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# CHURCH OF ST NECTAN, STOKE, HARTLAND, DEVON TREE-RING ANALYSIS OF TIMBERS

## SCIENTIFIC DATING REPORT

Alison Arnold and Robert Howard



INTERVENTION  
AND ANALYSIS



ENGLISH HERITAGE

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Research Report Series 47-2013

**CHURCH OF ST NECTAN,  
STOKE, HARTLAND,  
DEVON**

**TREE-RING ANALYSIS OF TIMBERS**

Alison Arnold and Robert Howard

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## SUMMARY

Analysis was undertaken on samples or *in situ* measurements from roof timbers, boards, and pews at this church.

The earliest dated roof is that of the Priest's Chamber, utilising timber of AD 1438–60. The Porch roof contains timber felled in AD 1487–1512, whilst that of the Vestry roof was felled in AD 1499–1524.

Six nave ceiling boards have a *terminus post quem* for felling of AD 1467 and four pulpit boards, a *terminus post quem* for felling of AD 1591.

Eleven type A1 pew bench ends are constructed of timber felled in AD 1584–1605, whilst one has a *terminus post quem* for felling of AD 1659. The majority of the type A2 pew bench ends were felled in AD 1590–1615 but two are later having a *terminus post quem* for felling of AD 1634 and felling date range of AD 1704–29 respectively. The dated type B pew bench ends were felled in AD 1583–1613 and AD 1620. Several of the dated samples from pew type F bench ends were felled in AD 1588–1613, whilst the others are later, including one that was felled in AD 1712–37. Finally one of the bench ends from an *ex situ* pew stored in the boiler room has a *terminus post quem* for felling of AD 1637.

## CONTRIBUTORS

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## INTRODUCTION

This Grade I listed parish Church is situated in the hamlet of Stoke, to the west of Hartland (Figs 1–3). It is believed that there has been a church here since the eleventh century although it is unknown what form this church took as nothing now remains of it. The present building, sometimes referred to as the Cathedral of North Devon, consists of nave, chancel, north and south aisles, transept chapels to both sides, and north and south porches (Fig 4). Over all these areas are wagon roofs, typical of churches in the south-west of England. The west tower is the highest church tower in North Devon. The main fabric of the church is thought to date to the fourteenth and fifteenth centuries, although restorations were undertaken in the nineteenth and twentieth centuries.

The magnificent roof screen is of 11 bays and extends the whole width of the church. Incorporating Pevsner A-type tracery and rich foliage carving, it has been described as the finest example in north Devon and is thought to date from AD 1450. The church is almost completely seated with wooden pews, most of which are oak. This seating is thought to have only changed very slightly since a record was made in AD 1613 (Fig 5) in response to apparent disputes over seating (Hobbs 2004).

### **Priest's Chamber (museum) roof**

The chamber above the two-storey north porch is known as the Priest's Chamber or Museum. The roof over this part of the church (Fig 6) consists of nine frames of common rafters, each with collar, archbraces, and stub ties. A collar purlin runs the length of the roof. This is thought to have been built sometime between the second half of the fourteenth and the later fifteenth century.

### **Priest's Chamber (museum) *ex situ* display items**

There are a number of items of interest on display in the museum including several painted ceiling boards removed during restoration of the nave in AD 1840 and one of the ceiling bosses (Figs 7 and 8). Another set of carved boards from a dismantled pulpit which spell out 'God Save King James Fines' can also be found here (Fig 9). This pulpit is thought to have been purchased in AD 1609 with the inscription being added in AD 1625 when King James died. Four *ex situ* roof timbers, possibly from the south aisle, are also stored here (Fig 10). The date of the south aisle is unknown but similarity to the porches potentially dates to sometime between the second half of the fourteenth and the later fifteenth century.



## **Vestry roof**

This roof is of two bays, separated by a single principal rafter truss with collar. There is a single through purlin to both sides and a through ridge (Fig 11). This roof is believed to be fourteenth century, although it has experienced a degree of repair, especially on the east side.

## **South Porch roof**

This roof consists of nine frames of common rafters, collars, and archbraces. There are moulded purlins to both slopes and a moulded collar purlin and ridge (Fig 12). This porch and the north porch are thought to be of late fourteenth- or fifteenth-century date.

## **Pews**

A detailed investigation of the pews is reported on by Hobbs (2004). The majority of the pews can be divided into two types; a larger type (by size of seats and bench ends), found only to the front half of the church (Type A), and a slightly smaller type, found only to the rear half of the church (Type B). Type A can be further divided into Type A1, found in the north and south aisles, which are moulded and stopped (Fig 13) and Type A2, found in the nave, moulded but not stopped (Fig 14). As indicated above, Type B are smaller but are moulded in the same way as Type A2.

There are a smaller number of pews which fall into different types. The most interesting, Type D, are found in the Stukeley Chapel (Fig 15). These are believed to be the oldest within the church and are composed of reused parts from at least two different sets of pews. They have a mixture of highly decorated and plain pew ends and are thought to have been a gift from Hugh Prust of Thorry in AD 1530. Type F is found to the front of the nave, they are similar in size to Type A, but have moulded top rails and unstopped moulded bench ends (Fig 16). Type G, located to the front of the north aisle, are a set of box pews made up of panels and thin pieces of oak board (Fig 17).

Of less interest within this study are the Type C and E pews, the former being early twentieth-century pine and oak replacements of pews destroyed in a fire and the latter being constructed from thin pieces of pine.

In addition to the pews in the church, a small number have been removed and are stored in a boiler room. These pews were taken from the front of the nave where they had been arranged facing each other in collegiate style. They have moulded top rails and one has what appears to be a series of hat-pegs (Fig 18); others have incised names and one an incised zoomorphic dragon.

## ASSESSMENT AND SAMPLING

Dendrochronological analysis was requested by Francis Kelly, English Heritage Inspector of Historic Buildings and Areas. It was hoped to elucidate the historical development of the church through the analysis of several of the roofs, the rood screen, various *ex situ* elements relating to the nave ceiling, pulpit and possibly the south aisle roof, and various pew types. The provision of independent dating evidence for various pew types would inform significance and hence the provision of advice with respect to the potential removal of some of these pews. In addition, it was hoped that this analysis would establish the extent of pre-AD 1613 pews and increase understanding with respect to how the seating has been altered since the AD 1613 plan.

The impressive rood screen which extends the whole width of the church (Fig 19) was assessed for dendrochronological potential. However, following on-site discussions, it was decided, given the highly decorated and carved nature of this item combined with the absence of any traces of heartwood/sapwood boundary, meaning that only a *terminus post quem* felling date could be gained, not to proceed with sampling. Access could not be gained to the roof of St Mary's Chapel to ascertain whether any of the original timbers remain and the *ex situ* ceiling boss displayed in the museum could be seen to have too few rings for successful analysis to be possible.

A total of 36 timbers was sampled from the roof timbers of three areas. Each sample was given the code NEC-C and numbered 01–36. Samples NEC-C01–10 were taken from the south porch roof, NEC-C11–22 from the roof over the vestry, NEC-C23–34 from the priest's chamber, and NEC-C35–36 from two of the *ex situ* roof timbers stored in the museum and thought to be from the south aisle. Fifty-one of the pew bench ends were sampled; each one given the code (NEC-P) and numbered 01–51. The location of all of these cored timbers was noted at the time of sampling and has been marked on Figures 20–38. Additionally, the ring sequences were measured directly on the ends of 11 of the nave ceiling boards and the five pulpit boards stored in the museum. These ring sequences were given the code NEC-B and numbered 01–11 (nave ceiling boards), and 12–16 (pulpit boards). Photographs of these boards are shown in Figures 39–51. Further details relating to all samples can be found in Table 1.

## ANALYSIS AND RESULTS

### Roofs

One sample from the Vestry roof, two from the Porch roof, and one from the Priest's Chamber roof were found to have too few rings for reliable dating and so were discarded prior to analysis. The remaining 32 samples were prepared by sanding and polishing and their growth-ring widths measured; the data of these measurements are given at the end of the report. These samples were then compared with each other by the

Litton/Zainodin grouping procedure (see Appendix), resulting in 22 samples matching to form five groups.

### **Priest's Chamber**

Firstly, three samples matched each other and were combined to form NECCSQ01, a site sequence of 105 rings (Fig 52). This site sequence was compared against a series of reference chronologies to match at a first-ring date of AD 1317 and a last-measured ring date of AD 1421. The evidence for this dating is given in Table 2.

Another three samples grouped and were combined to form NECCSQ02, a site sequence of 86 rings (Fig 53). This site sequence was found to span the period AD 1352–1437. The evidence for this dating is given in Table 3.

Attempts were then made to date the ungrouped samples by comparing them individually against both the other sequences from this site and the reference chronologies but this was unsuccessful, and all remain undated.

### **Porch**

Five samples matched each other and were combined at the relevant offset positions to form NECCSQ03, a site sequence of 135 rings (Fig 54). This site sequence was compared against a series of relevant reference chronologies where it was found to match consistently and securely at a first-ring date of AD 1339 and a last-measured ring date of AD 1473. The evidence for this dating is given in Table 4.

Two samples grouped to form NECCSQ04, a site sequence of 137 rings (Fig 55) but this could not be conclusively dated against the reference chronologies. Ungrouped sample NEC-C06 was then compared against both the other sequences from this site and the reference chronologies but remains undated.

### **Vestry**

Nine of these samples matched each other and were combined at the relevant offset positions to form NECCSQ05, a site sequence of 105 rings (Fig 56). When this site sequence was compared against the reference material it was found to span the period AD 1386–1490. The evidence for this dating is given in Table 5.

Attempts to date the two ungrouped samples by comparing them individually against both other sequences from this site and the reference material were unsuccessful and these two samples remain undated.

## **Ex situ timbers**

The ring width sequences of these two samples did not crossmatch and hence they were compared individually against both the other sequences from this site and the reference chronologies. No conclusive cross-dating could be found and both remain undated.

## **Pews**

All of the 51 samples taken from the pew bench ends were suitable for analysis. Thirty-nine of these samples matched each other and were combined at the relevant offset positions to form NECPSQ01, a site sequence of 258 rings (Fig 57). This site sequence was compared against the reference chronologies where it was found to match securely and consistently at the first-ring date of AD 1440 and the last-measured ring date of AD 1697. The evidence for this dating is given in Table 6.

Seven further samples grouped and were combined to form site sequence NECPSQ02 of 167 rings (Fig 58). This was compared against the reference chronologies where it was found to span the period AD 1410–1576. The evidence for this dating is in Table 7.

Two samples grouped to form NECPSQ03, a site sequence of 166 rings (Fig 59), but efforts to date this site sequence against both the other sequences from this site and the reference chronologies were unsuccessful. Attempts to date the remaining ungrouped samples were also unsuccessful.

## **Boards**

### **Nave ceiling boards**

Six samples matched and were combined to form NECBSQ01, a site sequence of 250 rings (Fig 60). This site sequence was compared against the reference chronologies where it was found to span the period AD 1203–1452. The evidence for this dating is given in Table 8.

Attempts to date the ungrouped samples by comparing them individually against both the other sequences from this site and the reference chronologies were unsuccessful and these remain undated.

### **Pulpit Boards**

Three of these grouped to form NECBSQ02, a site sequence of 135 rings (Fig 61). This was found to span the period AD 1442–1576. The evidence for this dating is given in Table 9.

Attempts were then made to date the remaining ungrouped samples by comparing them individually against both the other sequences from this site and the reference chronologies resulting in sample NEC-B14 being found to span the period AD 1474–1575. The evidence for this dating is given in Table 10.

## INTERPRETATION

### Roofs

#### Priest's Chamber

Six samples have been dated from this roof, four of which have the heartwood/sapwood boundary ring. In all cases, this is broadly contemporary and suggestive of a single felling. The average heartwood/sapwood boundary ring date is AD 1420, allowing an estimated felling date to be calculated for the four timbers represented of AD 1438–60 (this allows for sample NEC-C23 having a last-measured ring date of AD 1437 with incomplete sapwood). The last-measured heartwood ring dates and the level of matching of the other two dated samples make it likely that these were also felled in AD 1438–60.

#### Porch

Five of these samples have been dated, two of which have the heartwood/sapwood boundary ring date. The average of these two dates is AD 1472, allowing an estimated felling date range to be calculated for the two timbers represented to within the range AD 1487–1512. The overall level of crossmatching within this group of five dated timbers, with several *t*-values in excess of 6.0, suggests all are broadly coeval and that the other three dated samples without the heartwood/sapwood boundary are also likely to have been felled in AD 1487–1512.

#### Vestry

Nine of these samples have been dated, seven of which have the heartwood/sapwood boundary ring date. In all cases this date is broadly contemporary and suggestive of a single felling. The average heartwood/sapwood boundary ring date is AD 1484, allowing an estimated felling date range to be calculated for the timbers represented of AD 1499–1524. The other two dated samples from this roof do not have the heartwood/sapwood boundary but do have last-measured ring dates in the mid later fifteenth century. This, and the good level of matching seen between these samples and the rest of the dated Vestry material make it likely that they were also felled in AD 1499–1524.

## Pews

### Type A1

Twelve of the A1 type pew bench ends have been dated, ten of which have the heartwood/sapwood boundary ring, which in all cases is broadly contemporary and suggestive of a single felling. The average of these is AD 1565, giving an estimated felling date range of AD 1580–1605 for the pew bench ends represented. Two of the dated A1 type pew bench end samples do not have the heartwood/sapwood boundary ring and so an estimated felling date cannot be calculated for them. However, one of these, NEC-P23, matches sample NEC-P21 at such a level ( $t=13.2$ ) to suggest that the two timbers represented were cut from the same tree and therefore felled at the same time; sample NEC-P21 is one of the samples with an estimated felling of AD 1580–1605. The second, NEC-P20 has a last-measured ring date of AD 1644 which means it is significantly later than the rest of the timber with a *terminus post quem* felling of AD 1659.

### Type A2

Eleven of the type A2 pew bench ends have been dated, four of which have the heartwood/sapwood boundary ring present. Three have similar heartwood/sapwood boundary ring dates, the average of which is AD 1575, allowing an estimated felling date to be calculated for the bench ends represented of AD 1590–1615. Six of the samples without the heartwood/sapwood boundary ring have last-measured ring dates in the mid-sixteenth century making it possible that they were also felled in AD 1590–1615. Additionally, the overall crossmatching between these samples and the three with the estimated felling date range of AD 1590–1615 (several  $t$ -values in excess of 6.0 and at least one potential same tree match, NEC-P02, matches NEC-P10 at  $t=12.6$ ), lends further support to contemporary felling for all nine timbers. Sample NEC-P05 has a later heartwood/sapwood boundary date of AD 1689, giving an estimated felling date range of AD 1704–29. The final dated sample, NEC-P06, has the last-measured ring date of AD 1619, giving it a felling date of after AD 1634, and was potentially also felled in AD 1704–29.

### Type B

Eleven of the type B pews have been dated, of which six have the heartwood/sapwood boundary ring present. One of these (NEC-P30), has complete sapwood and a last-measured ring date of AD 1620, the felling date of the timber represented. Two others have heartwood/sapwood boundary ring dates which are similar to that of NEC-P30 making it likely that these were also felled in AD 1620. Additionally, one of these, NEC-P35, matches NEC-P30 at the high value of  $t=12.2$ , raising the possibility that these two samples come from timbers cut from the same tree. Three other samples have earlier,

similar, heartwood/sapwood boundary ring dates, the average of which is AD 1568, giving an estimated felling date range for the three timbers represented of AD 1583–1608. Of the remaining five dated type B pew bench ends, four have last-measured heartwood ring dates ranging from AD 1499 to AD 1565. The matching between these four samples and those felled in AD 1583–1608 is very good with at least one (and probably more), same tree match noted (sample NEC-P29 matches NEC-P34 at a value of  $t=15.2$ ), suggesting contemporary felling for all seven timbers. Sample NEC-P33, with a last-measured heartwood ring date of AD 1590, matches most highly against samples NEC-P30 and NEC-P35 and it is thought likely that the timber represented was also felled in AD 1620.

## Type F

Eleven of the samples taken from these pews have been dated, only four of which have the heartwood/sapwood boundary ring date. Three (NEC-P38, NEC-P39, and NEC-P41), of these are broadly contemporary with the average heartwood/sapwood boundary ring date of AD 1573, allowing an estimated felling date range to be calculated for the timbers represented to the range AD 1588–1613. Two of the samples without the heartwood/sapwood boundary ring (NEC-P40 and NEC-P42), match each other and these three samples match at a generally high value, indeed sample NEC-P39 matches NEC-P42 at 11.0, signifying a potential same tree match, and are thought likely to have also been felled in AD 1588–1613. Sample NEC-P48 has the later heartwood/sapwood boundary ring date of AD 1697, giving an estimated felling date range of AD 1712–37. The remaining five dated samples have last-measured heartwood ring dates in the late sixteenth and seventeenth centuries which make it possible that they were also felled in AD 1712–37; again this is supported by the generally good level of crossmatching seen between these samples and NEC-P48.

## Ex situ pews

Only one of these samples has been dated. With a last-measured heartwood ring date of AD 1622, the timber represented has a *terminus post quem* for felling of AD 1637.

## Boards

### Nave ceiling boards

The six dated boards appear likely to be broadly coeval. None of these samples has the heartwood/sapwood boundary ring date which means it is not possible to calculate an estimated felling date for the timbers represented. The latest ring date is AD 1452 for sample NEC-B05 which would give a *terminus post quem* for felling of AD 1467 for this group of boards. Given the length of the ring sequences and hence the age of the trees at

felling, it seems likely that these boards represent trees felled in the latter part of the fifteenth century or possibly the early sixteenth century.

### **Pulpit boards**

Four of the boards from the pulpit have been successfully dated and appear likely to be coeval. Unfortunately, none of them have the heartwood/sapwood boundary ring and so an estimated felling date range cannot be calculated for them except to say that with NEC-B12 having the latest heartwood ring date of AD 1576, felling would have to be after AD 1591.

## **DISCUSSION**

Prior to the dendrochronological analysis being undertaken at this church dating of the various elements was based mainly on stylistic grounds with the main fabric of the church believed to date to the fourteenth and fifteenth centuries. Documentary evidence indicated the presence of a large number of pews in AD 1613 and also the purchase of the pulpit in AD 1609. However, the date of the nave ceiling boards, removed during restoration work in AD 1840, was unclear.

Of the three roofs analysed the earliest timbers identified are those utilised within the construction of the Priest's Chamber roof (Fig 62). These were felled in AD 1438–60, suggesting construction of this part of the church in the mid-fifteenth century. The roof of the south porch is now known to have been constructed with timber felled in AD 1487–1512, making this roof late-fifteenth/early sixteenth century, somewhat later than previously believed. With a slightly later felling date range of AD 1499–1524, the vestry roof timbers suggest construction at the very end of the fifteenth century/first quarter of the sixteenth century, again later than previously thought. The felling date ranges of these two latter roofs do overlap which makes it possible that they are in fact contemporary or at least part of the same building campaign.

During initial assessment differences in the appearance of the timber used within the vestry roof raised the possibility that the structure had undergone some degree of repair or modification. However, the dendrochronological research has identified only one felling phase within the dated timbers from this roof. Timbers dated include the principal rafters and common rafters of both 'types' which indicates that the difference in appearance must be to do with subsequent conditions (ie roof underboarded in part and/or localised water damage).

It was hoped that the dendrochronological analysis would identify whether the pew type depended on when they were made and, with the existence of a document describing the arrangement of the pews at the church in AD 1613, whether specific pew types, which pre- and post-dated this document, could be clearly identified.



The majority (32) of dated bench ends from all four dated pew types appear most likely to have been present when the AD 1613 seating plan was created. All but one of the bench ends from type A1 pews were probably felled in AD 1584–1605 and all but two of the bench ends from type A2 pews were probably felled in AD 1590–1615. The dated type B pew bench ends include seven probably felled in AD 1583–1608, whilst the type F pew bench ends include five probably felled in AD 1588–1613. These felling date ranges all clearly overlap significantly which makes it possible that the bench ends from the various pew types are in fact contemporary or at least part of a single campaign of construction of pews that may have spanned several years.

The remaining 14 dated bench ends all clearly post date AD 1613 and, as all four pew types and the *ex situ* pews are represented, could represent repairs, replacements or additions. Four type B pew bench ends were probably all felled in AD 1620 and are perhaps more likely to represent the construction of additional pews in the same style. Six type F pew bench ends and one type A2 pew bench end are all significantly later and have been identified as probably felled in the early eighteenth century. The potential same-tree match between NEC-P48 (type F) and NEC-P05 (type A2), suggest that this type A2 bench end and the type F bench ends represent a single phase of felling in the range AD 1708–33. The remaining three dated bench ends, representing type A1, type A2 and an *ex situ* pew, each have a *terminus post quem* for felling in the mid-seventeenth century. It is possible that these are all associated with the AD 1708–33 felling date range but equally so they could represent earlier one-off repairs or replacements.

It can be seen that it does not follow absolutely that the style of pew is determined by when they were made. The later pew bench ends are not only found in places without pews in AD 1613 (ie at the rear of the nave; Fig 5), but also where it is known that there were pews at the time of the seating plan. It does appear that a degree of replacement or reorganisation has been undertaken at the front of the nave, post dating the AD 1613 document. For instance, the bench ends in row 8 on the north side of the nave being dated to the early decades of the eighteenth century, whilst the bench end from a pew stored in the boiler room and hence representing a pew originally in rows 1–5 of the nave having a *terminus post quem* for felling of AD 1637.

Boards have been successfully dated from both the nave ceiling and the dismantled pulpit (Fig 62). The timber used for the nave ceiling boards has been shown to have been felled after AD 1467, and it is quite possible that they are part of the same building campaign which saw the construction of the vestry and porch roofs in the late fifteenth or early sixteenth centuries. The dendrochronological analysis of the pulpit boards shows that they were used in construction after AD 1591. This provides some support for the documentary date identified for the purchase of the pulpit in AD 1609 and would suggest that not much more than the sapwood was trimmed from these boards during the construction of the pulpit

In spite of the overlapping nature of the various site chronologies produced there are only very low levels of similarity found between them and insufficient to justify producing a single site master chronology. This disparity suggests the use of varied woodland sources for the material, though the nature of the matching of the various site chronologies with reference chronologies does suggest a relatively local origin for the structural timbers, the majority of the bench ends, and the nave ceiling boards, with the possibility that a few of the bench ends and the pulpit boards come from slightly further afield. The location of the site very near to the coast on a promontory does raise the possibility of somewhat varied growth conditions within a relatively small source area.

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## TABLES

*Table 1: Details of tree-ring samples from St Nectan's Church, Hartland, Devon*

Sample number	Sample location	Total rings	Sapwood rings	First measured ring date (AD)	Last heartwood ring date (AD)	Last measured ring date (AD)
Roofs						
Porch						
NEC-C01	East upper rib, frame 1	100	08	----	----	----
NEC-C02	East upper rib, frame 3	72	h/s	1402	1473	1473
NEC-C03	West upper rib, frame 5	80	--	1380	----	1459
NEC-C04	East upper rib, frame 5	116	--	1339	----	1454
NEC-C05	East lower rib, frame 5	78	--	1365	----	1442
NEC-C06	East lower rib, frame 6	92	h/s	----	----	----
NEC-C07	East upper rib, frame 9	NM	--	----	----	----
NEC-C08	East upper rib, frame 2	78	h/s	1394	1471	1471
NEC-C09	West purlin (north end)	NM	--	----	----	----
NEC-C10	Collar purlin (north end)	92	--	----	----	----
Vestry						
NEC-C11	North rafter 2, bay 1	50	h/s	1432	1481	1481
NEC-C12	North rafter 3, bay 1	56	h/s	1428	1483	1483
NEC-C13	North rafter 5, bay 1	52	h/s	1433	1484	1484
NEC-C14	South rafter 5, bay 1	51	h/s	----	----	----
NEC-C15	South rafter 6, bay 1	54	h/s	----	----	----
NEC-C16	North principal rafter	73	h/s	1407	1479	1479
NEC-C17	South principal rafter	63	--	1414	----	1476
NEC-C18	South rafter 1, bay 2	56	h/s	1432	1487	1487
NEC-C19	North rafter 4, bay 2	51	h/s	1437	1487	1487
NEC-C20	South rafter 5, bay 2	50	h/s	1441	1490	1490
NEC-C21	South rafter 6, bay 2	82	--	1386	----	1467
NEC-C22	North rafter 2, bay 2	NM	--	----	----	----
Priest's Chamber (Museum)						

NEC-C23	West lower rib, frame 2	45	13	1393	1424	1437
NEC-C24	East lower rib, frame 3	NM	--	----	----	----
NEC-C25	West rafter, frame 4	85	h/s	1334	1418	1418
NEC-C26	West lower rib, frame 4	54	07	1372	1418	1425
NEC-C27	East rafter, frame 5	64	h/s	----	----	----
NEC-C28	East tie, frame 6	94	--	1317	----	1410
NEC-C29	West lower rib, frame 6	65	39C	----	----	----
NEC-C30	West rafter, frame 6	83	h/s	1339	1421	1421
NEC-C31	West lower rib, frame 7	62	20	----	----	----
NEC-C32	East lower rib, frame 7	59	--	1352	----	1410
NEC-C33	East rafter, frame 8	75	h/s	----	----	----
NEC-C34	East lower rib, frame 8	77	05	----	----	----
<i>Ex situ</i> timbers						
NEC-C35	'Rib No 8 South side)	60	h/s	----	----	----
NEC-C36	Rib	155	h/s	----	----	----
Pews						
Type A2						
NEC-P01	South nave 13N	86	h/s	1484	1569	1569
NEC-P02	South nave 12N	62	--	1494	----	1555
NEC-P03	South nave 11N	166	h/s	----	----	----
NEC-P04	South nave 10S	91	01	----	----	----
NEC-P05	South nave 11S	191	h/s	1499	1689	1689
NEC-P06	South nave 10N	105	--	1515	----	1619
NEC-P07	South nave 9N	76	--	1485	----	1560
NEC-P08	North nave 13S	84	--	1468	----	1551
NEC-P09	North nave 12S	89	h/s	1487	1575	1575
NEC-P10	North nave 10S	57	--	1496	----	1552
NEC-P11	North nave 10N	121	--	1451	----	1571
NEC-P12	North nave 11N	114	--	1449	----	1562
NEC-P13	North nave 12N	52	h/s	1530	1581	1581
Type A1						
NEC-P14	North aisle 7S	84	17	1499	1565	1582



NEC-P15	North aisle 9S	76	19	1508	1564	1583
NEC-P16	North aisle 10S	113	h/s	1457	1569	1569
NEC-P17	North aisle 11S	78	09	1498	1566	1575
NEC-P18	North aisle 8S	87	18	1490	1558	1576
NEC-P19	North aisle 12S	71	02	1497	1565	1567
NEC-P20	South aisle 1N	109	--	1536	----	1644
NEC-P21	South aisle 3N	96	h/s	1464	1559	1559
NEC-P22	South aisle 5N	85	h/s	1480	1564	1564
NEC-P23	South aisle 9N	107	--	1449	----	1555
NEC-P24	South aisle 11N	87	h/s	1491	1577	1577
NEC-P25	South aisle 12N	72	07	1495	1559	1566
Type B						
NEC-P26	North nave 15N	75	--	1469	----	1543
NEC-P27	North nave 15S	110	h/s	1459	1568	1568
NEC-P28	North nave 16S	60	h/s	----	----	----
NEC-P29	North nave 18S	84	--	1482	----	1565
NEC-P30	North nave 20S	161	15C	1460	1605	1620
NEC-P31	North nave 21S	63	--	1437	----	1499
NEC-P32	North nave 22S	101	h/s	1476	1576	1576
NEC-P33	South nave 15N	118	--	1473	----	1590
NEC-P34	South nave 16N	156	--	1410	----	1565
NEC-P35	South nave 21N	179	12	1440	1606	1618
NEC-P36	South nave 22N	99	06	1512	1604	1610
NEC-P37	South aisle 21N	55	13	1518	1559	1572
Type F						
NEC-P38	South nave 6S	71	01	1505	1574	1575
NEC-P39	South nave 7S	116	01	1465	1579	1580
NEC-P40	South nave 8S	78	--	1486	----	1563
NEC-P41	South nave 6N	92	h/s	1475	1566	1566
NEC-P42	South nave 7N	92	--	1486	----	1577
NEC-P43	North nave 6S	118	--	1540	----	1657
NEC-P44	North nave 7S	65	--	1593	----	1657

