136	150	112			

hrf28

55	67	46	60	65	45	54	79	42	51
49	45	57	44	44	26	28	35	37	55
41	52	50	43	44	47	46	55	57	51
69	50	47	54	50	47	48	55	40	52
36	46	44	54	60	42	42	59	50	67
51	43	49	36	44	42	44	60	61	60
45	57	58	69	51	57	56	55	63	54
61	49	50	50	46	43	49	65	56	59
67	67	58	58	51	51	40	53	69	61
47	56	53	52	55	61	48	54	49	64
69	63	72	82	75	50	57	58	52	56
64	57	55	57	74	59	73	67	68	81



## **ENGLISH HERITAGE RESEARCH DEPARTMENT**

*English Heritage undertakes and commissions research into the historic environment, and the issues that affect its condition and survival, in order to provide the understanding necessary for informed policy and decision making, for sustainable management, and to promote the widest access, appreciation and enjoyment of our heritage.*

*The Research Department provides English Heritage with this capacity in the fields of buildings history, archaeology, and landscape history. It brings together seven teams with complementary investigative and analytical skills to provide integrated research expertise across the range of the historic environment. These are:*

- \* Aerial Survey and Investigation*
- \* Archaeological Projects (excavation)*
- \* Archaeological Science*
- \* Archaeological Survey and Investigation (landscape analysis)*
- \* Architectural Investigation*
- \* Imaging, Graphics and Survey (including measured and metric survey, and photography)*
- \* Survey of London*

*The Research Department undertakes a wide range of investigative and analytical projects, and provides quality assurance and management support for externally-commissioned research. We aim for innovative work of the highest quality which will set agendas and standards for the historic environment sector. In support of this, and to build capacity and promote best practice in the sector, we also publish guidance and provide advice and training. We support outreach and education activities and build these in to our projects and programmes wherever possible.*

*We make the results of our work available through the Research Department Report Series, and through journal publications and monographs. Our publication Research News, which appears three times a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities. A full list of Research Department Reports, with abstracts and information on how to obtain copies, may be found on [www.english-heritage.org.uk/researchreports](http://www.english-heritage.org.uk/researchreports)*

*For further information visit [www.english-heritage.org.uk](http://www.english-heritage.org.uk)*