NEC-P45	North nave 8S	56	--	1543	----	1598
NEC-P46	North nave 6N	153	--	1529	----	1681
NEC-P47	North nave 7N	88	--	1545	----	1632
NEC-P48	North nave 8N	193	h/s	1505	1697	1697
Loose						
NEC-P49	1 – north end	98	--	1525	----	1622
NEC-P50	1 – south end	83	14	----	----	----
NEC-P51	4 – south end	109	--	----	----	----
Boards						
Nave ceiling						
NEC-B01	Board	224	--	1221	----	1444
NEC-B02	Board	165	--	----	----	----
NEC-B03	Board	140	--	1304	----	1443
NEC-B04	Board	136	--	----	----	----
NEC-B05	Board	169	--	1284	----	1452
NEC-B06	Board	97	--	----	----	----
NEC-B07	Board	235	--	1208	----	1442
NEC-B08	Board	102	--	----	----	----
NEC-B09	Board	130	--	----	----	----
NEC-B10	Board	205	--	1231	----	1435
NEC-B11	Board	156	--	1203	----	1358
Pulpit						
NEC-B12	'God'	116	--	1461	----	1576
NEC-B13	'Save'	150	--	----	----	----
NEC-B14	'James'	102	--	1474	----	1575
NEC-B15	'Fines'	80	--	1468	----	1547
NEC-B16	'King'	102	--	1442	----	1543

**Table 2: Results of the cross-matching of site sequence NECCSQ01 and relevant reference chronologies when the first-ring date is AD 1317 and the last-measured ring date is AD 1421**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
Devon County	7.8	AD 775–1799	Tyers <i>pers comm</i> 2004
46 High Street (Thorntons), Exeter, Devon	7.4	AD 1309–1491	Arnold and Howard 2009a
St Johns Commandery, Swingfield, Kent	7.2	AD 1312–82	Howard <i>et al</i> /1997
Mercer's Hall, Gloucestershire	7.0	AD 1289–1541	Howard <i>et al</i> /1996
West Challacombe, Devon	6.8	AD 1319–1452	Tyers and Groves 1999
Pendennis Castle, Cornwall	6.6	AD 1358–1541	Tyers 2004
Hole Farm, Hockworthy, Devon	6.1	AD 1306–1468	Miles <i>et al</i> /2004

**Table 3: Results of the cross-matching of site sequence NECCSQ02 and relevant reference chronologies when the first-ring date is AD 1352 and the last-measured ring date is AD 1437**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
Devon County	6.4	AD 775–1799	Tyers <i>pers comm</i> 2004
Hambledon Church, Hampshire	6.7	AD 1343–1443	Bridge 2006
Moorstone Barton, Halberton, Devon	6.3	AD 1337–1439	Tyers <i>et al</i> /forthcoming
Old Rectory, Withington, Gloucestershire	5.5	AD 1252–1429	Howard <i>et al</i> /1998a
Hall Broom Farm, Dungworth, Derbyshire	5.5	AD 1382–1495	Howard <i>et al</i> /1993
Pockerly Farm, Beamish, County Durham	5.4	AD 1342–1441	Howard <i>et al</i> /1990, unpubl
Lower Chilverton, Coldridge, Devon	5.1	AD 1396–1488	Groves 2005

**Table 4: Results of the cross-matching of site sequence NECCSQ03 and relevant reference chronologies when the first-ring date is AD 1339 and the last-measured ring date is AD 1473**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
Devon County	7.7	AD 775–1799	Tyers <i>pers comm</i> 2004
46 High Street (Thorntons), Exeter, Devon	7.1	AD 1309–1491	Arnold and Howard 2009a
Warleigh House, Tamerton Foliot, Devon	6.7	AD 1367–1539	Howard <i>et al</i> 2006
The Ship Inn, Morwellham Quay, Devon	6.5	AD 1361–1508	Tyers <i>et al</i> /forthcoming
Halesowen Abbey, Dudley, West Midlands	6.3	AD 1310–1535	Arnold and Howard 2008
The Commandery, Worcester, Worcestershire	5.9	AD 1284–1473	Arnold and Howard 2006a
St Martin's Church, Looe, Cornwall	5.8	AD 1363–1518	Arnold <i>et al</i> 2006

**Table 5: Results of the cross-matching of site sequence NECCSQ05 and relevant reference chronologies when the first-ring date is AD 1386 and the last-measured ring date is AD 1490**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
Devon County	6.8	AD 775–1799	Tyers <i>pers comm</i> 2004
St Andrew's Church, Alwington, Devon	7.8	AD 1342–1490	Arnold and Howard 2009b
St Martin's Church, Looe, Cornwall	7.3	AD 1363–1518	Arnold <i>et al</i> 2006
Halesowen Abbey, Dudley, West Midlands	6.8	AD 1310–1535	Arnold and Howard 2008
St Fimbarrus Church, Fowey, Cornwall	6.8	AD 1375–1511	Arnold and Howard 2010
St Ildierna, Lansallos, Cornwall	6.8	AD 1355–1514	Arnold and Howard 2006b
St Teatha's Church, St Teath, Cornwall	6.8	AD 1396–1477	Arnold and Howard 2007a

**Table 6: Results of the cross-matching of site sequence NECPSQ01 and relevant reference chronologies when the first-ring date is AD 1440 and the last-measured ring date is AD 1697**

Reference chronology	t-value	Span of chronology	Reference
Devon County	8.4	AD 775–1799	Tyers <i>pers comm</i> 2004
Yarde Farm, Malborough, Devon	8.9	AD 1432–1603	Arnold and Howard 2009c
1–5 Bridge Street, Bideford, Devon	8.8	AD 1484–1706	Arnold and Howard 2012, unpubl
St Ildierna, Lansallos, Cornwall	8.8	AD 1355–1514	Arnold and Howard, 2006b
Warleigh House, Tamerton Foliot, Devon	8.2	AD 1367–1539	Howard <i>et al</i> 2006
St Briavel's Castle, Gloucestershire	8.1	AD 1362–1636	Howard <i>et al</i> 1999a
Treludick House, Egloskerry, Cornwall	7.9	AD 1516–1630	Arnold and Howard 2007b

**Table 7: Results of the cross-matching of site sequence NECPSQ02 and relevant reference chronologies when the first-ring date is AD 1410 and the last-measured ring date is AD 1576**

Reference chronology	t-value	Span of chronology	Reference
Le Marinel, Jersey	5.9	AD 1448–1565	Miles <i>pers comm</i>
St Michael's Cottage, Chilbolton, Hampshire	5.8	AD 1421–1554	Miles <i>et al</i> 2007
Chiddingly Place, East Sussex	5.6	AD 1324–1576	Arnold and Litton 2003
Manor Court House, Chard, Somerset	5.5	AD 1408–1517	Arnold <i>et al</i> 2004
The Jetty, Titchfield, Hampshire	5.4	AD 1355–1486	Miles and Worthington 1999
Manor Farm, Boarhunt, Hampshire	5.4	AD 1412–1551	Miles <i>et al</i> 2007
Danny House, Sussex	5.3	AD 1389–1589	Miles and Bridge 2010

**Table 8: Results of the cross-matching of site sequence NECBSQ01 and relevant reference chronologies when the first-ring date is AD 1203 and the last-measured ring date is AD 1452**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
England	7.1	AD 401–1981	Baillie and Pilcher 1982, unpubl
Forde Abbey, Dorset	6.3	AD 1386–1485	Miles 1998
Cradley Village Hall, Herefordshire	6.3	AD 1347–1530	Miles <i>et al</i> 2004
46 High Street (Thorntons), Exeter, Devon	6.1	AD 1309–1491	Arnold and Howard 2009a
Lydart Farm, Monmouth, Monmouthshire	6.0	AD 1211–1494	Howard 2002, unpubl
St Andrew's Church, Alwington, Devon	5.5	AD 1342–1490	Arnold and Howard 2009b
Bridford Barton, Bridford, Devon	5.5	AD 1228–1322	Tyers <i>et al</i> /forthcoming

**Table 9: Results of the cross-matching of site sequence NECBSQ02 and relevant reference chronologies when the first-ring date is AD 1442 and the last-measured ring date is AD 1576**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
Mercer's Hall, Gloucestershire	7.0	AD 1289–1541	Howard <i>et al</i> /1996
Sinai House, Burton on Trent, Staffordshire	6.9	AD 1529–1616	Howard <i>et al</i> /1999b
Court House, Shelsley Walsh, Worcestershire	6.9	AD 1387–1575	Arnold <i>et al</i> /2008
New Inn, Oxford, Oxfordshire	6.8	AD 1443–1557	Fletcher unpubl
Cradley Village Hall, Herefordshire	6.7	AD 1347–1530	Miles <i>et al</i> 2004
Kingsbury Hall, Kingsbury, Warwickshire	6.2	AD 1391–1564	Arnold and Howard 2006c
Dore Abbey, Herefordshire	6.9	AD 1363–1612	Tyers and Boswijk 1998

**Table 10: Results of the cross-matching of sample NEC-B14 and relevant reference chronologies when the first-ring date is AD 1474 and the last-measured ring date is AD 1575**

Reference chronology	<i>t</i> -value	Span of chronology	Reference
26 Westgate Street, Gloucester, Gloucestershire	6.4	AD 1399–1622	Howard <i>et al</i> /1998b
Kingsbury Hall, Kingsbury, Warwickshire	6.0	AD 1391–1564	Arnold and Howard 2006c
Church of St Nicholas, Brighthelmston, Leicestershire	5.7	AD 1502–1687	Arnold <i>et al</i> /2005
Manor House, Alford, Lincolnshire	5.7	AD 1500–1668	Arnold <i>et al</i> /2003
Polesworth Abbey Gatehouse, Warwickshire	5.6	AD 1446–1582	Arnold and Howard 2007c
Lower Bean Hall, Bradley Green, Feckenham, Worcestershire	5.6	AD 1419–1565	Arnold and Howard 2005, unpubl
St John the Baptist Church, Mable, Worcestershire	7.1	AD 1348–1582	Tyers 1996

## FIGURES



Figure 1: Map to show the general location of Hartland, Devon, arrowed. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900



Figure 2: Map to show the general location of St Nectan's Church, arrowed. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900



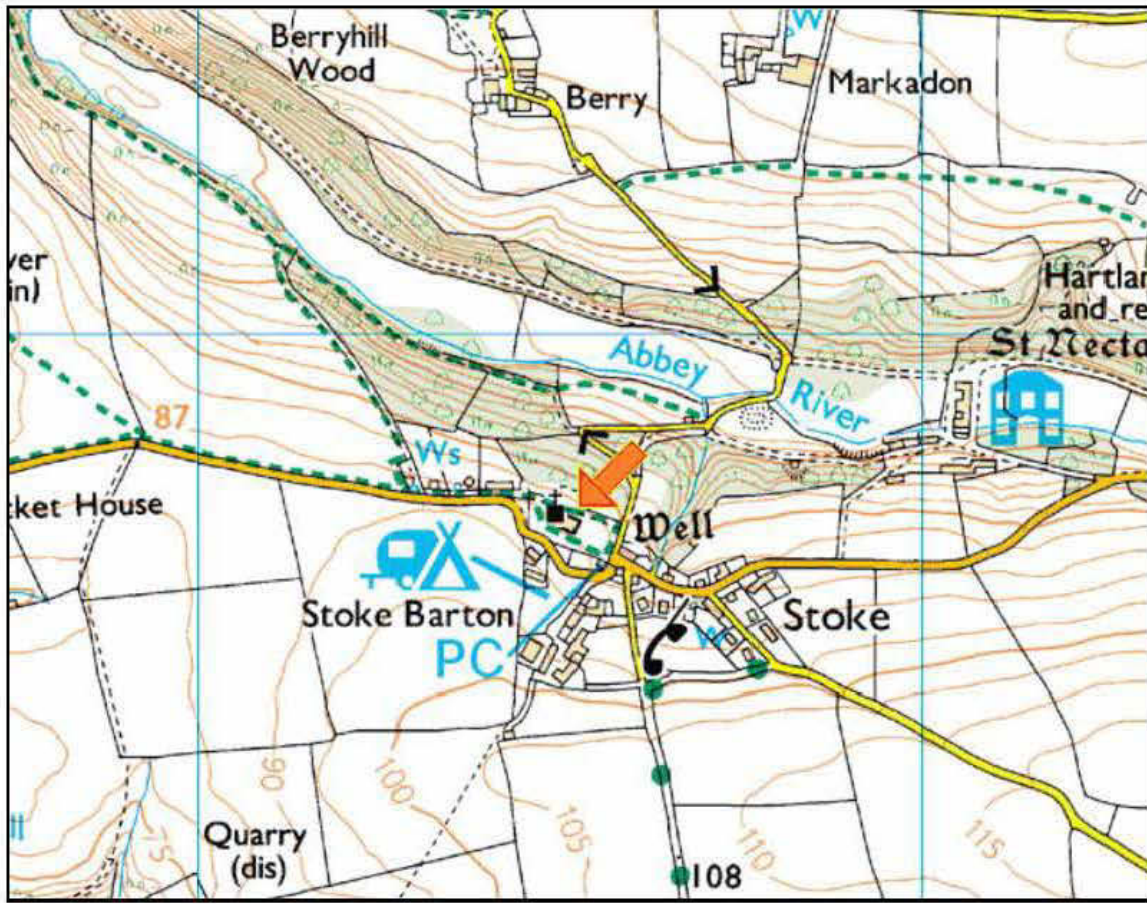


Figure 3: Map to show the location of St Nectan's Church, arrowed. © Crown Copyright and database right 2013. All rights reserved. Ordnance Survey Licence number 100024900

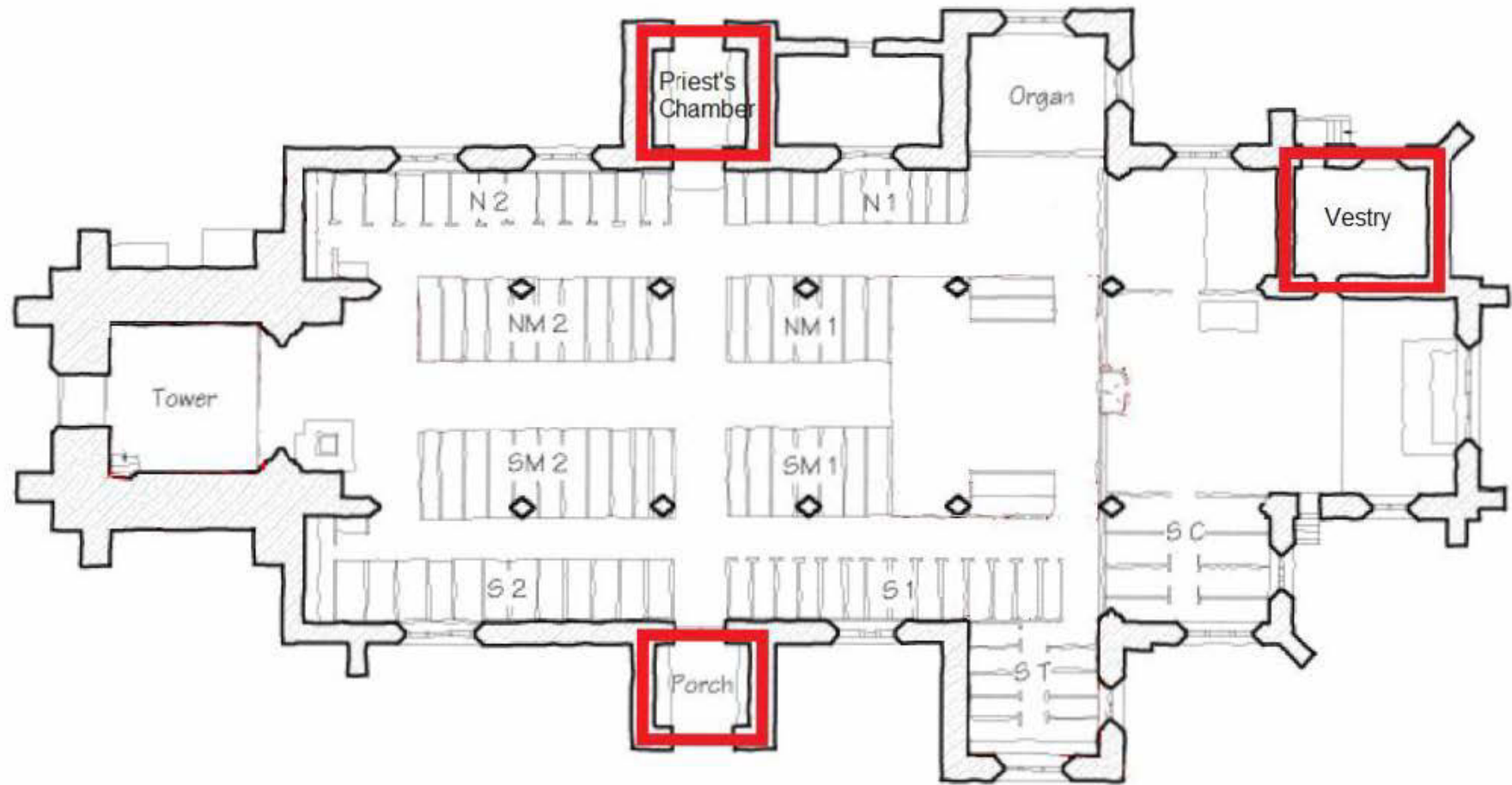
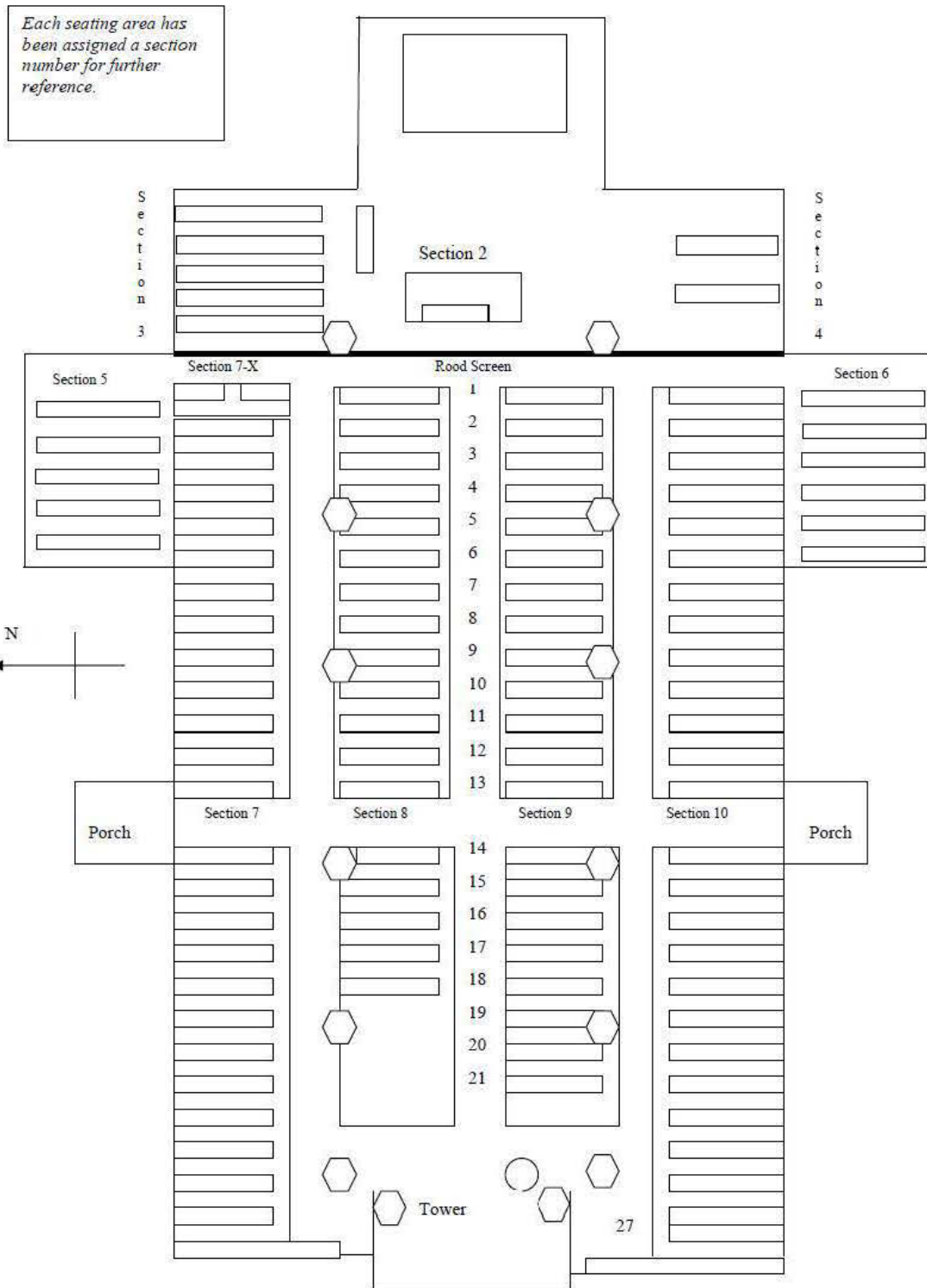


Figure 4: Plan of church, showing roofs sampled in red (after Jonathon Rhind Architects)



Dia 1: Seating layout at 1613 from the assignment.

Figure 5: Seating layout at AD 1613 from the assignment (Hobbs 2004)





*Figure 6: Priest's Chamber (museum); roof (Alison Arnold)*



*Figure 7: Ceiling boards removed from the Nave (Alison Arnold)*



*Figure 8: The ex situ Nave boss (Alison Arnold)*



*Figure 9: One of the boards from the dismantled pulpit (Alison Arnold)*





*Figure 10: Two of the ex situ roof timbers (Alison Arnold)*



*Figure 11: Vestry roof (Alison Arnold)*



Figure 12: Porch roof (Alison Arnold)



Figure 13: Type A1 pews, with stopped and moulded ends (Robert Howard)





*Figure 14: Type A2 pews, moulded but unstopped (Robert Howard)*



*Figure 15: Type D pews (Robert Howard)*



*Figure 16: Type F pew, with moulded top rails (Robert Howard)*





*Figure 17: Type G pews; box pews (Robert Howard)*



Figure 18: One of the pews stored in the boiler room, with hat pegs and incised name (Robert Howard)



*Figure 19: The rood screen (Robert Howard)*

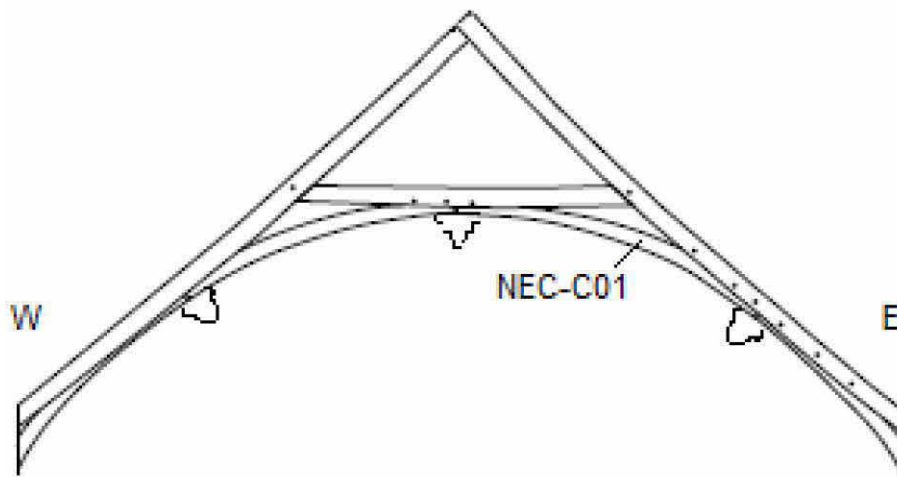


Figure 20: Porch; sketch of frame 1, showing the location of sample NEC-C01

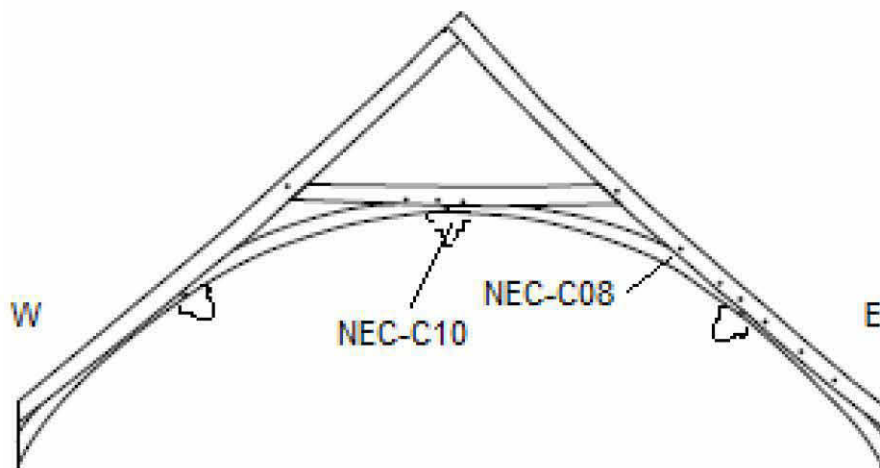


Figure 21: Porch; sketch of frame 2, showing the location of samples NEC-C08 and NEC-C10

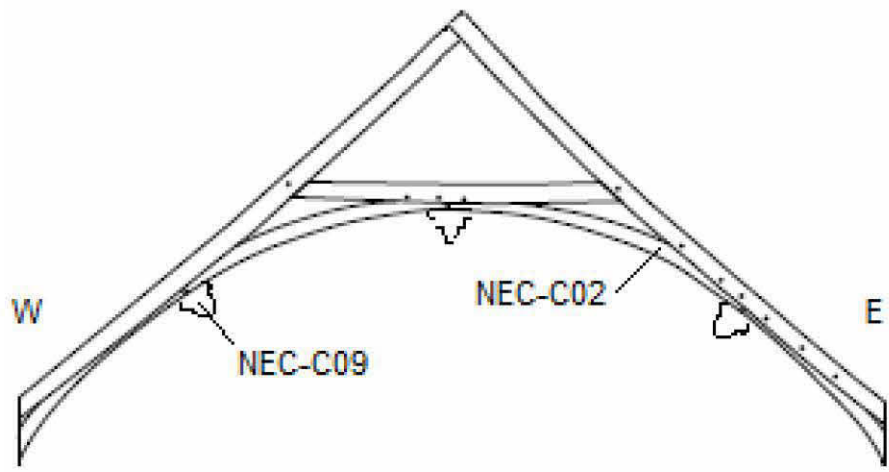


Figure 22: Porch; sketch of frame 3, showing the location of samples NEC-C02 and NEC-C09

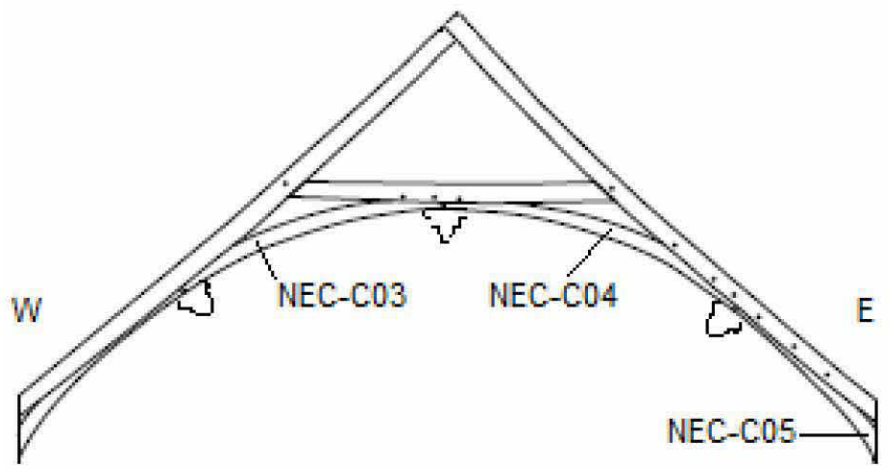


Figure 23: Porch; sketch of frame 5, showing the location of samples NEC-C03–05



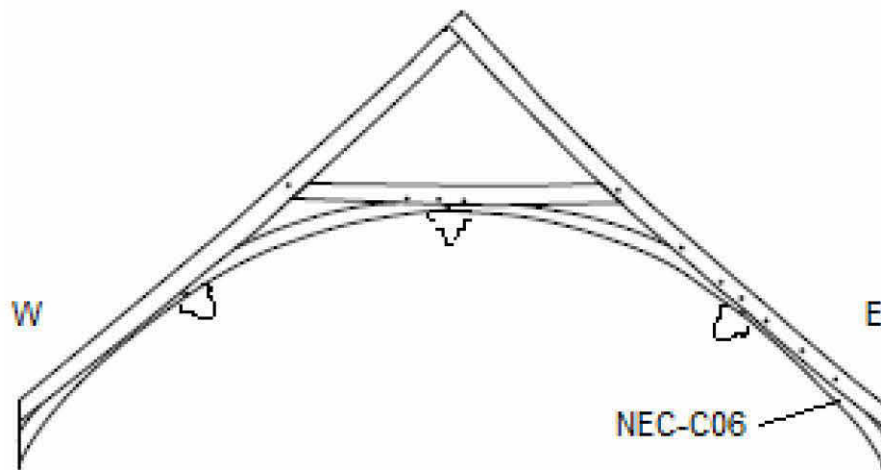


Figure 24: Porch; sketch of frame 6, showing the location of sample NEC-C06

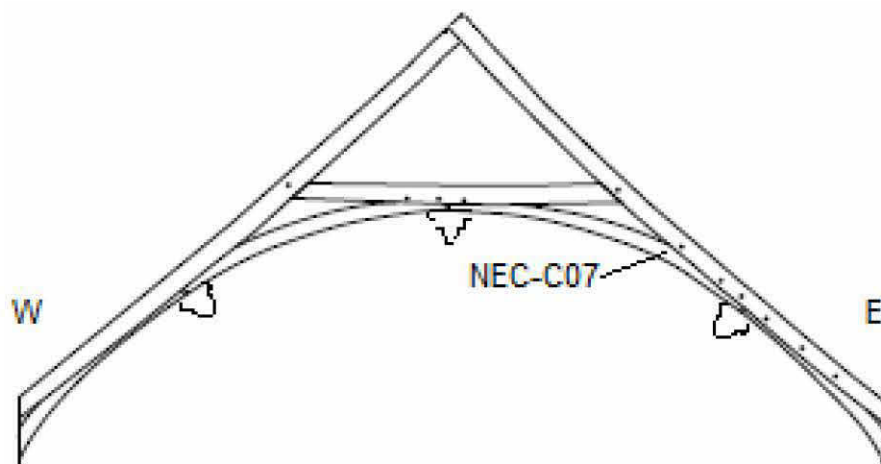


Figure 25: Porch; sketch of frame 9, showing the location of sample NEC-C07

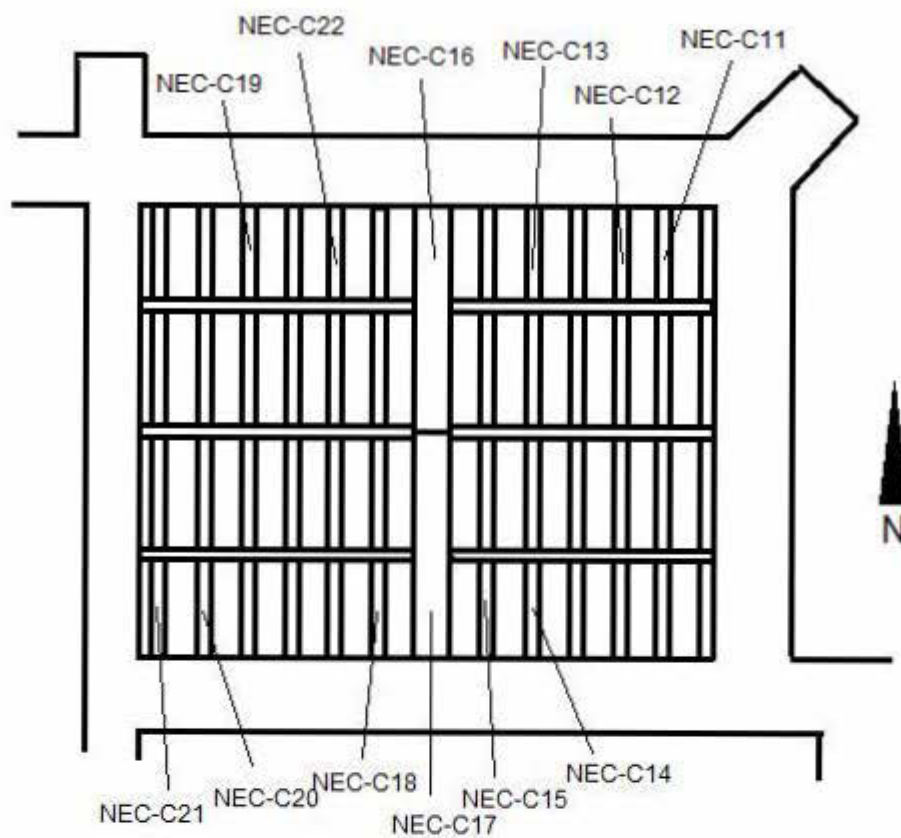


Figure 26: Plan of Vestry roof, showing the location of samples NEC-C11-22

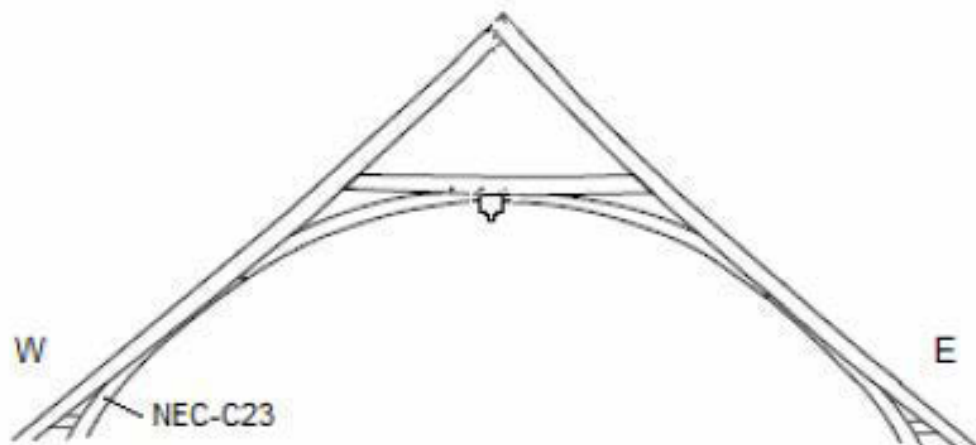


Figure 27: Priest's Chamber; sketch of frame 2, showing the location of sample NEC-C23

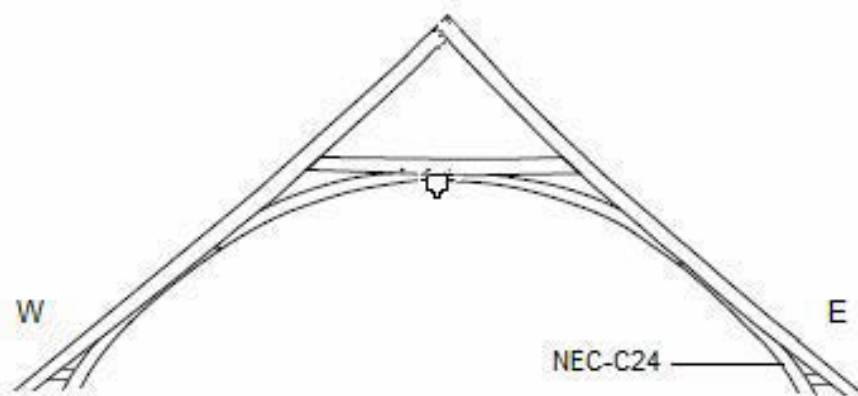


Figure 28: Priest's Chamber; sketch of frame 3, showing the location of sample NEC-C24

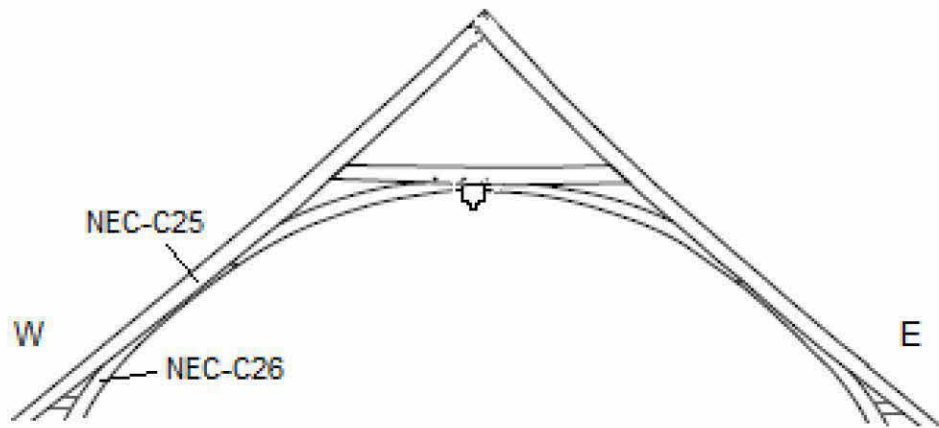


Figure 29: Priest's Chamber; sketch of frame 4, showing the location of samples NEC-C25 and NEC-C26

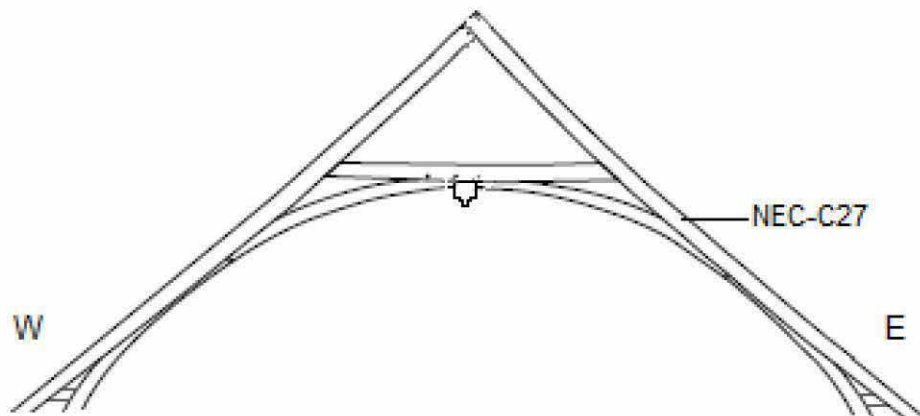


Figure 30: Priest's Chamber; sketch of frame 5, showing the location of sample NEC-C27

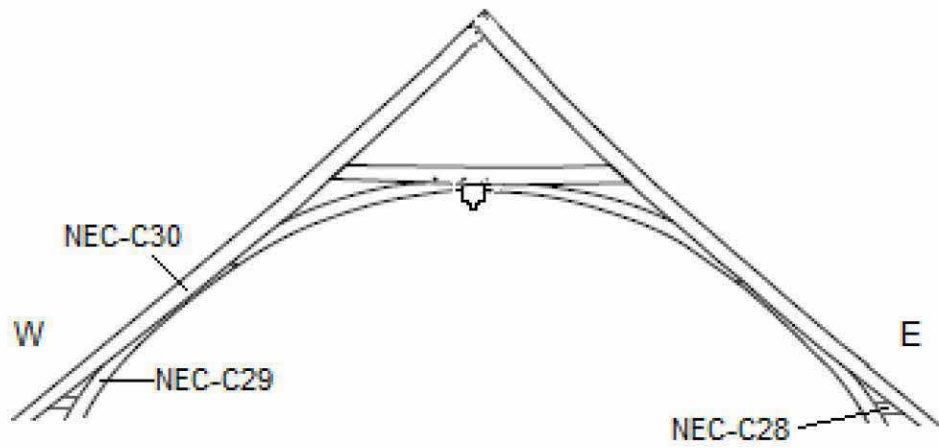


Figure 31: Priest's Chamber; sketch of frame 6, showing the location of samples NEC-C28–30

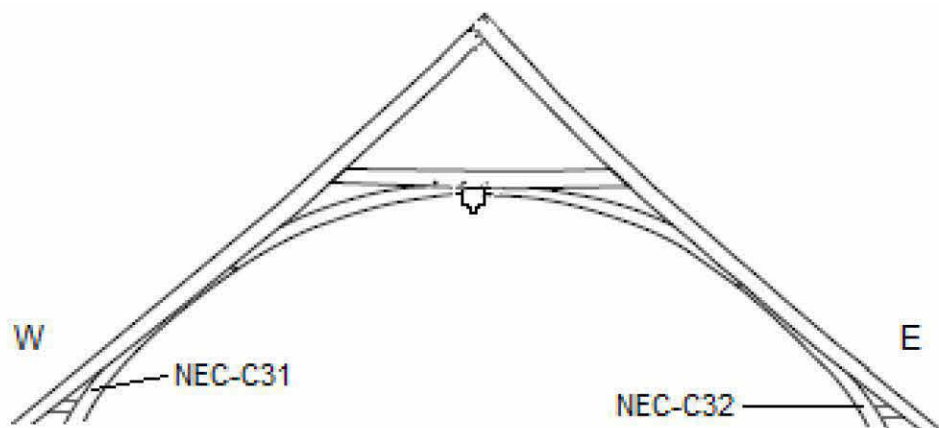


Figure 32: Priest's Chamber; sketch of frame 7, showing the location of samples NEC-C31 and NEC-C32

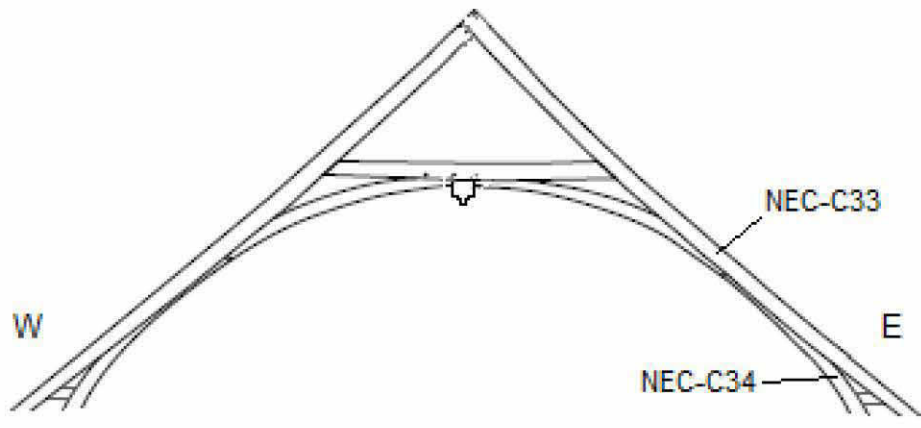


Figure 33: Priest's Chamber; sketch of frame 8, showing the location of samples NEC-C33 and NEC-C34

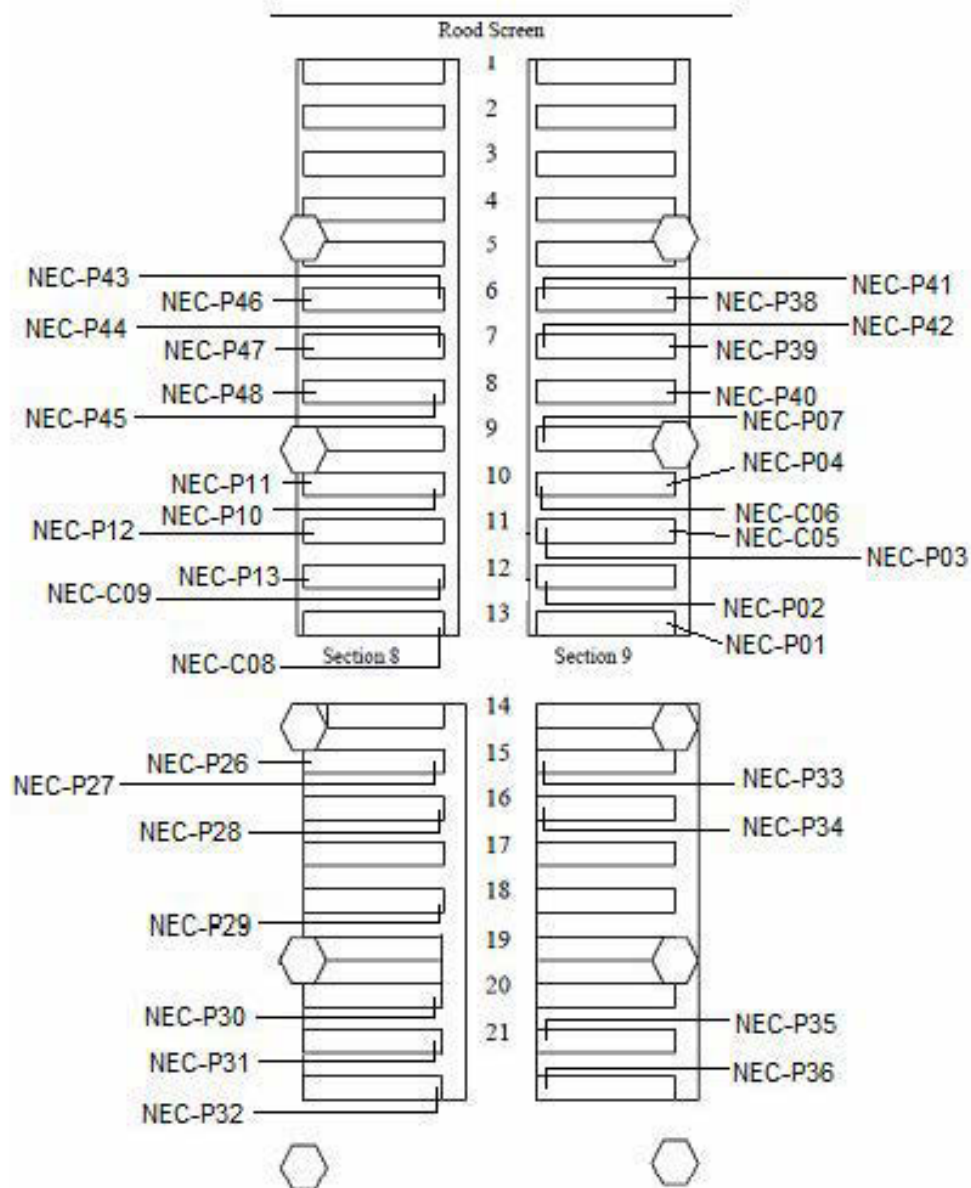


Figure 34: Plan of Nave, showing the location of samples NEC-P01–13, NEC-P26–36, and NEC-P38–48

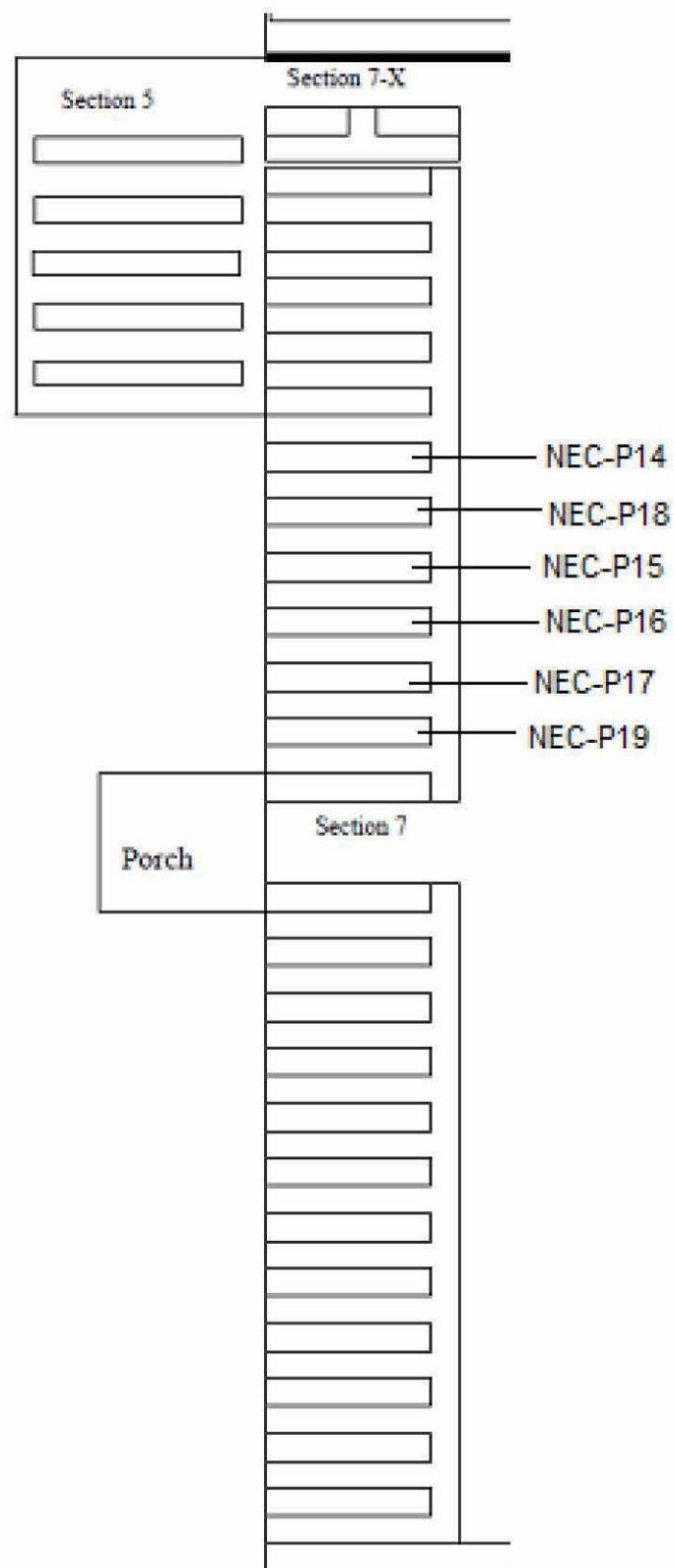


Figure 35: Plan of north aisle, showing the location of samples NEC-P14–19



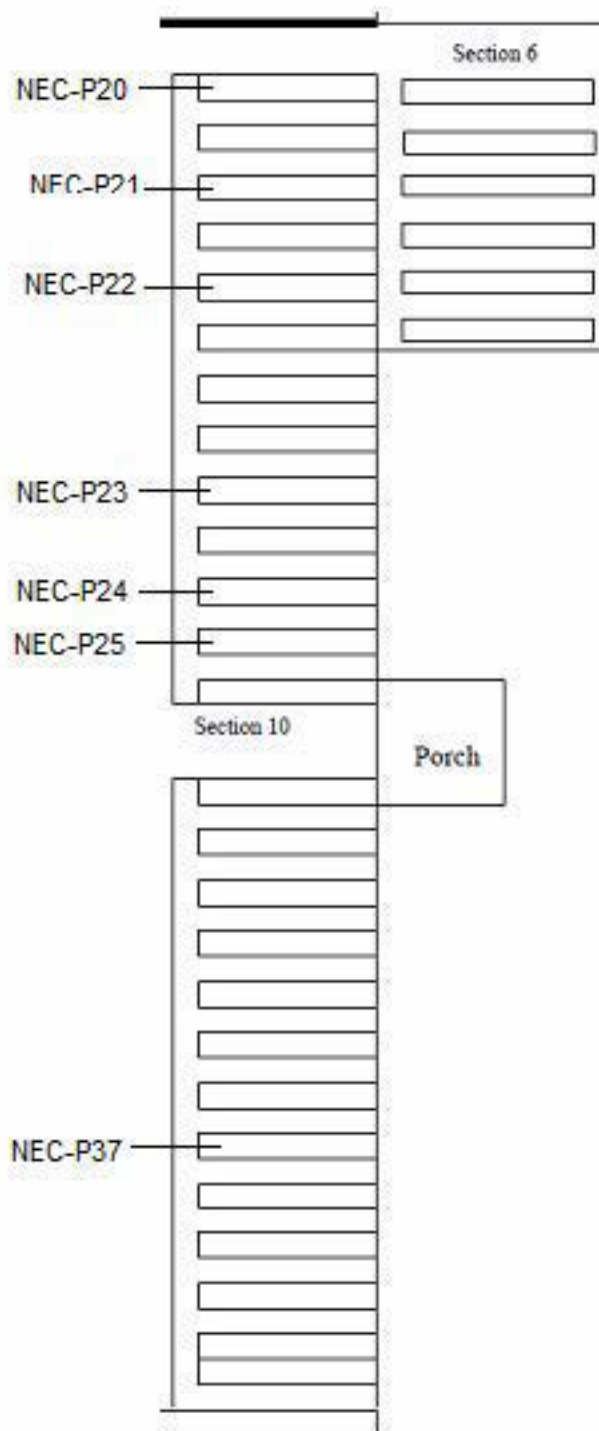


Figure 36: Plan of south aisle, showing the location of samples NEC-P20–25 and NEC-P37



*Figure 37: Photograph showing the location of samples NEC-P49 and NEC-P50 (Robert Howard)*



*Figure 38: Photograph to show the location of sample NEC-P51 (Robert Howard)*



*Figure 39: Photograph of nave board, sample NEC-B01 (Alison Arnold)*





*Figure 40: Photograph of nave ceiling board, sample NEC-B02 (Alison Arnold)*



*Figure 41: Photograph of nave ceiling board, sample NEC-B03 (Alison Arnold)*



*Figure 42: Photograph of nave ceiling board, sample NEC-B04 (Alison Arnold)*



*Figure 43: Photograph of nave ceiling board, sample NEC-B05 (Alison Arnold)*





*Figure 44: Photograph of nave ceiling board, sample NEC-B06 (Alison Arnold)*



Figure 45: Photograph of nave ceiling boards, samples NEC-B07-09 (Alison Arnold)



Figure 46: Photograph of nave ceiling boards, samples NEC-B10 and NEC-B11 (Alison Arnold)



*Figure 47: Photograph of pulpit board, sample NEC-B12 (Alison Arnold)*





Figure 48: Photograph of pulpit board, sample NEC-B13 (Alison Arnold)



*Figure 49: Photograph of pulpit board, sample NEC-B1 4 (Alison Arnold)*



*Figure 50: Photograph of pulpit board, sample NEC-B15 (Alison Arnold)*



*Figure 51: Photograph of pulpit board, sample NEC-B16 (Alison Arnold)*



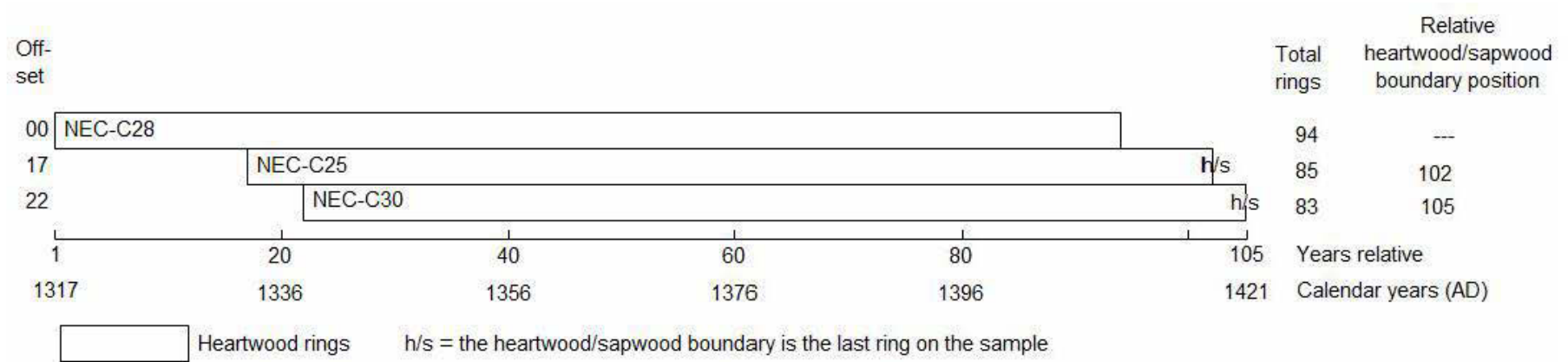


Figure 52: Bar diagram of samples from the Priest's Chamber roof in site sequence NECCSQ01

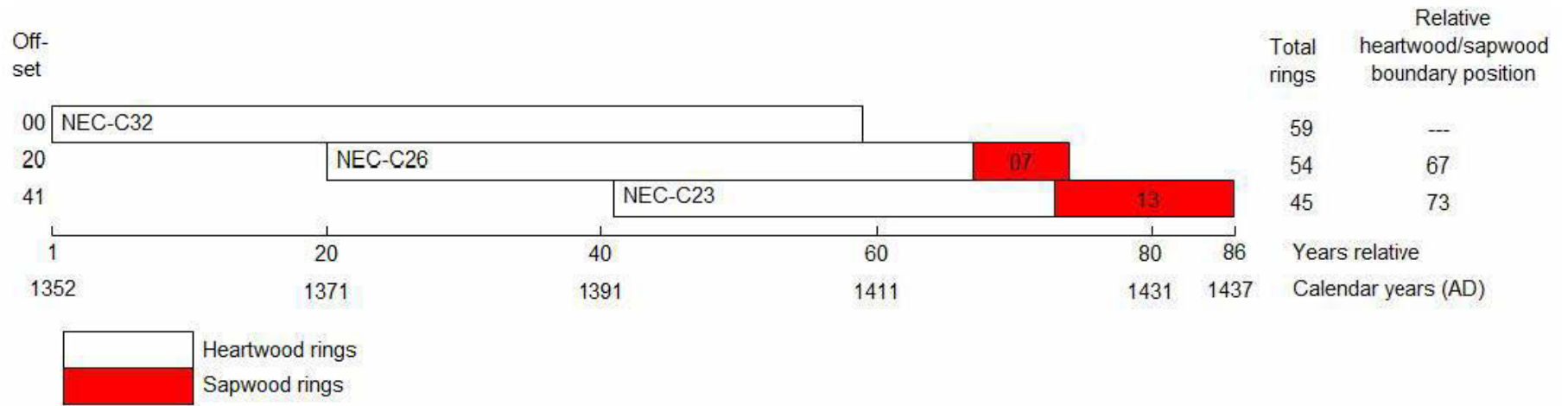


Figure 53: Bar diagram of samples from the Priest's Chamber roof in site sequence NECCSQ02

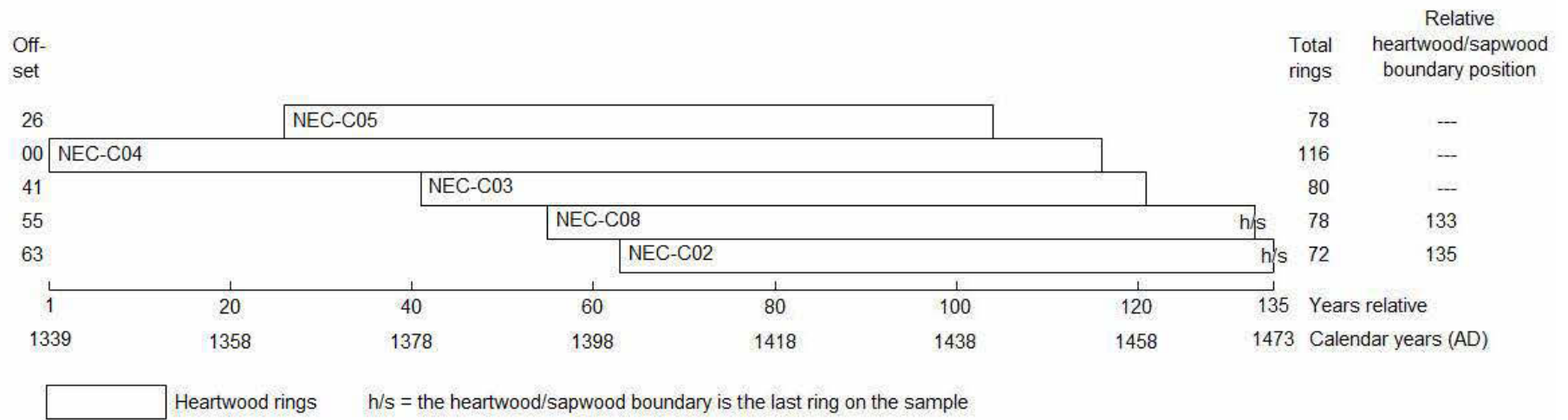


Figure 54: Bar diagram of samples from the South Porch roof in site sequence NECCSQ03

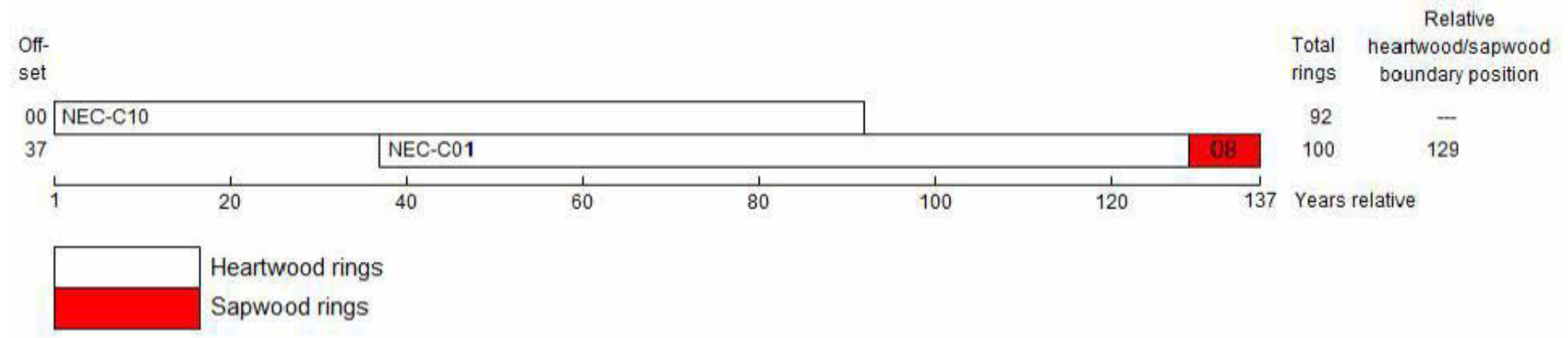


Figure 55: Bar diagram of samples from the South Porch roof in undated site sequence NECCSQ04

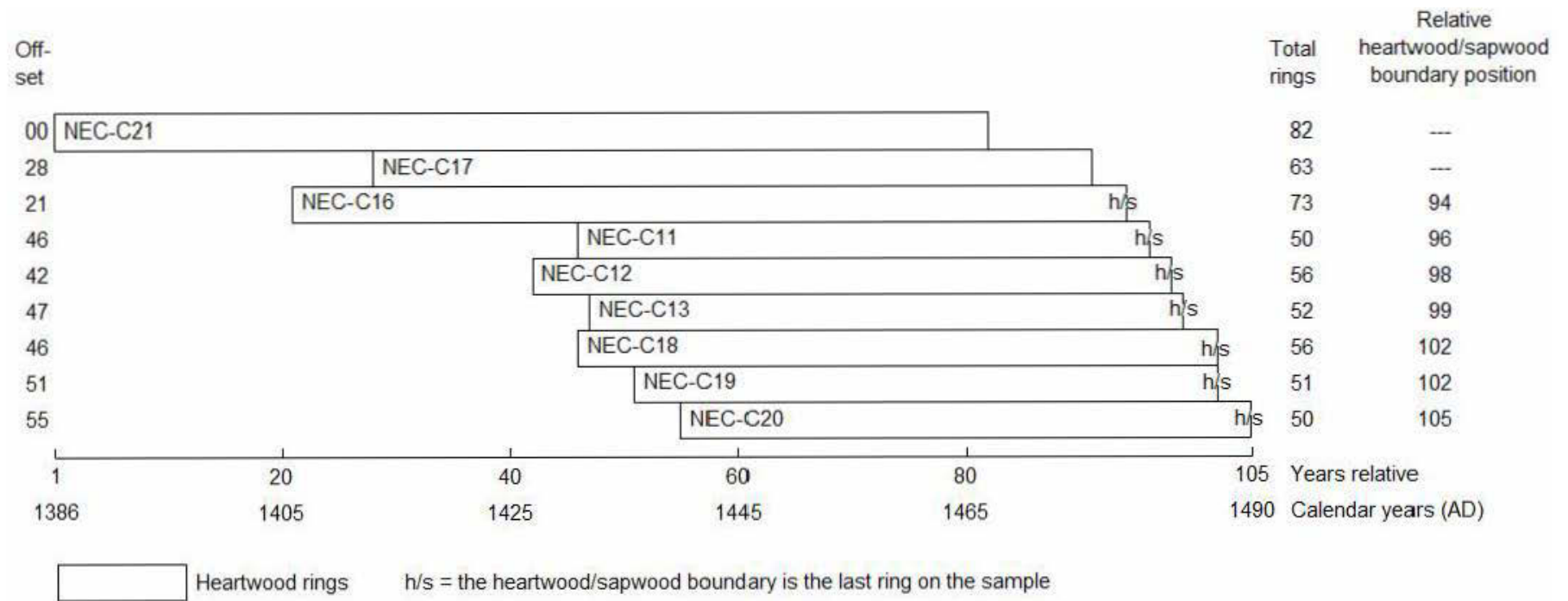


Figure 56: Bar diagram of samples from the Vestry roof in site sequence NECCSQ05

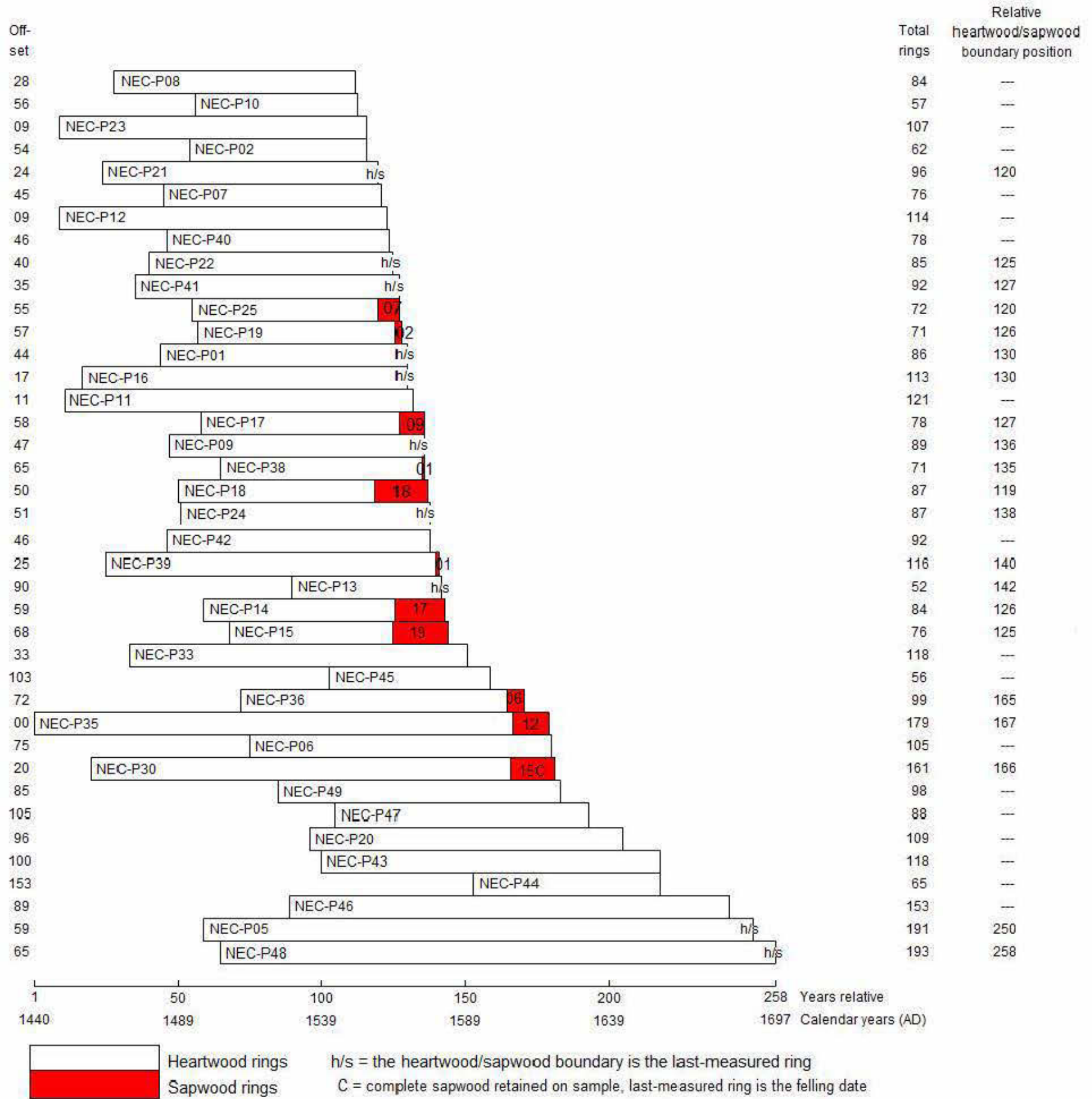


Figure 57: Bar diagram of samples from the pew bench ends in site sequence NECPSQ01

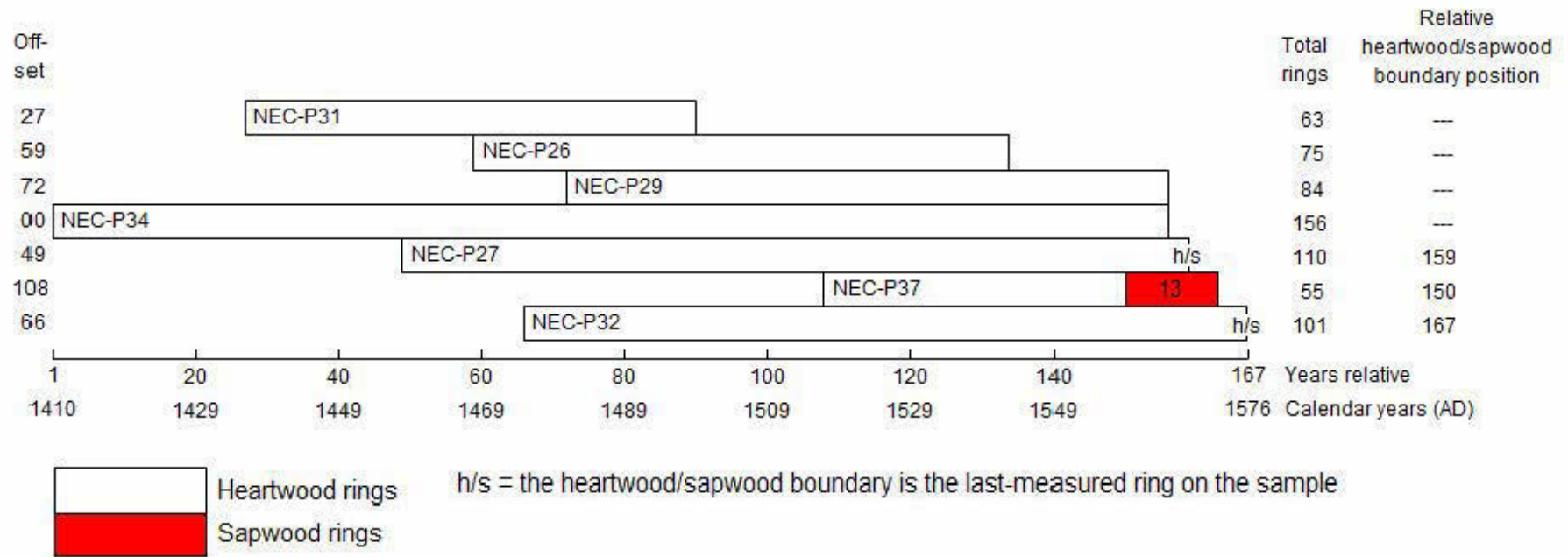


Figure 58: Bar diagram of the samples from the pew bench ends in site sequence NECPSQ02



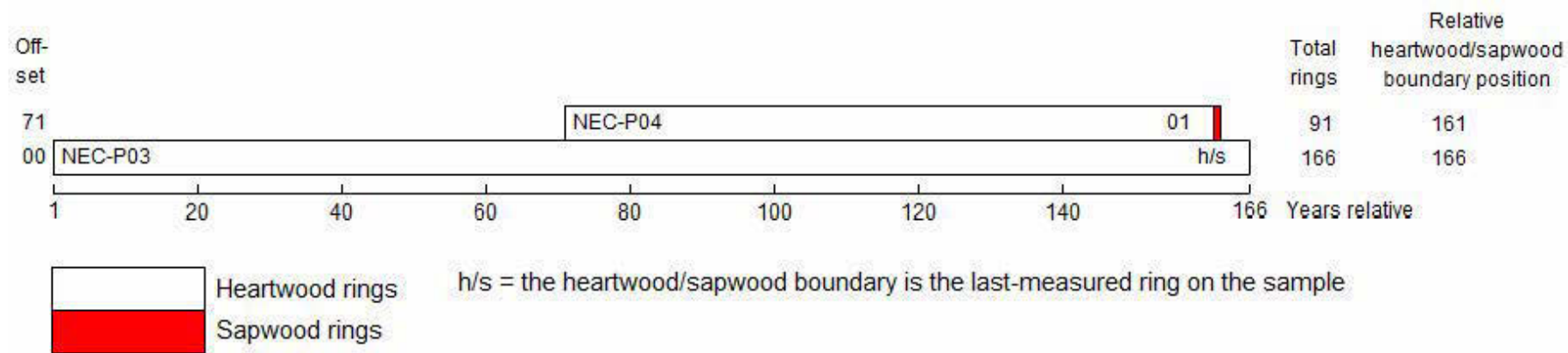


Figure 59: Bar diagram of samples from the pew bench ends in undated site sequence NECPSQ03

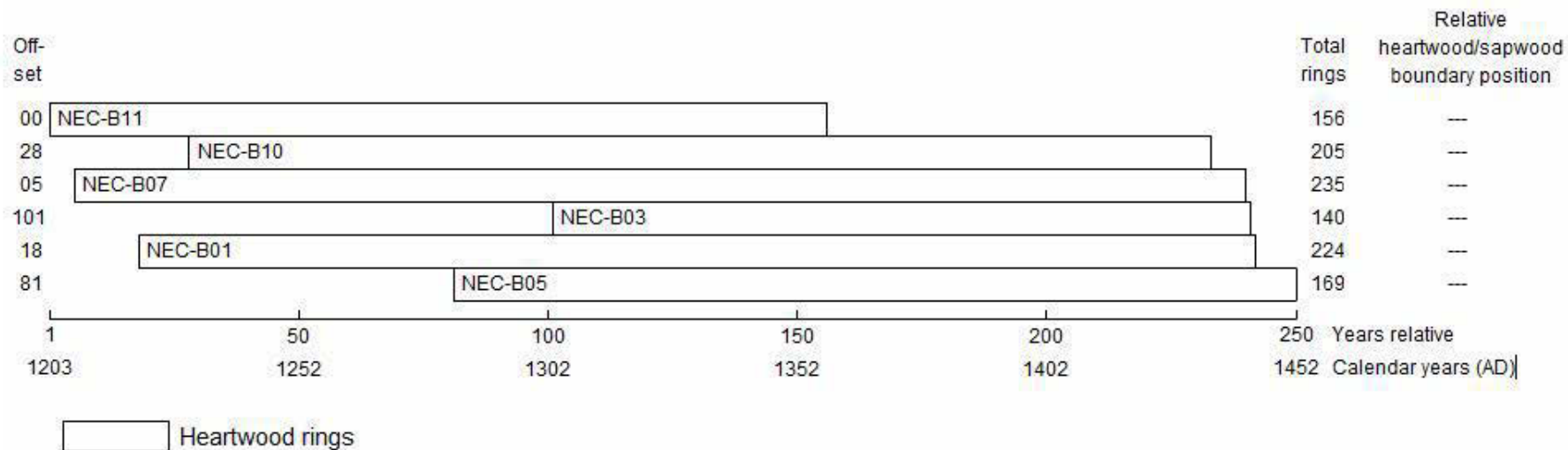


Figure 60: Bar diagram of samples from the nave ceiling boards in site sequence NECBSQ01

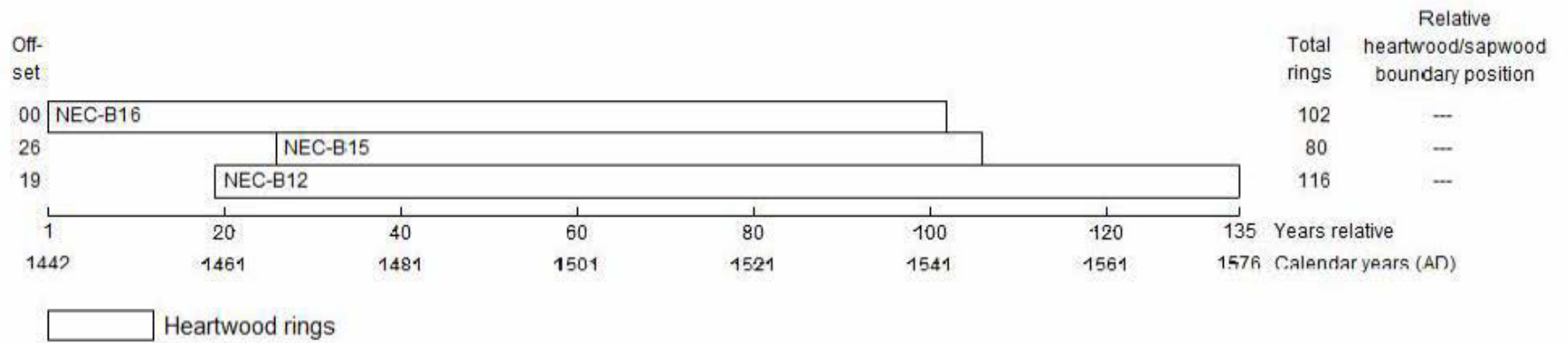


Figure 61: Bar diagram of samples from the pulpit boards in site sequence NECBSQ02

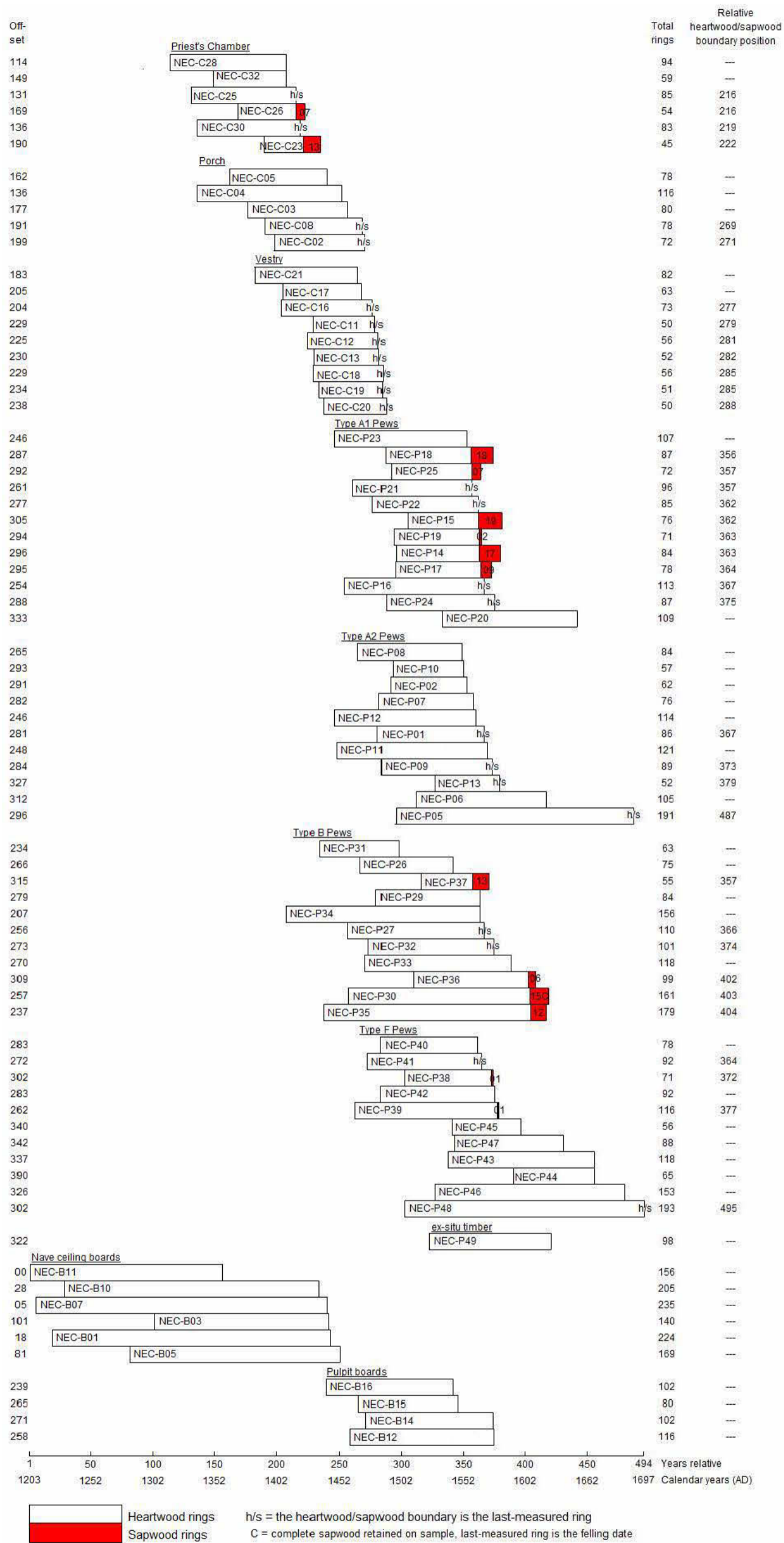


Figure 62: Bar diagram of all dated samples

## DATA OF MEASURED SAMPLES

Measurements in 0.01mm units

NEC-C01A 100

59 83 61 94 140 129 137 118 159 165 136 108 137 145 146 114 160 98 107 144  
176 125 82 153 91 70 85 124 110 131 71 57 63 78 65 63 62 58 55 57  
55 75 92 83 81 87 63 93 82 87 101 116 110 144 153 96 111 123 78 85  
128 92 114 155 112 144 120 100 100 90 94 108 102 109 113 140 116 89 87 99  
62 79 63 124 103 86 73 116 120 91 80 86 51 62 52 59 78 64 69 68

NEC-C01B 100

60 78 66 88 127 96 132 127 154 163 138 110 128 153 146 124 160 107 107 153  
174 131 84 151 84 72 82 123 107 135 75 54 64 78 63 66 66 50 60 49  
62 75 88 80 77 88 69 95 87 79 106 124 121 148 143 89 110 121 71 95  
131 104 124 160 108 149 118 106 100 88 104 115 115 104 118 132 117 90 85 100  
61 78 68 119 107 87 69 105 106 93 80 83 62 60 57 52 74 72 60 79

NEC-C02A 72

183 198 237 147 242 175 187 146 165 116 123 126 120 119 129 176 180 71 113 141  
91 137 127 84 68 95 130 115 96 97 147 126 117 133 110 109 80 90 109 161  
133 144 141 83 107 94 134 152 97 101 85 73 115 113 133 124 120 82 124 119  
117 166 111 84 124 101 114 71 123 100 83 73

NEC-C02B 72

160 194 230 151 244 169 185 149 143 144 116 130 125 114 137 176 192 79 119 140  
103 123 124 93 66 95 112 120 105 88 142 125 98 129 141 91 82 87 113 155  
153 140 146 72 97 104 135 158 94 107 77 71 117 130 145 118 118 97 119 131  
119 161 105 84 117 107 112 77 133 105 87 74

NEC-C03A 80

191 135 209 211 160 84 124 129 134 113 62 101 118 142 178 267 255 177 102 61  
51 47 74 106 123 91 122 84 75 37 56 41 43 247 302 161 108 131 158 112  
113 99 98 171 233 157 196 293 378 399 439 350 426 250 206 321 277 290 209 133  
226 217 218 190 201 174 182 155 185 145 156 161 135 159 246 179 178 177 226 194

NEC-C03B 80

191 132 203 211 172 132 191 173 141 116 65 98 108 148 183 226 265 182 98 62  
52 47 76 106 122 94 121 82 70 45 52 41 40 253 299 162 112 131 157 116  
112 100 97 168 223 146 198 223 402 393 442 345 431 246 208 325 276 293 208 132  
227 214 214 182 204 178 186 156 192 145 155 166 133 161 249 176 177 177 231 184

NEC-C04A 116

345 200 186 176 142 131 145 97 63 76 115 50 106 113 129 75 61 73 96 59  
73 46 64 39 58 53 23 35 41 23 35 23 21 26 35 62 59 38 33 28  
42 49 78 84 117 88 42 69 124 139 120 73 111 128 148 85 146 186 175 136  
93 56 53 87 120 81 82 141 113 111 69 62 53 52 107 138 124 142 189 159  
114 123 90 68 95 95 101 91 93 125 100 78 77 96 67 101 177 252 197 169  
94 147 222 163 185 198 186 180 184 285 246 221 271 198 190 189

NEC-C04B 116

352 195 192 169 153 116 142 94 54 75 111 46 109 112 115 83 69 81 100 60  
70 46 65 49 59 54 27 35 38 23 28 34 19 25 38 57 56 40 26 29  
41 63 72 90 121 90 42 63 122 143 120 72 113 128 141 93 147 185 170 133  
94 54 54 92 118 74 89 140 113 107 63 59 57 53 112 134 122 143 186 164  
119 118 96 60 99 103 99 87 94 129 92 80 74 100 72 92 190 239 193 170  
92 145 214 170 183 192 189 180 203 287 249 232 263 196 190 189

NEC-C05A 78

115 148 177 119 176 183 100 88 68 134 75 78 42 65 71 89 79 171 147 101

87 83 77 95 100 57 50 64 59 52 61 67 57 42 37 28 22 24 45 24  
31 38 38 63 27 39 27 30 63 62 75 77 114 105 90 84 74 48 59 81  
63 75 71 124 161 182 167 253 266 262 442 422 535 391 234 242 334 365

NEC-C05B 78

100 135 176 122 177 196 94 81 70 132 77 73 52 66 67 83 85 168 150 108  
90 89 78 101 98 58 58 59 59 56 55 61 58 37 33 34 26 19 45 30  
27 45 46 60 29 32 32 44 51 68 71 81 113 117 85 89 68 49 67 73  
74 66 69 129 187 193 172 247 282 278 433 461 514 388 250 248 342 362

NEC-C06A 92

172 91 144 82 113 181 100 178 111 102 118 146 151 94 111 109 123 158 68 131  
113 102 66 86 108 102 60 75 90 49 101 68 48 87 86 52 103 109 61 96  
48 44 45 39 33 21 19 13 35 10 22 21 17 22 18 16 24 71 61 39  
58 55 56 128 118 75 130 90 217 115 118 103 99 115 113 223 282 218 204 191  
214 203 138 139 140 130 201 175 123 277 143 311

NEC-C06B 92

156 92 144 82 114 180 85 170 115 85 125 152 162 81 131 110 117 151 90 115  
112 111 64 80 102 99 61 75 104 52 106 58 49 84 81 48 98 109 62 94  
53 42 46 35 38 28 26 17 30 11 15 13 22 21 25 14 25 63 61 28  
56 52 57 122 111 66 120 85 226 117 128 104 100 126 120 228 288 217 208 196  
213 207 135 139 133 140 204 196 120 277 153 308

NEC-C08A 78

103 126 143 110 108 101 78 92 71 90 111 79 119 107 105 123 102 48 83 97  
119 110 92 119 111 60 91 102 71 104 92 72 82 74 132 119 91 104 151 113  
89 146 117 123 77 52 60 74 67 96 109 90 91 83 106 137 104 112 112 73  
118 132 210 192 285 202 258 234 163 234 154 103 160 156 160 123 115 152

NEC-C08B 78

101 140 140 107 115 103 75 94 71 89 110 78 122 104 107 120 95 61 81 94  
128 90 92 109 119 62 94 110 71 104 85 76 82 74 126 125 88 96 148 115  
92 142 120 99 82 53 66 66 68 99 106 86 91 93 108 123 91 118 126 72  
116 143 199 186 277 190 265 212 149 215 163 108 152 162 159 125 119 138

NEC-C10A 92

127 140 105 114 128 106 95 87 128 113 218 192 169 185 218 183 171 108 143 146  
136 89 74 78 67 122 88 70 93 49 51 77 128 111 89 103 79 66 43 37  
62 56 45 51 39 38 30 28 29 43 97 116 92 113 93 81 68 82 45 43  
56 40 35 57 70 66 70 53 35 44 47 45 36 42 40 52 45 34 33 42  
25 29 37 28 35 33 33 32 40 33 21 38

NEC-C10B 92

137 144 110 116 137 112 82 92 126 126 183 202 164 193 212 182 176 107 148 151  
144 94 81 79 70 113 94 70 95 40 52 83 129 125 93 100 95 62 42 41  
58 62 49 55 35 41 26 29 35 47 100 111 103 104 104 82 71 79 48 42  
52 42 40 57 67 69 66 54 29 46 43 46 35 44 39 53 44 32 29 39  
25 29 35 29 39 29 30 42 34 30 24 33

NEC-C11A 35

356 332 362 254 253 318 257 344 317 383 328 388 280 327 294 249 257 171 229 257  
257 264 246 280 223 180 190 207 284 221 185 168 239 171 184

NEC-C11B 43

532 364 353 548 463 404 318 164 214 223 201 272 304 297 311 305 340 296 185 205  
237 218 283 260 310 249 248 163 227 196 168 155 107 147 188 185 209 199 233 158  
115 135 173

NEC-C12A 56

220 285 291 228 387 210 258 368 272 186 191 115 155 166 141 130 154 211 149 155  
153 190 105 152 106 122 106 140 178 127 163 142 171 170 135 134 80 120 119 105  
119 95 141 115 74 101 87 149 178 140 78 123 95 100 96 83

NEC-C12B 56

269 282 283 241 388 211 257 374 260 191 189 115 143 175 143 128 157 207 156 150  
158 194 108 151 109 116 110 156 183 117 170 140 171 166 140 131 87 114 110 106  
119 107 134 116 71 101 83 147 184 135 77 115 97 103 96 89

NEC-C13A 39

432 402 532 451 361 319 318 395 422 357 439 316 269 326 354 370 405 290 423 293  
257 342 218 240 225 157 146 181 182 176 185 137 193 239 275 268 104 122 141

NEC-C13B 51

360 485 438 324 313 296 346 384 335 417 329 268 328 352 323 337 264 306 250 205  
290 184 214 200 184 146 193 209 158 135 152 196 243 248 221 112 132 166 103 158  
187 304 331 194 172 190 176 196 166 199 128

NEC-C14A 51

237 305 356 366 372 282 269 276 252 349 280 206 196 203 257 145 258 183 189 201  
137 298 195 206 179 228 277 165 104 71 121 233 176 264 211 185 227 180 197 179  
147 126 143 198 231 188 183 264 258 188 163

NEC-C14B 51

204 313 355 362 374 283 270 271 252 351 280 205 195 203 232 152 249 195 185 201  
145 305 200 207 178 233 268 170 97 76 125 242 181 270 214 190 239 181 197 179  
144 130 138 193 232 179 188 251 243 183 155

NEC-C15A 54

131 132 309 217 232 235 278 250 171 225 217 169 157 173 332 203 272 172 181 242  
312 181 272 298 244 147 243 296 203 217 130 202 133 154 148 180 270 156 211 240  
216 213 128 134 164 135 184 135 142 105 122 109 110 115

NEC-C15B 54

134 126 318 204 236 235 261 257 185 235 220 166 151 175 336 203 280 169 183 231  
303 184 276 300 249 147 251 292 202 219 138 212 140 145 156 180 258 157 209 236  
223 219 124 133 165 134 180 144 134 127 115 115 113 108

NEC-C16A 73

162 240 238 197 281 300 278 321 310 246 300 313 202 293 358 289 341 282 227 370  
232 312 225 198 234 257 177 176 326 323 167 163 98 152 154 139 121 118 171 133  
127 140 147 104 130 130 120 129 142 177 154 188 150 181 177 156 161 116 126 173  
221 208 139 208 195 149 152 181 200 223 182 138 142

NEC-C16B 73

169 232 241 191 280 294 274 329 312 246 303 303 201 307 363 270 309 281 222 372  
223 316 231 197 245 252 176 169 312 327 155 162 105 159 157 137 121 116 170 138  
124 143 146 103 137 128 119 132 136 182 149 192 137 191 201 155 165 121 123 161  
219 232 127 207 190 149 150 193 197 208 174 145 141

NEC-C17A 63

365 571 404 413 391 225 298 323 255 329 325 254 323 268 338 226 224 252 304 245  
233 283 252 157 252 194 181 211 189 172 164 252 198 187 240 209 184 221 197 217  
247 280 268 247 282 182 302 334 265 254 160 161 247 234 272 182 241 201 109 135  
125 205 244

NEC-C17B 63

345 582 409 371 397 237 328 318 257 358 331 239 342 266 359 228 221 248 307 263  
222 292 239 173 241 187 176 218 182 172 158 246 197 177 203 220 205 215 196 211  
251 284 279 257 286 185 305 314 265 255 159 166 254 230 264 164 252 210 115 133  
119 199 242

NEC-C18A 56

438 279 392 433 320 192 142 104 130 163 159 150 182 178 150 173 167 161 102 161  
167 180 198 172 175 166 171 81 131 128 115 143 107 115 156 178 198 158 191 167  
96 94 116 175 221 152 109 124 138 122 136 142 130 160 172 192

NEC-C18B 56

384 271 378 441 314 195 118 129 132 160 160 145 185 180 143 174 168 160 108 170



161 181 192 176 171 165 172 75 130 131 112 143 114 109 156 180 196 157 195 160  
91 99 105 183 212 156 112 125 126 131 133 130 146 166 164 193

NEC-C19A 51

260 210 260 292 452 267 387 353 407 283 288 323 321 231 312 264 204 303 343 438  
377 358 241 327 296 245 218 171 193 212 315 289 206 271 261 192 180 135 169 197  
214 174 221 176 202 239 268 228 205 174 224

NEC-C19B 51

276 221 259 287 451 285 373 348 393 280 285 323 314 227 313 261 202 291 329 437  
375 360 235 329 299 242 224 168 196 217 312 290 204 276 257 187 173 125 172 198  
220 177 218 174 203 237 270 225 201 174 221

NEC-C20A 50

174 155 168 213 210 169 189 175 184 150 214 195 227 183 171 226 180 226 127 184  
176 149 161 129 130 179 220 231 180 199 199 117 105 108 159 190 162 140 134 151  
125 150 178 171 189 191 194 161 102 100

NEC-C20B 50

171 155 165 214 210 173 193 171 181 159 206 184 207 184 183 222 183 233 131 182  
181 136 163 133 132 176 212 233 179 195 205 103 124 101 168 187 165 116 135 143  
133 157 174 172 188 194 197 166 100 109

NEC-C21A 82

373 278 199 179 128 146 70 107 111 188 297 313 422 229 257 255 158 155 148 125  
130 144 167 137 107 140 162 158 148 141 170 157 150 109 187 120 128 199 172 136  
151 80 126 111 122 155 150 123 120 179 115 87 57 52 57 88 87 121 98 80  
85 90 111 119 78 90 96 86 93 100 91 84 93 84 93 100 129 159 88 123  
140 122

NEC-C21B 82

356 281 196 186 113 142 87 102 113 175 293 303 423 233 268 251 165 165 150 137  
143 150 174 136 104 145 156 162 147 144 172 157 146 111 189 120 134 192 167 140  
150 84 124 111 121 156 149 131 108 176 118 83 58 54 57 96 78 123 96 82  
90 95 108 120 80 88 95 89 91 100 99 77 95 84 92 101 128 164 91 117  
144 133

NEC-C23A 39

145 253 267 407 199 184 240 262 162 174 127 181 135 171 161 224 125 163 141 207  
193 214 267 248 207 214 136 311 129 131 333 279 317 415 166 160 168 223 327

NEC-C23B 34

149 173 188 197 250 142 136 116 119 105 127 133 191 156 230 130 253 192 187 367  
351 317 393 184 199 151 155 167 205 201 211 391 303 183

NEC-C25A 85

211 247 140 201 258 211 179 172 173 180 138 252 193 170 159 213 131 295 120 156  
119 127 106 133 120 89 79 63 46 79 108 79 93 85 72 72 87 61 60 74  
65 55 47 36 24 46 67 43 60 49 76 64 89 91 85 85 66 109 83 91  
61 74 117 88 97 113 93 116 68 102 94 77 81 67 75 97 44 41 38 51  
63 72 71 75 90

NEC-C25B 85

197 252 122 200 224 209 180 172 175 182 138 246 193 166 163 211 132 294 123 162  
97 147 106 131 124 85 80 63 48 79 105 77 88 81 75 76 85 62 57 74  
66 53 49 32 40 42 65 44 63 49 75 66 92 94 85 85 63 110 84 98  
61 74 115 82 88 106 94 108 73 118 91 79 79 70 83 94 45 39 35 58  
65 73 65 78 82

NEC-C26A 54

60 47 43 37 50 86 139 378 170 157 185 259 206 185 342 328 214 103 76 120  
170 327 387 378 623 389 468 455 370 167 108 141 118 125 191 194 346 205 268 293  
286 208 215 222 157 143 196 133 341 262 227 335 212 305

NEC-C26B 54

45 38 39 43 52 72 148 374 244 171 180 254 209 186 358 309 221 93 76 112  
158 311 409 373 606 383 420 465 342 167 108 144 119 124 184 181 346 203 270 333  
285 213 213 226 161 139 198 127 341 248 226 336 200 299

NEC-C27A 64

186 173 109 122 92 167 146 105 110 88 79 71 52 48 66 47 51 43 38 42  
54 74 65 50 58 93 134 111 169 213 228 266 180 179 220 428 228 182 290 240  
251 184 111 159 87 143 113 109 217 205 255 190 177 103 94 96 111 104 126 161  
139 101 143 92

NEC-C27B 64

155 181 109 118 100 167 137 105 122 76 82 60 64 51 73 44 54 49 27 44  
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248 181 123 170 95 147 115 114 211 202 253 200 178 107 89 88 111 105 120 140  
145 104 146 93

NEC-C28A 94

304 271 385 324 278 286 238 133 94 84 160 96 223 221 71 161 202 163 208 110  
131 126 115 109 103 104 64 60 79 71 96 117 121 109 167 100 91 88 98 61  
78 77 79 51 62 40 84 124 69 140 102 49 51 48 36 44 51 74 45 57  
58 60 105 94 93 122 115 85 68 105 86 80 89 65 135 61 68 56 62 105  
67 55 96 85 124 79 112 95 79 90 89 137 108 140

NEC-C28B 94

304 271 387 326 277 287 237 136 106 76 163 104 219 228 80 155 193 159 212 109  
136 133 114 106 107 101 69 56 83 70 98 114 127 105 164 103 96 88 97 57  
72 85 74 57 60 37 91 118 76 133 99 53 53 46 34 38 62 69 57 43  
44 58 119 96 82 124 103 85 66 104 87 82 86 66 137 61 64 58 64 106  
58 57 105 78 131 76 113 95 79 92 87 133 117 125

NEC-C29A 51

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63 89 54 68 97 98 63 79 72 94 63 89 97 118 96 83 80 93 65 66  
41 46 36 64 47 52 41 41 49 54 56

NEC-C29B 65

140 128 114 121 128 81 70 77 75 62 79 85 56 59 33 63 56 56 55 55  
58 50 53 77 96 98 64 78 69 77 54 84 87 129 82 83 79 94 69 62  
40 49 27 37 40 35 45 26 37 41 59 48 35 21 33 18 19 20 23 23  
20 35 33 47 39

NEC-C30A 83

157 168 142 181 167 153 227 157 153 125 125 102 194 143 143 138 139 119 108 106  
91 67 89 74 124 127 95 82 90 75 83 77 90 74 91 73 98 97 151 180  
155 141 125 80 136 175 90 142 202 203 212 118 221 119 133 133 160 201 150 122  
125 148 238 149 131 117 110 151 146 176 175 134 105 105 120 111 135 98 97 129  
89 152 169

NEC-C30B 83

153 167 151 181 162 156 197 156 157 129 123 101 199 135 159 137 140 116 109 104  
91 67 93 67 128 130 87 97 91 75 72 85 82 85 89 72 85 114 148 177  
153 139 133 74 131 160 95 143 201 201 213 121 221 116 133 133 166 198 147 132  
122 146 238 145 134 113 115 142 155 172 167 142 106 107 115 114 135 94 100 133  
93 148 170

NEC-C31A 62

301 249 240 226 250 217 156 168 164 173 168 186 215 258 259 148 177 217 193 377  
391 520 639 396 379 303 198 128 85 77 93 116 235 268 271 215 285 338 311 173  
208 218 172 110 105 176 91 93 172 137 125 109 86 79 70 71 80 117 132 99  
140 96

NEC-C31B 62

262 237 204 203 253 229 173 188 162 185 170 194 232 250 232 137 173 202 213 422

465 524 632 386 393 305 192 129 87 66 98 103 267 268 293 208 282 343 308 180  
215 221 171 114 104 173 95 94 169 138 129 97 93 102 71 68 83 112 137 97  
144 99

NEC-C32A 59

108 127 96 112 130 172 200 136 131 142 138 156 169 120 118 141 161 215 234 252  
325 237 255 208 200 275 360 435 333 308 239 260 260 360 426 391 299 209 206 214  
202 276 289 344 447 272 250 247 279 196 150 131 138 102 95 85 106 107 132

NEC-C32B 59

146 127 100 104 136 181 192 150 133 134 137 156 163 130 133 125 163 217 255 272  
344 249 263 211 191 245 321 393 334 308 237 270 248 364 433 384 304 208 202 217  
207 278 295 349 442 280 241 261 260 195 179 121 144 99 108 81 106 115 119

NEC-C33A 75

275 234 197 364 240 201 258 194 174 172 217 195 139 126 73 133 126 67 93 85  
93 89 64 56 76 49 63 51 47 34 50 53 44 33 32 70 81 59 105 151  
137 77 75 86 117 129 131 89 83 80 121 108 71 52 65 76 113 154 102 131  
157 148 113 78 62 79 96 107 141 107 128 89 96 163 164

NEC-C33B 75

288 252 207 360 231 211 247 208 168 180 217 197 135 127 75 143 131 67 97 79  
89 87 67 60 81 38 65 51 45 36 50 65 39 28 42 66 81 60 110 155  
142 70 96 81 112 141 114 90 77 87 111 97 67 63 60 79 106 156 100 136  
151 152 121 73 70 81 104 107 109 103 139 92 113 149 157

NEC-C34A 77

197 237 150 112 99 106 111 176 144 185 85 80 44 59 51 47 47 40 54 129  
187 191 176 125 124 124 90 88 66 61 46 57 47 49 53 48 90 74 125 121  
89 112 127 200 275 278 341 161 142 151 315 312 292 435 657 425 432 408 269 163  
208 149 126 118 131 219 363 296 322 199 351 272 200 277 272 237 249

NEC-C34B 77

220 242 151 105 103 109 104 181 142 182 93 72 51 64 50 45 49 45 46 132  
186 198 172 131 124 122 99 82 68 60 49 63 44 50 51 53 76 98 107 106  
114 103 116 190 232 292 341 173 157 165 313 307 309 452 634 505 489 407 264 158  
195 161 144 135 109 216 369 289 319 201 372 260 218 287 275 227 206

NEC-C35A 59

231 268 261 268 254 283 356 315 186 193 162 222 142 220 227 278 258 210 282 176  
217 225 154 222 175 165 208 168 271 237 159 117 154 171 177 174 150 175 164 234  
211 249 191 151 157 213 195 192 92 181 112 106 132 109 158 164 159 197 122

NEC-C35B 59

237 258 280 253 264 277 359 327 203 201 164 218 138 229 236 281 256 211 295 161  
218 227 153 204 165 157 207 166 273 239 170 118 157 173 157 192 154 174 164 231  
215 246 189 152 166 209 218 173 91 167 101 114 136 125 158 136 180 182 123

NEC-C36A 155

51 45 40 48 111 100 53 56 82 54 60 78 55 49 57 44 48 30 45 41  
53 55 44 41 47 27 35 42 37 44 72 50 73 40 37 32 67 64 75 74  
52 50 54 46 40 37 50 50 44 31 41 85 77 110 119 113 115 210 246 214  
141 124 172 136 119 104 123 115 92 57 62 107 101 77 120 81 87 94 108 84  
75 89 76 73 82 52 61 56 46 36 36 42 43 51 58 44 27 53 64 69  
72 58 94 65 107 72 72 82 96 102 121 72 69 67 39 56 64 65 89 83  
70 62 70 67 76 57 58 47 65 74 61 68 51 62 107 75 63 81 74 68  
72 64 59 69 59 55 69 77 79 81 65 80 67 86 80

NEC-C36B 155

45 48 40 49 110 95 58 54 93 51 62 76 54 49 56 46 42 34 44 37  
55 51 43 44 46 34 32 43 39 38 70 57 70 46 34 31 68 59 68 80  
49 46 57 49 34 38 54 49 40 32 45 79 79 114 110 117 117 203 245 212  
142 122 175 132 122 96 144 104 102 54 65 104 94 86 95 74 86 95 110 83

77 88 79 61 78 57 57 65 43 37 47 51 41 45 59 44 29 59 62 59  
72 60 92 68 108 73 71 86 88 108 112 87 63 65 38 58 60 67 90 88  
64 62 70 71 73 52 64 42 71 71 67 62 57 59 97 80 63 86 69 74  
68 64 63 66 58 57 73 71 76 81 58 88 70 85 75

NEC-P01A 86

389 475 424 339 206 159 167 96 112 144 129 213 300 272 168 189 234 149 165 198  
332 148 151 80 102 118 196 174 156 114 109 51 40 46 51 101 46 91 92 66  
40 40 44 45 45 36 34 99 80 64 96 64 133 141 149 98 131 102 47 82  
55 32 36 52 68 114 99 158 104 99 122 90 54 90 95 167 197 166 156 119  
138 154 127 81 65 112

NEC-P01B 86

360 479 416 329 224 159 167 99 106 151 134 216 299 274 167 182 230 152 169 202  
328 158 143 75 104 131 178 180 160 110 109 38 38 40 65 93 50 92 93 67  
44 45 39 44 44 38 33 97 76 62 102 59 123 160 150 96 134 104 48 93  
51 37 36 55 60 115 99 156 105 95 118 91 58 85 89 180 197 167 154 116  
141 149 139 89 65 104

NEC-P02A 62

106 178 231 270 162 189 171 115 117 205 378 346 244 134 171 220 257 332 224 266  
235 190 137 127 144 240 182 250 239 216 193 184 183 239 288 286 267 296 194 181  
168 206 173 193 151 167 168 190 118 130 73 93 110 245 248 429 442 398 334 291  
281 206

NEC-P02B 62

99 190 245 248 181 210 144 117 121 220 362 371 238 136 169 210 274 341 227 251  
242 192 134 120 153 243 181 250 242 216 203 183 178 241 290 295 263 296 195 181  
169 204 176 195 149 164 172 191 118 128 80 95 131 219 250 425 435 403 324 290  
284 212

NEC-P03A 166

168 135 139 117 108 114 148 91 113 179 113 143 94 150 79 112 69 92 69 115  
51 64 63 33 55 41 55 79 76 57 53 42 55 51 37 44 51 61 48 41  
51 26 53 66 41 25 42 36 34 30 26 22 24 16 26 22 16 17 14 24  
25 18 26 32 50 50 49 85 96 147 183 172 158 166 124 87 127 118 110 173  
115 138 97 99 66 78 79 45 39 32 31 27 21 25 39 47 36 43 36 35  
50 44 46 46 47 43 47 44 29 29 29 32 38 44 35 33 36 35 20 29  
28 26 16 22 26 15 20 20 14 21 27 26 32 48 49 85 67 58 102 84  
100 140 57 47 69 60 72 90 100 44 57 38 74 69 71 136 85 139 68 89  
75 97 66 121 167 138

NEC-P03B 166

157 136 143 115 104 130 127 84 129 168 111 147 96 144 87 115 72 92 72 118  
48 63 69 31 47 50 51 83 81 53 47 57 48 55 30 48 51 63 43 47  
45 21 57 72 30 33 45 35 33 28 24 24 24 22 27 23 26 21 17 17  
29 18 26 29 47 49 50 71 101 156 179 164 167 156 118 92 115 124 116 167  
102 140 96 88 76 70 78 44 41 31 29 23 24 27 31 52 40 42 38 34  
49 47 43 29 62 47 45 39 35 27 23 32 37 48 35 33 36 39 30 30  
29 27 17 23 17 16 24 15 23 29 22 27 31 52 48 94 73 57 103 84  
101 139 61 49 68 66 68 91 94 55 52 39 75 72 68 140 96 134 70 92  
83 82 72 119 164 150

NEC-P04A 91

105 128 172 74 77 80 131 131 191 81 143 82 92 76 111 100 61 61 46 44  
51 43 72 83 131 136 135 64 68 72 84 67 49 62 63 51 48 44 50 45  
32 51 54 32 41 36 41 38 36 44 46 28 31 34 25 23 26 30 22 36  
30 32 47 36 59 52 32 51 47 69 67 48 38 67 68 66 85 65 50 56  
48 84 74 54 68 65 112 58 88 69 76

NEC-P04B 91

89 118 164 97 94 90 112 130 159 118 137 89 99 67 110 116 65 60 42 48  
56 39 80 80 131 143 136 63 67 74 82 66 48 63 58 58 47 53 55 41  
35 48 56 30 39 37 41 39 34 36 48 31 30 32 23 22 27 33 21 24  
41 38 41 37 55 53 44 46 43 79 67 47 45 62 57 72 82 71 50 56  
44 84 63 56 65 71 111 59 98 82 74

NEC-P05A 191

199 178 142 105 141 226 181 154 92 88 112 71 108 172 168 154 93 72 94 69  
121 70 163 111 88 58 107 74 131 158 116 119 150 133 112 79 170 96 83 117  
232 151 119 74 84 63 65 67 75 78 111 107 122 87 83 78 83 48 85 83  
138 101 107 93 68 77 60 63 45 40 55 67 86 80 72 80 83 61 60 46  
69 52 65 61 36 51 43 39 43 45 61 43 54 53 46 61 83 78 90 83  
62 46 52 76 63 94 58 70 60 67 53 73 90 53 53 39 29 42 48 54  
44 68 72 65 73 41 49 58 61 47 67 71 58 70 57 42 52 43 66 45  
38 59 62 40 50 54 74 72 41 41 54 51 52 46 45 58 92 50 46 48  
52 52 55 44 63 51 82 64 65 43 36 39 52 76 87 58 50 57 58 54  
47 79 51 70 72 53 52 63 53 40 57

NEC-P05B 191

201 185 144 99 144 229 187 149 97 83 115 72 97 177 166 158 97 80 89 73  
123 94 156 108 84 59 119 75 126 155 111 113 157 138 104 91 167 96 91 108  
250 151 119 77 80 68 77 66 73 77 111 102 125 93 79 83 80 51 81 87  
135 108 100 95 63 85 68 72 46 40 53 67 84 82 72 81 82 71 52 48  
64 51 68 65 42 55 44 39 45 46 65 42 53 51 53 61 80 78 89 93  
68 53 59 73 71 87 62 67 66 65 53 78 68 64 47 43 36 39 40 47  
43 73 61 81 75 44 52 60 60 53 71 65 53 72 63 44 43 49 64 42  
48 60 60 44 48 56 65 74 51 61 52 53 49 46 50 55 90 49 41 50  
54 57 46 47 64 54 84 63 65 46 37 47 42 83 88 55 54 49 65 61  
42 84 55 68 77 50 52 67 38 36 50

NEC-P06A 105

146 145 121 140 191 126 165 155 112 115 116 93 82 72 70 54 129 103 106 86  
137 82 116 86 125 147 107 60 123 98 69 69 90 95 102 101 68 67 70 68  
64 48 71 78 112 88 80 97 51 54 102 53 49 64 48 54 57 65 50 74  
61 44 61 46 58 52 66 53 53 66 48 46 73 46 117 74 119 123 90 134  
150 110 136 145 98 88 110 131 116 130 78 112 66 93 45 72 65 46 66 31  
35 37 32 49 44

NEC-P06B 105

135 154 155 144 171 125 180 152 114 118 99 105 77 73 65 54 120 92 108 95  
118 100 110 85 124 156 100 63 128 104 55 75 87 87 97 99 66 66 76 64  
63 47 66 85 112 85 84 96 54 65 91 55 54 57 54 53 52 67 55 68  
76 43 59 38 71 49 70 63 49 69 51 44 66 53 114 77 116 122 90 126  
144 109 125 146 96 90 110 137 110 124 85 112 68 87 45 70 74 49 51 39  
36 39 34 49 49

NEC-P07A 76

389 238 398 310 348 431 367 321 262 319 430 584 454 292 448 458 238 230 145 254  
179 126 101 115 130 120 197 223 130 162 138 92 102 127 213 122 231 172 149 165  
183 162 179 288 161 109 120 103 106 131 153 142 139 151 172 157 135 75 114 74  
44 77 93 95 140 162 204 123 93 152 169 82 131 146 203 181

NEC-P07B 76

397 241 396 304 354 438 364 324 264 322 438 578 453 300 438 460 240 214 143 261  
173 108 105 118 128 118 200 222 163 131 132 85 92 135 211 118 236 166 142 164  
189 161 180 290 153 110 111 100 101 111 161 138 143 135 164 156 136 73 114 73  
48 68 100 95 139 167 202 132 93 143 171 81 132 137 212 189

NEC-P08A 84

169 124 149 145 171 136 274 377 267 238 171 365 244 224 167 194 340 309 239 250

179 140 168 102 74 94 77 120 213 164 102 143 117 112 127 139 208 122 70 86  
87 107 122 99 108 135 143 96 69 65 42 31 16 49 75 52 41 45 61 60  
88 105 78 70 66 75 76 77 106 79 100 131 214 264 109 145 104 80 57 138  
138 297 190 182

NEC-P08B 84

194 124 158 155 171 143 276 376 279 238 164 365 259 247 151 210 345 312 229 245  
199 140 156 103 70 105 83 121 214 159 101 148 111 110 126 140 206 128 71 87  
82 113 118 97 121 125 136 96 74 64 43 28 17 51 76 54 32 50 54 56  
93 117 69 74 62 69 74 91 89 79 111 130 221 251 95 152 93 87 58 128  
147 283 194 179

NEC-P09A 89

252 219 196 179 117 110 156 89 143 227 184 97 127 101 128 142 126 190 111 91  
115 98 111 137 122 115 135 152 82 67 59 72 88 40 67 71 57 48 59 62  
78 110 108 55 40 50 53 51 52 52 64 90 92 164 193 82 124 79 64 64  
174 146 291 256 244 168 154 251 149 95 159 228 261 246 265 328 206 187 269 204  
172 105 234 244 141 140 126 96 117

NEC-P09B 89

261 212 198 190 115 107 160 85 152 220 191 104 118 99 137 145 122 194 104 89  
108 109 107 138 133 108 130 139 82 64 55 81 87 41 68 75 49 52 69 54  
80 114 113 55 52 54 42 51 58 54 62 88 97 170 194 81 124 93 57 51  
187 148 290 255 257 166 158 244 151 100 159 230 261 260 269 326 208 205 254 205  
170 109 219 260 139 138 113 88 126

NEC-P10A 57

332 325 201 217 141 119 130 173 287 272 221 136 184 244 293 367 250 257 283 199  
140 123 153 230 169 303 290 178 176 159 141 185 268 249 196 278 182 139 133 177  
164 164 146 127 162 164 100 101 77 86 115 171 186 279 289 284 254

NEC-P10B 57

317 322 202 217 144 129 123 178 279 292 217 136 194 236 298 359 263 252 284 198  
141 127 150 229 169 308 289 176 187 160 147 187 273 244 191 272 192 141 128 173  
164 166 140 127 165 170 100 97 81 83 114 166 189 285 283 287 264

NEC-P11A 121

118 94 143 115 136 143 163 117 174 173 126 173 262 144 260 215 236 220 216 234  
251 180 214 194 246 220 227 203 333 272 211 210 277 325 351 291 323 212 199 273  
173 154 155 167 182 271 136 86 132 81 97 88 111 133 97 104 51 91 97 50  
106 84 107 148 67 84 83 75 113 70 105 102 77 59 58 39 64 88 59 31  
46 46 54 64 66 72 90 78 89 98 96 36 49 43 29 64 74 102 136 140  
89 70 81 83 73 55 104 123 195 135 202 185 140 156 207 123 96 110 181 210  
251

NEC-P11B 121

110 96 137 106 132 144 161 117 189 168 118 179 255 143 265 210 232 222 214 236  
258 170 211 194 243 222 224 199 334 280 213 204 277 332 353 281 323 206 201 275  
171 157 154 166 177 257 141 85 131 86 91 92 108 134 98 102 52 92 97 46  
99 90 110 128 67 83 80 72 121 65 119 110 80 59 59 40 57 102 56 36  
44 50 58 61 65 77 91 75 91 104 93 46 44 46 32 59 81 98 138 129  
82 74 73 81 89 51 116 138 191 126 206 206 128 163 202 127 94 105 164 224  
255

NEC-P12A 114

270 348 422 459 439 409 273 232 205 195 165 350 260 228 205 92 189 155 155 141  
123 112 92 96 67 109 107 61 50 25 38 28 39 37 44 146 141 149 132 164  
141 162 108 60 120 69 118 234 206 176 213 164 128 129 169 254 180 168 160 174  
170 217 236 231 214 184 172 95 155 119 178 134 197 241 208 199 265 203 189 217  
210 174 188 107 111 95 108 64 63 50 55 47 43 32 24 28 13 75 74 97  
171 175 327 261 323 367 380 237 368 338 329 313 236 266

NEC-P12B 114

281 342 424 461 437 465 225 227 194 198 178 371 260 222 208 90 190 148 145 143  
126 115 90 90 66 114 91 59 39 31 29 27 31 47 35 130 122 167 139 159  
128 164 105 65 106 78 122 236 196 179 217 158 128 128 167 254 186 165 158 175  
163 223 237 240 208 185 177 103 162 119 171 128 201 247 215 200 257 210 194 217  
215 169 184 107 102 98 101 70 62 50 53 46 42 37 20 22 24 61 83 91  
171 178 332 258 325 368 376 246 367 339 333 316 229 280

NEC-P13A 52

255 317 301 261 280 321 277 242 242 228 266 252 129 147 100 110 130 182 229 305  
358 402 345 296 278 353 246 335 323 432 395 353 357 259 268 308 305 212 198 250  
244 386 269 276 244 212 330 223 194 240 268 208

NEC-P13B 52

274 354 312 262 283 355 267 252 218 251 251 244 123 153 87 107 124 185 218 301  
366 409 319 307 262 357 243 334 324 428 398 353 358 263 266 312 306 213 197 252  
242 395 265 278 238 200 332 224 201 246 262 166

NEC-P14A 84

247 258 169 170 126 203 125 110 82 107 142 155 152 206 206 147 93 90 85 122  
172 113 84 129 141 121 144 116 162 133 90 88 121 120 125 97 92 80 101 100  
126 127 123 51 63 51 39 65 94 89 141 152 172 104 106 170 193 68 84 109  
139 138 108 120 83 80 119 102 80 55 135 121 162 103 95 159 152 153 154 94  
143 158 137 178

NEC-P14B 84

254 261 175 171 129 202 123 113 84 112 141 160 146 207 208 150 94 81 90 126  
173 115 96 129 146 127 150 107 156 143 104 74 125 135 126 101 83 85 96 97  
122 127 120 48 70 50 35 70 85 96 139 154 168 110 103 170 189 78 69 109  
139 142 105 123 79 85 112 114 70 58 135 129 148 84 112 153 158 158 153 108  
117 179 144 159

NEC-P15A 76

101 160 151 163 218 201 213 147 83 102 115 200 133 263 175 140 121 161 116 164  
140 119 116 142 117 134 112 170 118 144 152 321 247 197 114 132 61 61 78 115  
102 297 327 372 167 126 247 262 84 88 163 251 292 183 240 105 152 166 163 144  
74 263 217 257 109 145 114 122 103 120 121 118 174 144 109 88

NEC-P15B 76

109 159 145 168 213 199 218 149 84 101 115 198 129 273 176 141 118 145 122 161  
141 111 117 140 116 133 123 170 121 137 156 317 263 193 111 131 62 66 70 131  
97 295 319 371 163 119 250 268 83 85 171 255 288 181 239 108 152 153 186 123  
81 266 210 242 109 151 114 115 106 139 107 135 173 147 124 92

NEC-P16A 113

67 80 88 158 123 123 153 74 185 179 119 62 126 92 65 59 56 88 79 103  
71 70 64 122 68 69 87 111 158 163 144 108 108 153 81 66 124 110 175 195  
111 62 54 78 48 73 70 106 71 68 38 50 66 98 94 91 62 45 27 30  
31 36 47 24 47 42 27 31 31 32 42 38 35 26 59 66 53 89 61 96  
66 83 75 104 72 35 77 38 25 48 62 67 102 83 129 87 96 155 121 76  
112 113 178 173 143 158 103 136 140 148 98 71 146

NEC-P16B 113

127 69 93 159 112 115 155 77 190 161 115 60 126 103 63 67 54 86 97 102  
85 60 80 107 66 74 82 105 147 159 153 113 116 164 80 65 120 110 158 192  
116 59 58 75 50 71 73 109 64 72 38 50 66 99 94 90 63 47 28 26  
31 31 54 22 47 39 30 27 31 30 43 39 36 29 55 73 60 82 65 82  
79 83 75 99 74 44 71 40 27 48 58 73 101 91 122 90 99 149 126 74  
109 115 180 172 138 157 104 142 138 146 98 69 136

NEC-P17A 78

221 349 292 201 177 134 191 124 110 82 107 143 171 176 201 215 215 171 99 124



118 190 112 238 114 114 78 123 113 150 207 133 107 92 86 93 98 166 106 103  
88 172 129 127 86 114 91 61 67 95 113 178 178 186 148 109 146 183 95 153  
125 221 174 160 197 111 120 125 143 117 85 186 148 184 107 110 193 153

NEC-P17B 78

220 357 287 199 174 126 193 121 112 80 105 148 168 176 203 230 213 180 97 127  
121 182 115 242 121 104 72 120 105 135 205 139 97 94 85 94 104 161 114 111  
91 171 127 128 82 121 88 59 72 86 111 179 200 169 146 106 149 179 93 154  
129 219 173 162 189 112 118 123 144 116 85 185 160 171 116 116 195 158

NEC-P18A 87

335 291 189 254 161 203 321 303 198 319 325 201 211 141 243 106 99 101 108 187  
179 191 232 188 163 167 120 139 92 157 121 171 144 129 118 153 114 140 192 150  
122 101 74 81 90 67 66 58 40 89 68 59 53 56 48 46 58 77 78 134  
113 131 99 77 103 104 42 78 103 157 120 81 102 58 75 79 82 62 44 131  
82 88 76 95 147 145 135

NEC-P18B 87

329 299 197 256 153 208 314 297 208 316 336 203 220 148 254 115 109 98 103 192  
187 193 244 196 178 165 123 134 101 167 129 167 145 135 115 157 117 142 189 150  
123 102 75 82 94 62 67 62 52 73 70 60 60 54 45 39 67 77 83 129  
110 127 98 73 94 96 52 77 100 145 127 78 99 62 72 80 82 64 46 129  
76 101 63 103 156 136 130

NEC-P19A 71

268 172 163 245 174 122 102 188 173 119 83 94 128 136 165 167 166 175 138 66  
123 123 196 119 170 136 126 109 153 131 163 198 133 134 121 101 101 96 121 128  
139 128 184 136 147 87 136 82 94 105 115 83 175 177 140 91 76 128 120 61  
106 131 166 154 138 143 92 97 111 116 126

NEC-P19B 71

262 180 171 236 183 117 112 189 172 117 86 92 136 134 155 167 172 169 137 67  
130 121 197 119 186 110 126 100 158 140 163 207 143 126 125 95 113 84 124 125  
140 128 185 137 146 90 139 86 92 104 112 89 172 182 130 96 78 120 120 61  
108 131 170 155 138 139 94 99 114 106 120

NEC-P20A 109

59 48 66 72 83 55 53 50 37 40 65 86 83 95 122 137 99 118 114 129  
71 104 109 148 139 102 135 125 123 114 111 82 69 44 54 85 59 75 93 98  
84 89 97 111 109 99 106 101 108 80 73 98 92 103 70 111 111 82 97 117  
115 94 88 107 87 100 54 63 104 77 115 86 105 92 98 113 73 85 73 70  
51 63 54 63 74 56 67 59 57 54 54 59 49 65 56 62 58 39 34 44  
56 52 60 60 68 64 58 56 64

NEC-P20B 109

55 55 70 74 84 54 56 59 36 30 59 95 78 95 126 141 103 117 126 124  
69 104 102 153 145 96 136 126 115 114 112 82 73 39 68 84 54 86 82 101  
76 89 92 110 110 112 119 96 113 72 80 94 87 96 62 112 108 86 96 120  
115 92 86 109 86 103 53 70 99 85 107 81 103 87 94 96 81 78 69 78  
54 54 59 68 70 58 63 64 56 48 54 61 47 63 50 65 52 43 34 45  
49 49 60 65 66 67 52 61 65

NEC-P21A 96

141 231 177 193 244 206 170 156 180 142 219 289 184 203 136 293 187 180 116 169  
294 280 223 232 183 169 179 134 92 130 111 153 238 170 97 113 111 120 137 124  
183 106 73 91 89 114 142 107 106 142 116 62 60 52 50 44 30 39 52 41  
47 71 66 73 81 82 57 65 39 49 71 60 64 76 112 171 201 249 118 151  
91 124 125 187 148 324 303 260 212 214 340 235 130 256 276 172

NEC-P21B 96

147 239 178 190 249 200 172 146 186 133 217 289 185 209 133 287 186 173 120 174  
298 278 220 238 184 167 175 131 94 136 107 158 251 165 85 111 116 115 139 131

183 105 82 87 99 118 124 108 104 146 128 67 62 49 51 47 32 38 49 45  
48 59 60 88 76 82 55 72 40 46 74 58 60 80 104 174 197 255 102 147  
112 109 119 188 151 322 311 278 190 218 341 221 142 241 296 185

NEC-P22A 85

199 245 253 167 189 188 152 331 266 231 331 235 159 252 227 235 282 209 129 171  
221 187 116 92 176 181 120 58 104 99 100 133 158 139 112 116 48 81 105 126  
90 142 140 118 114 157 104 146 160 111 91 135 87 109 85 119 94 86 90 128  
99 89 55 84 67 64 72 108 91 217 171 168 112 104 152 172 78 98 119 150  
163 148 295 149 128

NEC-P22B 85

202 243 260 175 190 187 158 333 258 231 338 226 158 234 232 239 282 216 125 171  
224 182 113 104 171 182 126 54 88 117 96 125 168 138 121 107 53 74 111 122  
84 143 137 120 114 150 113 131 155 115 89 132 79 112 91 102 91 91 95 126  
102 97 62 80 78 50 82 117 97 201 172 163 118 99 150 155 61 95 117 149  
162 147 302 159 157

NEC-P23A 107

200 116 129 112 102 178 109 100 129 146 116 140 142 170 255 115 170 158 201 226  
187 170 162 219 185 235 288 182 216 159 303 240 232 164 233 312 378 273 375 248  
188 208 153 120 165 145 211 324 190 126 182 161 141 120 144 243 131 102 115 123  
140 169 136 131 183 128 112 64 85 97 134 78 115 99 68 63 81 75 93 118  
136 117 92 80 79 79 71 75 65 97 112 127 177 86 131 67 93 123 211 152  
406 303 281 185 218 348 237

NEC-P23B 107

218 106 132 111 99 176 114 86 133 137 117 137 138 168 248 119 166 156 197 229  
194 171 156 227 178 231 287 184 217 159 302 238 233 165 235 314 381 275 377 252  
185 203 153 120 168 142 211 322 192 123 189 160 137 122 145 241 131 87 137 113  
144 170 128 138 178 125 115 70 84 100 123 93 106 103 80 64 73 77 86 122  
131 122 88 67 94 72 77 82 65 96 102 131 165 84 136 73 89 131 203 156  
399 311 285 164 211 359 203

NEC-P24A 87

125 94 157 136 154 340 189 142 199 156 187 177 195 275 147 109 111 117 150 180  
179 184 200 203 108 95 91 112 216 129 151 166 119 97 145 121 147 199 143 110  
142 110 108 105 110 101 79 116 138 176 157 80 81 63 75 102 213 186 268 200  
214 144 176 227 153 84 118 174 192 247 215 246 171 175 168 143 137 110 170 171  
131 100 109 110 138 126 111

NEC-P24B 87

115 107 164 125 175 326 198 137 164 165 179 182 194 281 142 117 113 126 155 187  
167 182 202 199 113 83 103 112 209 113 152 166 120 97 145 126 147 194 139 110  
137 116 103 105 112 98 84 110 142 172 164 80 78 59 73 94 218 185 270 191  
227 145 167 225 158 77 108 180 193 255 233 251 169 169 169 141 138 115 168 175  
128 96 109 114 137 133 113

NEC-P25A 72

282 390 281 184 268 319 251 214 161 250 173 119 133 140 204 206 201 128 187 185  
195 103 158 117 206 129 219 157 134 101 171 147 169 242 155 107 90 86 87 86  
105 91 89 82 105 94 84 65 82 47 52 63 76 72 137 147 179 96 74 110  
124 62 85 111 162 145 120 116 72 86 91 95

NEC-P25B 72

283 387 280 182 270 317 252 212 158 252 174 118 135 136 214 219 190 131 177 186  
202 102 152 121 205 117 222 145 143 95 154 153 167 239 154 103 96 75 76 76  
99 99 76 80 101 90 83 68 78 52 47 50 90 79 138 147 181 94 78 103  
121 57 87 106 195 142 115 117 76 85 78 96

NEC-P26A 75

113 126 99 107 71 141 138 109 51 56 101 83 84 109 138 188 113 87 71 83

55 75 61 52 47 106 124 72 89 78 57 86 79 113 116 74 96 85 84 70  
63 46 90 98 76 89 28 65 42 81 93 94 81 82 71 45 59 48 83 70  
54 49 75 37 46 73 106 127 117 132 79 87 112 96 111

NEC-P26B 75

132 126 100 101 70 142 137 107 49 55 103 77 85 101 137 182 115 82 77 73  
60 80 60 55 49 98 122 76 83 74 58 77 83 102 123 74 98 88 80 80  
59 44 95 96 83 84 32 69 44 88 95 94 79 80 75 37 60 51 80 73  
58 39 82 35 40 75 110 126 121 123 83 80 111 94 111

NEC-P27A 110

104 66 98 132 175 133 73 214 149 49 107 107 71 90 95 125 117 83 42 60  
80 81 85 101 119 115 112 93 87 165 88 148 55 49 64 82 113 76 58 64  
58 49 59 75 92 46 95 64 65 64 57 40 73 84 53 73 33 40 54 68  
82 76 80 62 45 40 47 42 69 101 49 38 74 35 41 70 133 161 123 112  
66 100 97 88 126 62 40 83 115 73 97 130 134 129 102 70 90 84 101 107  
158 88 72 73 92 138 132 68 67 68

NEC-P27B 110

105 66 95 138 174 136 74 228 136 47 98 110 66 88 105 135 121 81 45 60  
78 89 79 104 117 123 109 85 97 162 87 150 54 51 62 83 112 74 64 68  
61 51 54 76 80 54 91 70 69 62 61 36 77 82 49 76 35 43 49 71  
78 75 79 63 45 42 45 38 74 97 49 36 74 32 51 64 134 157 123 121  
63 102 96 87 128 61 41 84 113 77 89 131 134 134 98 73 86 91 99 106  
162 84 72 74 98 132 134 67 65 74

NEC-P28A 60

96 117 105 107 102 113 90 123 86 99 65 42 81 64 100 74 95 119 82 52  
76 104 172 224 93 109 94 92 67 75 67 88 59 48 50 73 64 69 64 64  
66 59 36 63 63 70 61 43 44 48 62 73 73 66 65 83 61 79 79 71

NEC-P28B 60

93 115 104 114 90 102 83 120 93 79 73 47 67 63 95 94 102 114 68 65  
73 103 175 231 92 110 91 88 75 71 63 76 57 46 53 72 64 73 63 65  
67 61 42 55 62 77 64 49 47 56 53 73 74 61 65 79 53 87 78 79

NEC-P29A 84

141 140 161 114 112 127 128 145 153 82 69 63 101 128 61 81 70 59 89 72  
86 124 79 91 72 85 81 59 53 88 78 56 73 23 56 55 105 79 87 88  
121 74 59 84 59 86 80 47 39 89 31 52 75 160 117 87 109 66 73 98  
78 95 70 63 109 105 92 91 149 194 155 91 54 129 91 124 97 151 132 88  
103 121 143 138

NEC-P29B 84

146 138 162 112 113 120 132 145 155 80 69 62 107 121 54 73 63 53 90 68  
92 123 74 98 60 90 77 62 52 87 72 59 71 28 48 54 104 79 89 88  
122 71 61 80 63 89 78 49 37 80 31 53 73 160 117 87 109 67 72 100  
80 93 72 56 115 99 86 91 146 199 151 96 50 126 96 119 100 146 136 89  
109 122 129 135

NEC-P30A 161

136 153 191 129 161 174 143 186 191 79 124 85 106 117 122 96 151 139 134 129  
105 186 146 124 110 130 133 136 95 63 100 85 66 67 97 86 108 92 84 126  
121 79 76 72 106 82 82 44 73 79 66 86 69 74 88 53 51 64 77 82  
51 83 88 59 69 49 45 83 77 80 95 116 63 81 95 73 84 106 106 121  
88 102 65 63 50 36 58 52 59 64 55 64 45 52 97 95 111 138 172 163  
63 103 134 118 81 189 134 114 111 139 145 150 106 137 132 149 95 108 145 168  
137 110 99 96 107 99 92 139 137 147 94 123 117 103 111 150 113 106 100 128  
127 122 124 107 137 124 95 100 140 98 128 128 116 190 165 151 188 188 211 168  
196

NEC-P30B 161

127 168 188 136 148 167 145 180 190 95 111 90 116 107 116 107 145 123 138 129  
112 194 137 124 115 125 134 141 84 67 91 87 57 78 90 89 98 99 80 129  
117 78 74 76 102 81 79 47 71 75 70 86 68 71 93 48 50 69 72 90  
49 73 87 57 73 48 40 87 76 89 88 121 64 92 87 80 82 116 92 123  
85 96 69 60 51 35 66 50 52 63 66 65 43 56 96 96 102 146 163 159  
72 99 131 120 75 194 131 119 107 131 148 148 116 133 144 141 90 107 153 167  
138 106 102 91 114 97 97 138 136 144 97 125 114 112 107 144 118 98 99 130  
130 115 124 103 135 108 105 90 148 98 133 112 117 189 161 153 176 187 206 192  
157

NEC-P31A 63

183 134 110 79 56 59 76 46 79 68 80 90 95 43 69 58 46 105 39 43  
59 60 52 74 70 83 144 96 62 161 128 62 134 91 78 165 130 138 162 215  
108 150 230 201 135 139 143 139 119 128 129 155 101 122 67 58 78 107 102 68  
84 77 49

NEC-P31B 63

141 135 107 86 51 63 78 41 89 70 81 90 104 45 57 45 56 87 44 41  
60 61 48 74 64 84 147 111 67 143 121 66 137 96 80 172 144 130 166 222  
110 159 237 199 133 149 144 135 121 126 137 160 95 120 67 66 73 110 105 73  
83 82 54

NEC-P32A 101

82 42 92 134 99 132 72 111 110 148 125 130 126 79 96 76 63 72 162 99  
87 79 89 75 75 93 100 94 61 94 80 84 70 75 51 71 65 72 76 33  
68 60 75 81 78 63 66 58 30 56 44 77 73 61 50 66 31 40 63 72  
109 104 122 66 101 142 97 107 58 50 94 96 78 117 120 97 88 85 53 80  
68 103 98 110 76 73 92 112 114 145 64 112 112 74 118 119 149 121 73 74  
58

NEC-P32B 101

80 59 67 112 84 124 70 112 110 145 124 133 128 72 103 71 67 69 163 95  
89 76 93 72 74 89 109 97 63 89 83 76 78 70 45 69 61 68 73 33  
72 66 68 88 69 64 70 53 34 60 47 72 76 56 50 68 29 37 70 69  
112 104 120 66 99 142 100 111 56 50 90 100 76 121 114 98 96 78 55 79  
64 97 98 110 70 71 90 106 108 146 62 109 113 71 117 119 147 121 77 69  
61

NEC-P33A 118

56 55 97 100 70 61 47 49 70 95 71 80 57 66 67 66 38 65 62 61  
39 72 67 107 91 76 82 126 86 91 109 194 102 112 76 78 82 76 113 77  
111 122 82 97 171 175 155 123 113 94 100 80 56 40 115 99 89 76 106 48  
29 42 81 104 136 95 97 63 84 50 87 54 37 71 25 38 55 56 50 75  
62 65 57 55 132 140 210 163 256 390 387 342 474 272 389 199 199 334 292 304  
262 295 237 140 139 167 248 218 137 191 156 177 165 175 154 208 287 267

NEC-P33B 118

47 53 100 103 66 57 48 52 71 97 78 69 64 64 57 60 42 66 71 63  
36 80 69 114 85 80 85 127 90 83 114 195 105 109 86 79 84 76 114 74  
115 123 85 94 170 171 157 121 115 83 116 55 62 60 104 101 77 79 100 51  
33 40 82 111 129 104 93 68 77 54 87 62 35 82 32 39 56 56 55 69  
65 64 59 51 139 138 204 163 258 386 393 340 478 272 381 203 195 334 297 302  
260 295 231 146 132 167 240 215 152 186 170 179 168 176 157 205 296 249

NEC-P34A 156

107 131 89 108 88 62 85 64 83 96 124 185 253 216 293 191 322 256 275 164  
55 182 270 161 193 213 187 214 115 107 129 79 75 78 77 149 115 117 74 87  
55 76 87 85 134 59 72 120 119 156 101 190 255 266 227 169 240 310 171 164  
178 150 140 65 159 236 142 70 80 94 88 72 147 127 114 128 115 142 142 96  
100 64 27 55 95 164 75 92 63 61 56 46 82 120 59 62 59 63 52 48

45 85 88 47 85 29 50 44 105 67 120 81 85 64 51 63 52 57 63 49  
33 86 34 32 111 223 165 148 189 102 103 156 113 162 125 89 177 193 122 147  
249 417 321 138 82 232 192 242 204 324 356 215 221 254 180 164

NEC-P34B 156

113 128 86 120 78 57 87 76 94 90 122 191 243 229 282 207 343 247 284 144  
62 182 275 157 188 212 189 213 114 110 127 79 78 73 81 152 116 118 77 89  
52 81 85 87 134 57 70 119 120 154 102 193 256 262 230 172 239 308 166 167  
182 144 139 66 158 235 132 79 76 89 85 77 145 116 126 125 123 139 146 104  
100 60 33 57 94 168 66 100 63 57 56 50 78 126 59 63 57 66 47 50  
46 89 83 52 79 35 46 47 99 82 105 88 103 64 39 66 52 62 56 50  
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246 419 319 129 95 227 190 233 212 324 363 192 220 245 186 159

NEC-P35A 179

70 111 86 133 157 146 168 148 234 251 102 174 135 117 126 97 159 106 217 133  
137 144 135 110 117 186 189 206 148 66 104 83 106 111 117 142 139 121 87 96  
93 142 154 115 128 168 132 141 80 86 131 128 98 83 119 113 88 78 78 104  
130 87 100 88 129 106 80 51 95 81 50 85 66 79 97 37 55 62 82 104  
89 113 124 85 87 54 62 92 85 66 71 123 76 61 122 121 104 132 127 125  
84 114 103 74 63 40 93 88 82 96 107 106 128 126 131 107 96 127 122 216  
114 129 147 153 98 179 128 99 114 139 123 137 143 131 106 117 65 87 108 116  
114 73 76 69 73 88 123 183 153 160 94 114 112 105 127 154 108 109 119 158  
117 99 140 128 142 119 132 111 202 160 231 152 115 174 126 127 128 164 140

NEC-P35B 179

75 108 83 136 160 152 167 156 228 256 107 169 129 120 130 97 159 106 219 135  
144 147 133 107 122 175 191 199 146 60 101 87 107 103 132 144 138 119 90 98  
95 139 145 117 123 173 135 141 79 94 128 127 105 78 125 121 84 80 78 104  
128 102 87 93 129 105 86 43 99 79 42 99 64 80 95 39 77 60 88 102  
90 111 127 87 86 55 61 92 93 61 74 121 77 74 113 126 108 122 127 122  
83 120 98 78 80 41 91 81 93 95 97 113 127 128 135 102 112 115 137 199  
113 130 148 152 105 175 125 106 113 130 141 140 137 121 108 122 65 101 106 115  
106 82 75 72 74 92 120 175 157 169 103 114 120 108 134 148 111 110 122 151  
128 104 142 133 144 114 129 124 195 167 214 155 119 174 123 118 144 164 144

NEC-P36A 99

31 33 46 25 47 80 99 99 51 54 56 32 29 29 43 63 35 40 33 47  
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122 61 71 71 44 124 83 88 59 80 104 73 88 119 69 95 75 94 136 114  
108 91 99 119 97 99 107 134 118 109 167 174 161 109 109 199 107 130 128 202  
195 254 236 203 145 168 175 112 128 159 107 101 112 88 106 79 133 80 81

NEC-P36B 99

27 35 42 23 54 78 97 75 37 54 51 32 31 36 39 64 36 39 31 46  
29 24 40 128 135 100 140 97 67 133 47 62 43 65 65 75 28 41 100 101  
119 74 84 69 57 128 72 83 62 74 108 73 86 108 76 94 78 89 144 113  
108 96 90 136 84 107 109 116 130 110 171 175 162 106 153 179 117 132 111 213  
186 247 213 224 143 154 230 127 123 144 82 105 107 103 97 76 137 82 85

NEC-P37A 55

66 75 65 76 69 52 44 43 36 54 57 41 29 65 35 41 59 213 139 149  
126 79 113 134 97 134 90 62 90 131 81 81 121 229 141 86 55 75 91 98  
103 211 127 115 87 126 149 164 89 94 88 100 69 98 109

NEC-P37B 55

79 66 71 66 78 54 41 45 37 60 46 45 35 60 30 44 65 211 144 142  
121 83 108 136 100 115 91 50 98 127 80 83 117 232 141 87 55 75 83 103  
97 208 127 116 100 113 155 179 79 75 96 84 68 99 136

NEC-P38A 71

155 95 100 115 137 152 178 171 190 209 101 74 78 108 186 92 126 126 78 62  
82 87 107 177 137 91 88 81 82 81 87 85 86 108 96 170 163 90 145 72  
71 51 157 107 256 143 163 123 141 176 167 83 136 197 204 202 207 236 146 174  
156 120 121 103 173 148 105 87 88 83 71

NEC-P38B 71

157 98 98 116 136 160 176 174 190 204 105 71 69 108 185 96 122 125 77 58  
79 90 106 174 135 80 86 90 72 74 87 86 80 102 109 168 167 87 157 70  
57 65 141 109 253 162 166 129 134 174 161 79 139 184 210 207 201 237 150 173  
164 122 109 100 174 146 107 89 89 83 76

NEC-P39A 116

248 202 123 98 92 78 103 106 113 169 275 171 175 108 206 165 159 112 111 200  
200 185 218 148 132 163 118 92 126 87 119 198 133 79 104 95 94 130 108 180  
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64 66 114 134 112 84 100 74 76 83 81 61 72 105 108 128 159 83 105 71  
66 61 186 141 269 234 193 111 145 149 114 81 134 178 197 269 250 303 222 177  
185 175 167 111 198 177 160 133 109 135 170 135 123 116 141 94

NEC-P39B 116

252 206 125 101 91 78 100 116 114 168 277 172 175 112 219 158 155 100 123 192  
215 189 226 142 133 166 117 93 129 103 113 192 133 86 100 99 82 125 125 181  
134 81 87 108 118 137 113 99 130 100 57 61 46 57 103 85 113 78 72 55  
88 55 106 119 137 77 103 74 79 78 83 65 66 102 114 126 157 85 105 74  
58 78 185 157 275 242 195 117 124 143 111 90 135 177 198 261 232 321 212 189  
188 177 164 100 211 171 137 132 117 127 184 131 120 117 149 96

NEC-P40A 78

421 401 276 244 230 196 163 248 173 256 298 275 150 123 228 162 244 208 275 161  
178 124 90 173 184 267 236 152 148 46 55 44 77 180 102 117 115 67 40 40  
37 46 45 50 34 77 62 70 100 83 125 164 158 146 171 184 45 106 43 39  
57 122 124 179 136 196 137 131 132 160 70 124 134 267 240 249 258 187

NEC-P40B 78

418 403 284 241 209 192 172 250 182 256 317 276 155 129 230 154 244 201 307 151  
188 129 98 184 182 265 236 150 147 48 52 45 76 182 98 115 116 65 39 38  
41 40 44 50 35 70 66 71 98 84 127 164 159 145 178 172 51 104 42 35  
54 119 120 164 135 198 139 133 123 167 69 127 126 267 237 246 251 194

NEC-P41A 92

172 147 147 145 265 112 150 191 232 259 319 240 459 348 323 363 263 241 387 411  
294 389 244 186 223 265 205 157 152 290 212 178 106 103 141 139 184 196 219 170  
136 112 111 104 143 90 120 107 87 71 90 81 106 216 161 94 101 77 81 83  
130 105 101 98 145 140 128 96 125 94 80 89 102 113 163 212 248 192 134 156  
208 101 109 104 175 163 146 161 103 97 107 100

NEC-P41B 92

174 143 158 150 258 119 144 195 233 264 329 233 461 336 332 368 274 239 389 415  
296 385 279 189 240 279 199 161 149 286 217 174 99 111 152 139 179 200 222 180  
139 105 108 105 142 92 121 106 83 70 91 74 114 216 160 91 101 72 82 88  
119 100 107 99 144 138 128 99 125 94 78 93 102 112 165 222 236 191 129 159  
215 97 110 105 178 168 142 160 109 96 110 91

NEC-P42A 92

78 129 133 95 126 99 90 159 67 98 161 145 86 125 115 68 126 106 129 103  
62 106 84 94 134 114 105 118 102 60 54 67 58 82 64 91 93 58 73 96  
78 115 104 130 84 102 73 82 89 92 74 81 96 136 152 177 109 141 72 102  
110 193 167 301 193 193 140 162 211 136 84 141 237 373 315 271 301 173 178 192  
149 128 91 196 159 121 104 92 81 131 112 97

NEC-P42B 92

78 133 131 87 126 100 92 161 66 102 160 144 83 132 114 69 135 94 135 85

76 105 84 106 132 113 107 116 98 58 59 68 53 86 61 93 92 70 67 90  
84 112 111 133 96 99 82 77 94 92 70 76 104 127 158 190 102 146 61 90  
119 194 168 298 193 189 142 170 218 151 84 138 240 372 315 274 298 172 181 190  
148 125 91 188 164 121 100 92 83 132 123 99

NEC-P43A 117

384 326 293 380 277 271 139 95 81 94 78 82 78 77 87 84 74 100 137 162  
214 150 181 137 147 133 151 119 121 112 113 133 119 121 115 130 90 125 134 145  
88 104 97 83 112 89 80 94 65 75 68 68 91 65 68 71 73 57 57 57  
57 76 80 57 72 71 89 51 75 66 85 93 75 86 54 38 41 44 71 66  
88 85 111 114 87 100 71 97 96 99 90 83 104 101 119 96 82 114 138 112  
130 129 129 121 127 116 147 91 121 114 133 88 96 103 87 91 100

NEC-P43B 103

76 58 83 95 106 123 104 137 116 99 99 105 79 82 76 85 73 87 88 86  
98 71 93 97 91 60 75 69 58 87 76 52 87 57 76 68 66 81 64 59  
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39 48 47 64 77 87 86 106 108 89 102 80 85 88 101 108 83 120 114 133  
122 73 149 151 126 151 140 148 137 136 126 140 110 129 147 163 102 91 102 89  
88 105 79

NEC-P44A 65

74 73 90 89 106 94 84 81 153 118 80 139 102 114 104 94 97 155 178 124  
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180 191 196 162 211 211 158 180 143 168 185 161 126 179 148 175 173 132 95 71  
98 74 144 157 167

NEC-P44B 65

78 74 101 79 108 99 95 86 150 122 98 119 110 106 103 108 93 170 177 127  
144 89 53 57 76 95 104 98 111 87 116 84 100 83 104 126 202 165 114 164  
190 186 197 140 210 195 168 184 180 182 183 156 117 187 153 188 175 132 96 76  
94 76 142 158 165

NEC-P45A 56

368 264 277 209 192 190 173 209 211 153 142 233 277 182 293 338 431 456 317 356  
255 358 310 304 144 196 247 206 330 233 294 201 168 125 134 130 133 162 122 113  
126 201 150 138 168 119 137 111 122 139 124 125 88 63 59 50

NEC-P45B 56

371 284 277 212 192 198 176 207 211 154 146 232 283 181 286 332 439 444 320 359  
273 364 326 308 145 192 256 201 337 221 284 209 173 127 131 119 145 154 122 118  
126 198 149 137 161 125 140 108 118 151 120 130 81 65 60 54

NEC-P46A 153

151 174 224 161 165 197 184 208 153 171 119 167 126 75 121 94 84 106 112 68  
92 52 66 50 50 49 61 45 68 79 98 98 73 90 73 94 74 81 64 75  
64 67 71 65 63 82 80 67 85 85 93 67 64 62 69 77 88 71 105 85  
85 73 80 68 84 69 71 81 77 63 63 64 79 77 55 81 65 89 75 65  
49 84 68 67 103 75 41 55 56 72 100 103 115 123 116 93 104 81 87 95  
120 112 79 92 111 115 190 163 176 153 116 145 163 131 176 156 154 143 150 220  
206 135 120 107 100 99 124 128 193 173 120 161 146 128 120 128 103 101 70 82  
84 81 76 84 93 77 118 103 115 114 95 109 72

NEC-P46B 153

153 185 264 162 167 201 187 217 148 182 124 167 133 74 114 96 91 113 109 73  
90 63 71 46 50 58 59 45 73 83 96 95 76 85 78 89 84 78 68 77  
62 73 72 63 69 78 87 61 93 82 90 73 59 71 64 102 70 72 106 92  
81 76 80 66 88 69 75 80 80 69 60 64 81 80 57 82 65 86 79 67  
74 81 73 71 101 76 43 53 63 74 94 102 123 122 110 94 106 86 93 99  
121 113 81 99 110 113 193 171 176 154 120 147 165 133 182 164 156 144 148 224  
194 145 120 107 111 93 123 134 209 181 123 160 130 129 126 125 99 103 74 78



89 80 78 84 100 76 117 108 101 122 91 109 72

NEC-P47A 88

262 154 144 139 185 96 126 110 114 141 172 108 182 172 303 241 206 213 166 212  
181 184 109 98 116 112 215 140 143 156 187 146 166 198 227 200 170 176 154 238  
222 167 235 198 213 158 240 243 193 220 100 89 85 82 73 85 137 125 118 201  
140 173 136 134 134 184 223 126 180 109 63 71 73 69 85 104 127 114 112 93  
88 81 94 68 74 96 87 117

NEC-P47B 88

211 148 156 123 174 97 125 101 118 143 180 115 190 176 318 278 217 225 167 214  
181 178 110 96 130 119 218 158 138 160 196 150 176 190 226 205 176 176 162 241  
240 173 249 216 204 158 245 261 208 221 105 91 93 87 69 89 143 118 125 193  
144 177 137 138 131 193 208 127 185 103 60 73 76 76 81 109 119 115 119 76  
92 82 94 73 83 89 88 133

NEC-P48A 190

210 227 110 101 128 100 101 109 80 103 107 82 94 89 146 125 198 164 149 92  
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29 42 44 53 82 69 84 45 52 73 87 32 90 58 128 93 74 93 72 117  
96 89 57 55 55 58 87 68 53 72 89 43 47 54 70 61 58 61 57 67  
39 34 58 76 97 55 118 107 82 82 99 94 93 71 78 61 53 30 67 115  
63 109 82 87 87 114 111 55 66 57 34 34 44 39 34 56 56 45 47 42  
40 42 32 33 58 42 42 31 34 25 36 31 50 44 36 60 48 38 51 43  
80 69 37 69 42 37 37 39 44 56 71 52 37 57 54 53 43 44 67 64  
77 86 62 43 50 62 64 69 85 66 56 54 71 64 47 60 63 80 86 80  
80 94 51 52 50 52 64 52 37 49

NEC-P48B 193

215 225 114 92 139 95 101 108 78 108 105 80 94 93 142 114 202 163 141 94  
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26 44 46 58 73 83 76 44 58 66 91 33 67 61 123 85 63 92 69 119  
85 94 53 56 46 51 78 66 44 71 84 45 46 49 68 53 62 72 43 70  
53 33 57 86 98 54 111 116 81 81 100 93 89 67 73 65 58 36 61 117  
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39 42 31 32 60 39 44 40 30 24 34 30 48 46 36 59 46 43 49 44  
79 68 39 70 39 35 45 41 43 53 76 50 36 52 56 52 43 47 69 57  
77 89 61 48 60 55 70 75 84 54 63 46 81 60 45 67 71 84 94 69  
83 96 51 50 45 57 56 47 45 53 43 44 56

NEC-P49A 98

54 60 80 109 76 104 138 87 76 70 109 75 81 81 164 119 124 76 125 92  
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68 74 58 52 75 95 108 76 86 70 101 77 66 68 52 75 76 81 57 43  
77 42 34 44 64 59 69 66 62 67 102 102 141 112 88 61 69 62 75 101  
66 81 73 79 84 120 92 46 51 49 38 47 38 58 53 78 80 102

NEC-P49B 98

50 57 85 105 73 103 122 85 83 72 115 77 77 85 168 136 121 79 128 86  
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66 73 60 57 75 87 107 81 83 63 103 70 76 47 61 82 82 73 50 50  
67 46 39 38 72 47 73 66 61 70 105 106 135 122 85 63 64 74 69 103  
60 87 73 92 79 129 92 53 46 48 39 46 42 57 54 71 83 85

NEC-P50A 83

70 62 45 41 46 50 46 45 61 63 63 83 80 69 95 88 109 99 45 68  
85 82 113 79 72 79 52 55 61 65 70 80 121 101 123 111 165 150 133 163  
118 95 120 136 86 81 78 85 78 74 82 76 86 78 84 72 85 94 74 77  
73 85 51 55 77 61 65 68 61 78 78 67 65 59 54 64 71 73 67 64  
68 85 76

NEC-P50B 83

62 57 44 47 45 43 51 46 59 56 72 73 86 62 103 66 124 81 49 66  
85 82 108 84 70 79 43 65 63 54 73 70 123 98 120 115 163 148 128 160  
121 88 126 131 78 84 78 84 78 69 82 82 85 66 92 68 83 87 76 79  
74 91 52 65 74 60 66 62 66 73 80 66 61 64 53 66 69 73 67 68  
64 86 78

NEC-P51A 109

275 178 197 164 199 259 264 61 59 64 102 82 88 87 105 115 164 257 185 98  
206 198 189 184 153 118 199 210 270 266 125 93 132 126 130 105 214 117 107 97  
93 59 82 48 44 53 47 61 81 51 55 68 76 47 54 56 85 63 69 64  
84 147 118 109 98 62 77 76 99 121 93 70 110 82 74 69 61 69 75 56  
56 77 53 52 41 48 42 47 61 46 50 44 36 43 38 57 61 96 63 50  
36 48 43 45 40 37 61 61 65

NEC-P51B 109

274 174 201 155 205 241 274 53 58 58 92 93 89 83 95 101 170 284 179 100  
210 191 161 152 153 115 186 195 244 277 113 101 125 127 130 108 213 114 105 102  
81 60 78 48 48 50 48 61 81 52 57 65 77 46 56 53 87 56 76 63  
81 149 130 96 100 67 79 74 104 127 90 77 109 79 68 60 58 63 66 52  
60 79 49 56 40 54 33 46 60 44 42 50 40 42 36 59 64 105 82 47  
38 45 46 37 39 34 61 45 63

NCB-A01A 224

122 188 177 131 142 137 105 149 114 130 151 136 124 147 146 122 154 116 140 139  
117 138 182 181 119 135 128 100 157 117 137 108 89 95 174 110 100 131 103 175  
102 85 89 108 100 152 168 187 164 164 119 114 164 108 96 128 145 115 115 117  
137 142 171 110 179 170 138 139 155 151 125 115 115 109 115 140 148 107 129 107  
126 89 70 83 130 98 118 109 126 123 96 114 134 114 117 101 117 118 101 97  
130 125 117 106 91 96 83 105 91 71 68 90 114 84 109 78 81 76 88 69  
86 93 57 85 103 68 75 28 75 58 87 68 76 71 81 51 97 97 96 69  
83 100 71 96 84 106 99 98 71 84 88 82 59 69 74 62 50 72 125 71  
62 96 69 68 95 106 129 76 93 79 123 91 65 68 74 91 75 68 76 97  
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59 79 118 96 78 125 106 80 71 80 90 82 93 96 128 81 109 78 90 112  
88 158 140 178

NCB-A01B 224

169 146 165 120 154 131 115 159 123 132 135 149 103 168 125 116 148 107 149 160  
134 147 185 169 144 114 136 94 132 114 121 93 99 104 192 145 100 108 121 157  
108 89 71 117 109 140 177 217 177 157 117 117 145 128 101 109 114 107 85 114  
157 119 176 110 185 176 134 143 129 145 92 114 118 117 146 95 167 117 101 96  
134 71 73 64 111 132 98 107 114 151 75 90 110 100 118 107 125 100 110 101  
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56 66 76 86 100 61 73 80 79 63 78 79 102 81 111 58 108 121 71 85  
92 112 79 115 100 99 96 104 104 111 68 85 65 90 64 59 81 62 103 87  
80 87 72 78 100 106 106 114 106 93 112 87 62 75 60 83 88 69 106 95  
84 63 84 91 90 112 87 109 96 73 60 80 99 84 87 96 118 131 55 57  
65 70 95 112 120 119 90 61 91 85 91 97 87 100 121 68 71 99 87 135  
96 104 168 143

NCB-X02A 67

175 141 89 112 140 113 153 121 151 130 68 125 77 135 107 98 108 96 64 49  
44 57 66 99 102 103 100 135 80 64 87 101 93 103 125 116 105 130 119 207  
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133 153 99 126 132 143 181

NCB-X02B 67

180 137 98 109 138 108 152 118 156 119 97 123 99 112 134 96 96 89 60 55  
64 49 64 101 87 105 119 119 78 71 88 91 78 117 115 109 116 145 125 159  
128 121 111 114 121 117 152 112 109 118 151 100 114 130 133 154 113 117 117 149  
171 126 134 123 114 176 151

NEC-B02A 100

256 194 205 230 189 154 123 148 205 251 217 294 219 248 233 316 263 349 277 230  
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162 172 215 236 190 256 250 263 283 278 262 193 240 207 181 171 122 191 214 222  
99 125 130 140 108 118 154 189 245 221 198 200 137 150 160 168 163 181 186 229

NEC-B02B 100

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138 180 221 247 173 231 259 258 250 278 245 242 236 218 156 150 133 200 221 211  
139 118 120 152 106 127 146 168 221 236 240 209 130 187 178 181 165 183 206 209

NEC-B03A 140

604 330 182 244 208 282 270 267 289 244 157 205 268 268 278 217 318 277 165 176  
193 229 185 253 260 269 116 331 162 357 414 275 296 290 193 94 87 107 143 235  
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NEC-B03B 140

580 331 175 238 206 254 369 294 312 257 162 188 265 275 284 216 347 266 169 189  
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103 202 243 191 137 124 171 100 126 130 93 109 136 155 130 225 289 215 287 181  
137 227 152 190 227 260 148 159 212 225 146 99 96 128 174 104 156 164 205 274  
231 283 205 187 247 331 222 218 284 170 179 189 178 210 196 181 226 213 112 187

NEC-B04A 136

243 165 142 128 164 157 167 204 166 138 172 177 151 144 219 123 123 201 184 174  
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133 165 135 109 146 125 146 187 143 143 148 165 116 229 131 168 143 134 125 135  
157 103 69 85 100 128 130 68 104 101 89 81 84 112 91 65 78 73 90 80  
113 97 170 96 166 134 120 122 115 141 100 155 106 108 88 121 121 120 95 121  
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NEC-B04B 136

215 151 134 141 152 164 182 198 150 139 175 176 134 146 224 144 110 201 165 163  
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143 167 137 109 150 126 151 190 136 148 140 178 111 223 135 162 162 137 120 150  
145 107 81 82 105 138 125 76 92 106 100 71 96 99 84 84 65 83 67 91  
113 78 184 98 159 132 137 119 107 137 87 152 103 107 100 100 116 111 103 116  
134 107 94 115 100 109 82 93 100 78 62 77 86 90 80 83

NEC-B05A 169

196 125 145 139 135 111 123 127 136 109 99 152 126 143 94 66 97 108 116 73  
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111 78 82 120 106 100 126 131 126 125 115 178 107 115 172 162 104 87 190 154  
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70 84 79 74 74 74 56 76 58 69 60 41 46 30 49 82 80 91 73 116  
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138 119 102 114 117 125 85 121 75

NEC-B05B 169

240 138 138 137 125 107 124 138 135 123 100 155 117 151 101 60 91 110 110 75  
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93 71 87 82 68 84 77 75 107 96 112 127 107 131 94 75 106 93 93 121  
145 128 96 117 116 106 112 73 99

NEC-B06A 95

215 343 241 231 297 262 284 244 251 257 234 323 264 268 200 271 288 300 227 240  
259 271 252 177 205 243 346 314 331 312 325 185 132 135 86 129 101 110 123 137  
126 75 108 71 81 92 125 120 83 92 100 73 104 117 106 118 89 117 123 81  
51 65 50 56 60 83 78 98 118 107 106 89 94 91 95 100 100 127 90 126  
103 112 84 85 106 118 103 158 135 128 104 157 137 146 116

NEC-B06B 97

241 372 261 242 305 287 301 251 269 282 264 364 276 294 205 324 310 335 242 253  
298 278 284 190 218 260 389 343 336 329 325 192 140 134 96 131 101 129 108 140  
137 85 95 73 92 108 120 104 106 95 135 89 104 101 134 140 84 98 107 101  
53 81 51 53 60 84 81 101 121 112 103 92 100 90 101 96 102 121 99 137  
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NEC-B07A 235

166 169 215 203 178 140 162 172 169 181 173 142 178 194 135 187 266 238 221 148  
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228 259 266 254 145 210 133 183 160 225 138 245 207 204 239 173 218 200 164 148  
217 194 147 134 90 106 121 114 120 178 158 153 137 106 134 137 141 124 165 171  
153 117 89 103 114 97 98 125 116 134 78 89 83 77 115 109 75 112 142 107  
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115 106 106 148 79 55 60 70 65 59 63 59 53 52 78 92 226 119 164 164  
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108 83 101 116 114 87 80 93 79 85 90 94 96 96 100 114 95 111 89 78  
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100 82 92 112 108 87 93 119 95 120 79 94 118 100 112

NEC-B07B 235

169 179 188 221 212 131 165 181 161 176 169 159 179 173 139 202 252 241 223 171  
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262 229 265 251 147 235 121 189 166 222 200 242 240 203 209 172 214 181 170 151  
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133 148 124 104 121 119 76 82 104 88 124 118 82 83 89 100 108 112 144 133  
143 68 84 123 107 83 81 70 92 89 87 95 101 98 104 107 106 89 89 78

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## APPENDIX: TREE-RING DATING

### The Principles of Tree-Ring Dating

Tree-ring dating, or dendrochronology as it is known, is discussed in some detail in the Laboratory's Monograph, *An East Midlands Master Tree-Ring Chronology and its uses for dating Vernacular Building* (Laxton and Litton 1988) and *Dendrochronology: Guidelines on Producing and Interpreting Dendrochronological Dates* (English Heritage 1998). Here we will give the bare outlines. Each year an oak tree grows an extra ring on the outside of its trunk and all its branches just inside its bark. The width of this annual ring depends largely on the weather during the growing season, about April to October, and possibly also on the weather during the previous year. Good growing seasons give rise to relatively wide rings, poor ones to very narrow rings and average ones to relatively average ring widths. Since the climate is so variable from year to year, almost random-like, the widths of these rings will also appear random-like in sequence, reflecting the seasons. This is illustrated in Figure A1 where, for example, the widest rings appear at irregular intervals. This is the key to dating by tree rings, or rather, by their widths. Records of the average ring widths for oaks, one for each year for the last 1000 years or more, are available for different areas. These are called master chronologies. Because of the random-like nature of these sequences of widths, there is usually only one position at which a sequence of ring widths from a sample of oak timber with at least 70 rings will match a master. This will date the timber and, in particular, the last ring.

If the bark is still on the sample, as in Figure A1, then the date of the last ring will be the date of felling of the oak from which it was cut. There is much evidence that in medieval times oaks cut down for building purposes were used almost immediately, usually within the year or so (Rackham 1976). Hence if bark is present on several main timbers in a building, none of which appear reused or are later insertions, and if they all have the same date for their last ring, then we can be quite confident that this is the date of construction or soon after. If there is no bark on the sample, then we have to make an estimate of the felling date; how this is done is explained below.

### The Practice of Tree-Ring Dating at the Nottingham Tree-Ring Dating Laboratory

**1. Inspecting the Building and Sampling the Timbers.** Together with a building historian the timbers in a building are inspected to try to ensure that those sampled are not reused or later insertions. Sampling is almost always done by coring into the timber, which has the great advantage that we can sample in situ timbers and those judged best to give the date of construction, or phase of construction if there is more than one in the building. The timbers to be sampled are also inspected to see how many rings they have. We normally look for timbers with at least 70 rings, and preferably more. With fewer rings than this, 50 for example, sequences of widths become difficult to match to a unique

position within a master sequence of ring widths and so are difficult to date (Litton and Zainodin 1991). The cross-section of the rafter shown in Figure A2 has about 120 rings; about 20 of which are sapwood rings – the lighter rings on the outside. Similarly the core has just over 100 rings with a few sapwood rings.

To ensure that we are getting the date of the building as a whole, or the whole of a phase of construction if there is more than one, about 8–10 samples per phase are usually taken. Sometimes we take many more, especially if the construction is complicated. One reason for taking so many samples is that, in general, some will fail to give a date. There may be many reasons why a particular sequence of ring widths from a sample of timber fails to give a date even though others from the same building do. For example, a particular tree may have grown in an odd ecological niche, so odd indeed that the widths of its rings were determined by factors other than the local climate! In such circumstances it will be impossible to date a timber from this tree using the master sequence whose widths, we can assume, were predominantly determined by the local climate at the time.

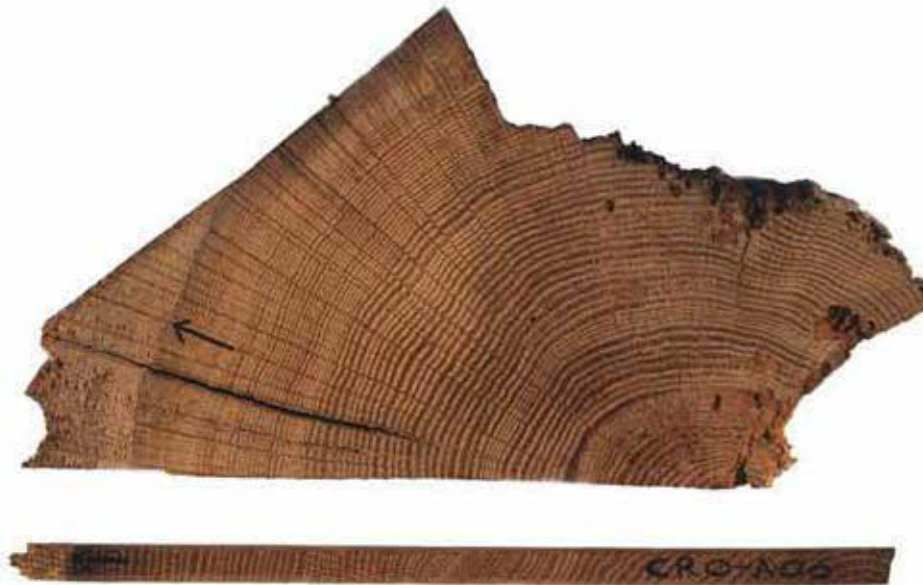
Sampling is done by coring into the timber with a hollow corer attached to an electric drill and usually from its outer rings inwards towards where the centre of the tree, the pith, is judged to be. An illustration of a core is shown in Figure A2; it is about 150mm long and 10mm diameter. Great care has to be taken to ensure that as few as possible of the outer rings are lost in coring. This can be difficult as these outer rings are often very soft (see below on sapwood). Each sample is given a code which identifies uniquely which timber it comes from, which building it is from and where the building is located. For example, CRO-A06 is the sixth core taken from the first building (A) sampled by the Laboratory in Cropwell Bishop. Where it came from in that building will be shown in the sampling records and drawings. No structural damage is done to any timbers by coring, nor does it weaken them.

During the initial inspection of the building and its timbers the dendrochronologist may come to the conclusion that, as far as can be judged, none of the timbers have sufficient rings in them for dating purposes and may advise against sampling to save further unwarranted expense.

All sampling by the Laboratory is undertaken according to current Health and Safety Standards. The Laboratory's dendrochronologists are insured.



*Figure A1: A wedge of oak from a tree felled in 1976. It shows the annual growth rings, one for each year from the innermost ring to the last ring on the outside just inside the bark. The year of each ring can be determined by counting back from the outside ring, which grew in 1976.*



*Figure A2: Cross-section of a rafter, showing sapwood rings in the left-hand corner, the arrow points to the heartwood/sapwood boundary (H/S); and a core with sapwood; again the arrow is pointing to the H/S. The core is about the size of a pencil*



*Figure A3: Measuring ring widths under a microscope. The microscope is fixed while the sample is on a moving platform. The total sequence of widths is measured twice to ensure that an error has not been made. This type of apparatus is needed to process a large number of samples on a regular basis*



*Figure A4: Three cores from timbers in a building. They come from trees growing at the same time. Notice that, although the sequences of widths look similar, they are not identical. This is typical*

**2. Measuring Ring Widths.** Each core is sanded down with a belt sander using medium-grit paper and then finished by hand with flourgrade-grit paper. The rings are then clearly visible and differentiated from each other with a result very much like that shown in Figure A2. The core is then mounted on a movable table below a microscope and the ring-widths measured individually from the innermost ring to the outermost. The widths are automatically recorded in a computer file as they are measured (see Fig A3).

**3. Cross-Matching and Dating the Samples.** Because of the factors besides the local climate which may determine the annual widths of a tree's rings, no two sequences of ring widths from different oaks growing at the same time are exactly alike (Fig A4). Indeed, the sequences may not be exactly alike even when the trees are growing near to each other. Consequently, in the Laboratory we do not attempt to match two sequences of ring widths by eye, or graphically, or by any other subjective method. Instead, it is done objectively (ie statistically) on a computer by a process called cross-matching. The output from the computer tells us the extent of correlation between two sample sequences of widths or, if we are dating, between a sample sequence of widths and the master, at each relative position of one to the other (offsets). The extent of the correlation at an offset is determined by the *t*-value (defined in almost any introductory book on statistics). That offset with the maximum *t*-value among the *t*-values at all the offsets will be the best candidate for dating one sequence relative to the other. If one of these is a master chronology, then this will date the other. Experiments carried out in the past with sequences from oaks of known date suggest that a *t*-value of at least 4.5, and preferably at least 5.0, is usually adequate for the dating to be accepted with reasonable confidence (Laxton and Litton 1988; Laxton *et al* 1988; Howard *et al* 1984–1995).

This is illustrated in Figure A5 with timbers from one of the roofs of Lincoln Cathedral. Here four sequences of ring widths, LIN-C04, 05, 08, and 45, have been cross-matched with each other. The ring widths themselves have been omitted in the bar diagram, as is usual, but the offsets at which they best cross-match each other are shown; eg the sequence of ring widths of C08 matches the sequence of ring widths of C45 best when it is at a position starting 20 rings after the first ring of C45, and similarly for the others. The actual *t*-values between the four at these offsets of best correlations are in the matrix. Thus at the offset of +20 rings, the *t*-value between C45 and C08 is 5.6 and is the maximum found between these two among all the positions of one sequence relative to the other.

It is standard practice in our Laboratory first to cross-match as many as possible of the ring-width sequences of the samples in a building and then to form an average from them. This average is called a site sequence of the building being dated and is illustrated in Figure A5. The fifth bar at the bottom is a site sequence for a roof at Lincoln Cathedral and is constructed from the matching sequences of the four timbers. The site sequence width for each year is the average of the widths in each of the sample sequences which has a width for that year. Thus in Fig A5 if the widths shown are 0.8mm for C45, 0.2mm for C08, 0.7mm for C05, and 0.3mm for C04, then the corresponding width of the site



sequence is the average of these, 0.55mm. The actual sequence of widths of this site sequence is stored on the computer. The reason for creating site sequences is that it is usually easier to date an average sequence of ring widths with a master sequence than it is to date the individual component sample sequences separately.

The straightforward method of cross-matching several sample sequences with each other one at a time is called the 'maximal *t*-value' method. The actual method of cross-matching a group of sequences of ring-widths used in the Laboratory involves grouping and averaging the ring-width sequences and is called the 'Litton-Zainodin Grouping Procedure'. It is a modification of the straightforward method and was successfully developed and tested in the Laboratory and has been published (Litton and Zainodin 1991; Laxton *et al* 1988).

**4. Estimating the Felling Date.** As mentioned above, if the bark is present on a sample, then the date of its last ring is the date of the felling of its tree (or the last full year before felling, if it was felled in the first three months of the following calendar year, before any new growth had started, but this is not too important a consideration in most cases). The actual bark may not be present on a timber in a building, though the dendrochronologist who is sampling can often see from its surface that only the bark is missing. In these cases the date of the last ring is still the date of felling.

Quite often some, though not all, of the original outer rings are missing on a timber. The outer rings on an oak, called sapwood rings, are usually lighter than the inner rings, the heartwood, and so are relatively easy to identify. For example, sapwood can be seen in the corner of the rafter and at the outer end of the core in Figure A2, both indicated by arrows. More importantly for dendrochronology, the sapwood is relatively soft and so liable to insect attack and wear and tear. The builder, therefore, may remove some of the sapwood for precisely these reasons. Nevertheless, if at least some of the sapwood rings are left on a sample, we will know that not too many rings have been lost since felling so that the date of the last ring on the sample is only a few years before the date of the original last ring on the tree, and so to the date of felling.

Various estimates have been made and used for the average number of sapwood rings in mature oak trees (English Heritage 1998). A fairly conservative range is between 15 and 50 and that this holds for 95% of mature oaks. This means, of course, that in a small number of cases there could be fewer than 15 and more than 50 sapwood rings. For example, the core CRO-A06 has only 9 sapwood rings and some have obviously been lost over time – either they were removed originally by the carpenter and/or they rotted away in the building and/or they were lost in the coring. It is not known exactly how many sapwood rings are missing, but using the above range the Laboratory would estimate between a minimum of 6 (=15-9) and a maximum of 41 (=50-9). If the last ring of CRO-A06 has been dated to 1500, say, then the estimated felling-date range for the tree from which it came originally would be between 1506 and 1541. The Laboratory uses this estimate for sapwood in areas of England where it has no prior information. It



also uses it when dealing with samples with very many rings, about 120 to the last heartwood ring. But in other areas of England where the Laboratory has accumulated a number of samples with complete sapwood, that is, no sapwood lost since felling, other estimates in place of the conservative range of 15 to 50 are used. In the East Midlands (Laxton *et al* 2001) and the east to the south down to Kent (Pearson 1995) where it has sampled extensively in the past, the Laboratory uses the shorter estimate of 15 to 35 sapwood rings in 95% of mature oaks growing in these parts. Since the sample CRO-A06 comes from a house in Cropwell Bishop in the East Midlands, a better estimate of sapwood rings lost since felling is between a minimum of 6 (=15-9) and 26 (=35-9) and the felling would be estimated to have taken place between 1506 and 1526, a shorter period than before. Oak boards quite often come from the Baltic region and in these cases the 95% confidence limits for sapwood are 9 to 36 (Howard *et al* 1992, 56).

Even more precise estimates of the felling date and range can often be obtained using knowledge of a particular case and information gathered at the time of sampling. For example, at the time of sampling the dendrochronologist may have noted that the timber from which the core of Figure A2 was taken still had complete sapwood but that some of the soft sapwood rings were lost in coring. By measuring into the timber the depth of sapwood lost, say 20mm, a reasonable estimate can be made of the number of sapwood rings lost, say 12 to 15 rings in this case. By adding on 12 to 15 years to the date of the last ring on the sample a good tight estimate for the range of the felling date can be obtained, which is often better than the 15 to 35 years later we would have estimated without this observation. In the example, the felling is now estimated to have taken place between AD 1512 and 1515, which is much more precise than without this extra information.

Even if all the sapwood rings are missing on a sample, but none of the heartwood rings are, then an estimate of the felling-date range is possible by adding on the full complement of, say, 15 to 35 years to the date of the last heartwood ring (called the heartwood/sapwood boundary or transition ring and denoted H/S). Fortunately it is often easy for a trained dendrochronologist to identify this boundary on a timber. If a timber does not have its heartwood/sapwood boundary, then only a *post quem* date for felling is possible.

**5. Estimating the Date of Construction.** There is a considerable body of evidence collected by dendrochronologists over the years that oak timbers used in buildings were not seasoned in medieval or early modern times (English Heritage 1998; Miles 1997, 50–5). Hence, provided that all the samples in a building have estimated felling-date ranges broadly in agreement with each other, so that they appear to have been felled as a group, then this should give an accurate estimate of the period when the structure was built, or soon after (Laxton *et al* 2001, fig 8; 34–5, where 'associated groups of fellings' are discussed in detail). However, if there is any evidence of storage before use, or if there is evidence the oak came from abroad (eg Baltic boards), then some allowance has to be made for this.

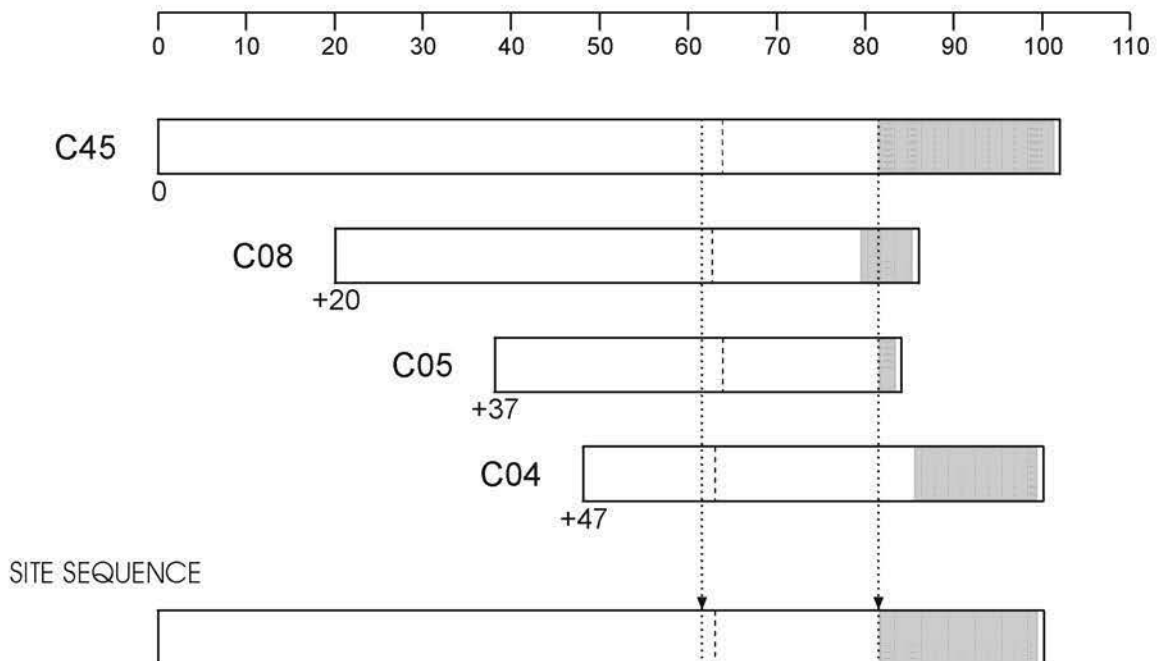
**6. Master Chronological Sequences.** Ultimately, to date a sequence of ring widths, or a site sequence, we need a master sequence of dated ring widths with which to cross-match it, a Master Chronology. To construct such a sequence we have to start with a sequence of widths whose dates are known and this means beginning with a sequence from an oak tree whose date of felling is known. In Figure A6 such a sequence is SHE-T, which came from a tree in Sherwood Forest which was blown down in a recent gale. After this other sequences which cross-match with it are added and gradually the sequence is 'pushed back in time' as far as the age of samples will allow. This process is illustrated in Figure A6. We have a master chronological sequence of widths for Nottinghamshire and East Midlands oak for each year from AD 882 to 1981. It is described in great detail in Laxton and Litton (1988), but the components it contains are shown here in the form of a bar diagram. As can be seen, it is well replicated in that for each year in this period there are several sample sequences having widths for that year. The master is the average of these. This master can now be used to date oak from this area and from the surrounding areas where the climate is very similar to that in the East Midlands. The Laboratory has also constructed a master for Kent (Laxton and Litton 1989). The method the Laboratory uses to construct a master sequence, such as the East Midlands and Kent, is completely objective and uses the Litton-Zainodin grouping procedure (Laxton *et al* 1988). Other laboratories and individuals have constructed masters for other areas and have made them available. As well as these masters, local (dated) site chronologies can be used to date other buildings from nearby. The Laboratory has hundreds of these site sequences from many parts of England and Wales covering many short periods.

**7. Ring-Width Indices.** Tree-ring dating can be done by cross-matching the ring widths themselves, as described above. However, it is advantageous to modify the widths first. Because different trees grow at different rates and because a young oak grows in a different way from an older oak, irrespective of the climate, the widths are first standardized before any matching between them is attempted. These standard widths are known as ring-width indices and were first used in dendrochronology by Baillie and Pilcher (1973). The exact form they take is explained in this paper and in the appendix of Laxton and Litton (1988) and is illustrated in the graphs in Figure A7. Here ring-widths are plotted vertically, one for each year of growth. In the upper sequence of (a), the generally large early growth after 1810 is very apparent as is the smaller later growth from about 1900 onwards when the tree is maturing. A similar phenomenon can be observed in the lower sequence of (a) starting in 1835. In both the widths are also changing rapidly from year to year. The peaks are the wide rings and the troughs are the narrow rings corresponding to good and poor growing seasons, respectively. The two corresponding sequence of Baillie-Pilcher indices are plotted in (b) where the differences in the immature and mature growths have been removed and only the rapidly changing peaks and troughs remain, that are associated with the common climatic signal. This makes cross-matching easier.

*t*-value/offset Matrix

	C45	C08	C05	C04
C45		+20	+37	+47
C08	5.6		+17	+27
C05	5.2	10.4		+10
C04	5.9	3.7	5.1	

Bar Diagram



**Figure A5: Cross-matching of four sequences from a Lincoln Cathedral roof and the formation of a site sequence from them**

The bar diagram represents these sequences without the rings themselves. The length of the bar is proportional to the number of rings in the sequence. Here the four sequences are set at relative positions (offsets) to each other at which they have maximum correlation as measured by the *t*-values. The *t*-value/offset matrix contains the maximum *t*-values below the diagonal and the offsets above it. Thus, the maximum *t*-value between C08 and C45 occurs at the offset of +20 rings and the *t*-value is then 5.6. The site sequence is composed of the average of the corresponding widths, as illustrated with one width.

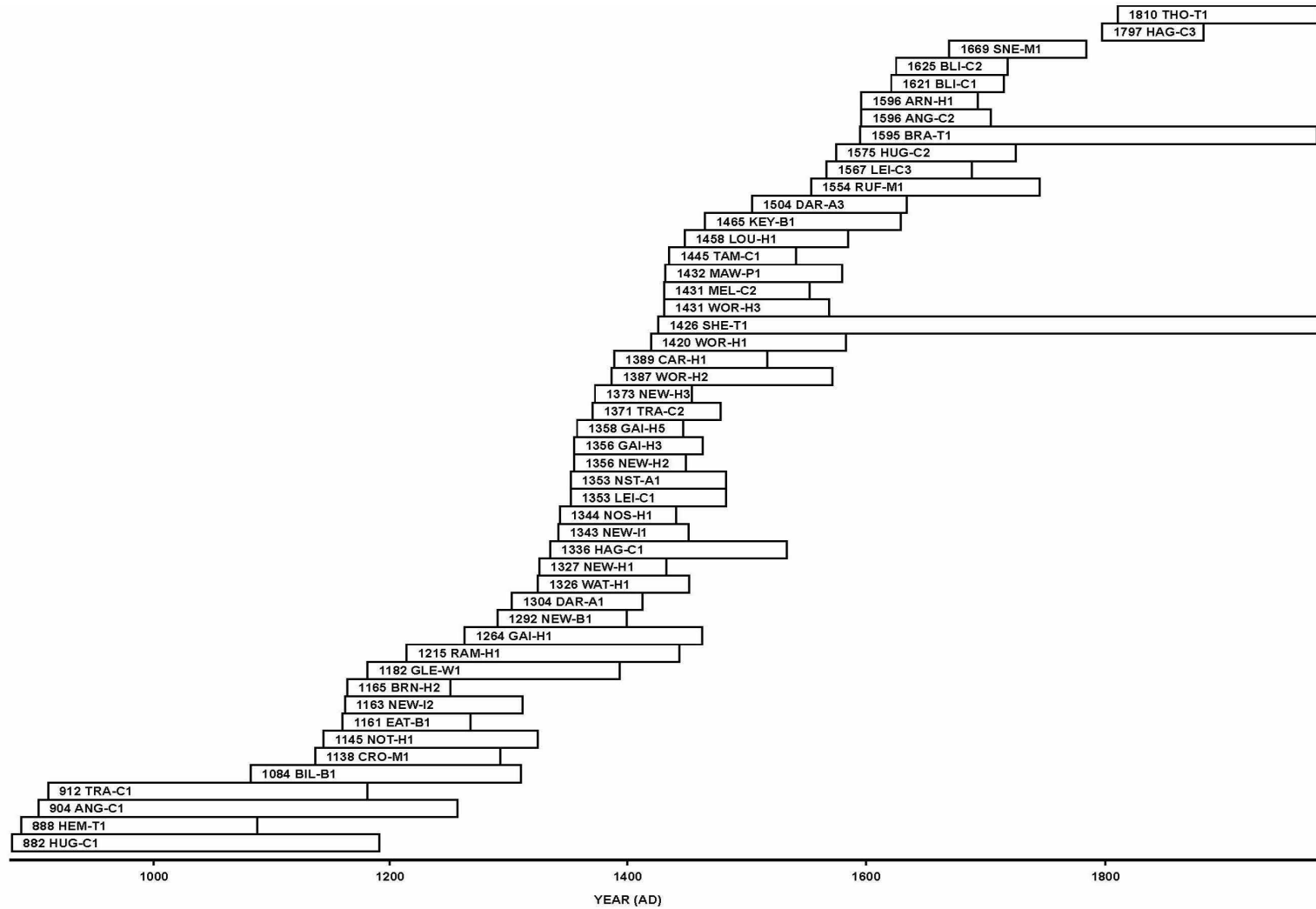
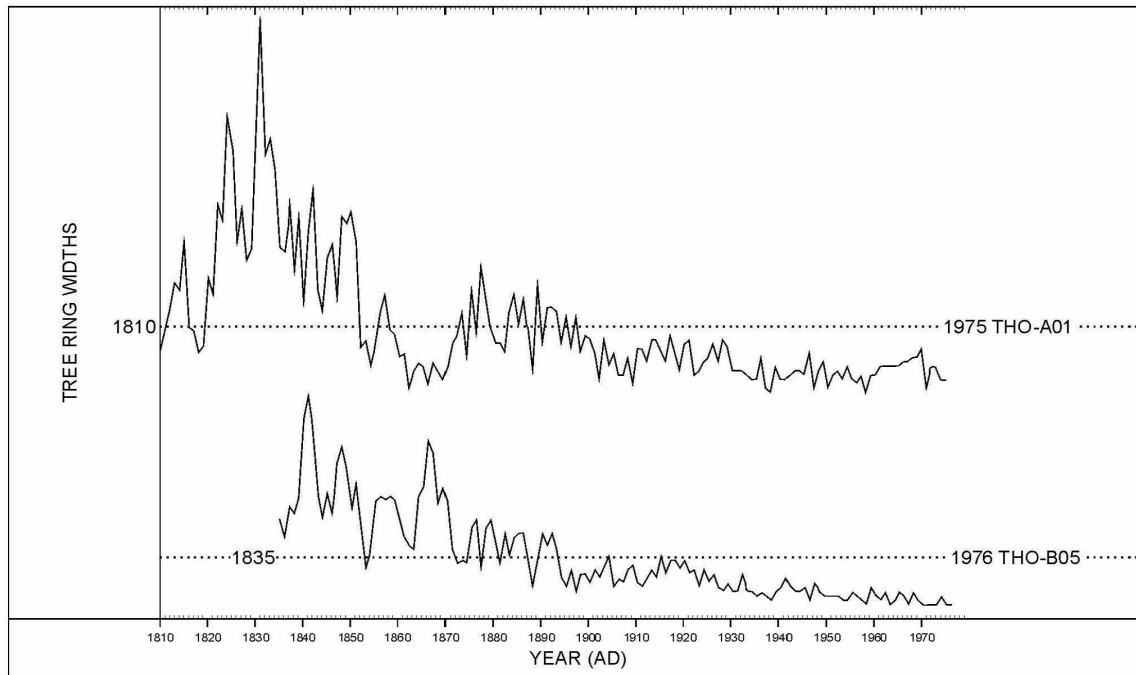
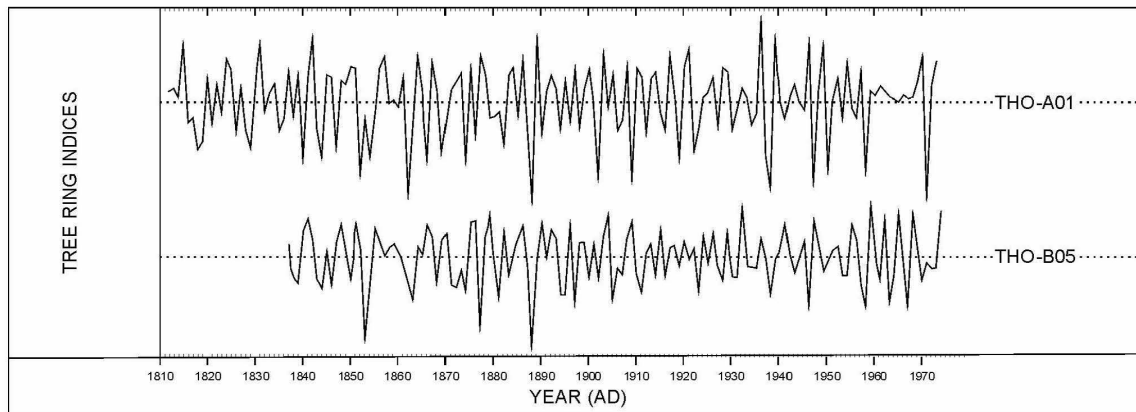


Figure A6: Bar diagram showing the relative positions and dates of the first rings of the component site sequences in the East Midlands Master Dendrochronological Sequence, EM08187

(a)



(b)



**Figure A7 (a): The raw ring-widths of two samples, THO-A01 and THO-B05, whose felling dates are known**

Here the ring widths are plotted vertically, one for each year, so that peaks represent wide rings and troughs narrow ones. Notice the growth-trends in each; on average the earlier rings of the young tree are wider than the later ones of the older tree in both sequences

**Figure A7 (b): The Baillie-Pilcher indices of the above widths**

The growth trends have been removed completely

## References

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## ENGLISH HERITAGE RESEARCH AND THE HISTORIC ENVIRONMENT

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 the protection and sustainable management of the resource, and to promote the widest access, appreciation and enjoyment of our heritage. Much of this work is conceived and implemented in the context of the National Heritage Protection Plan. For more information on the NHPP please go to <http://www.english-heritage.org.uk/professional/protection/national-heritage-protection-plan/>.

The Heritage Protection Department provides English Heritage with this capacity in the fields of building history, archaeology, archaeological science, imaging and visualisation, landscape history, and remote sensing. It brings together four teams with complementary investigative, analytical and technical skills to provide integrated applied research expertise across the range of the historic environment. These are:

- \* Intervention and Analysis (including Archaeology Projects, Archives, Environmental Studies, Archaeological Conservation and Technology, and Scientific Dating)
- \* Assessment (including Archaeological and Architectural Investigation, the Blue Plaques Team and the Survey of London)
- \* Imaging and Visualisation (including Technical Survey, Graphics and Photography)
- \* Remote Sensing (including Mapping, Photogrammetry and Geophysics)

The Heritage Protection 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 community engagement and build this in to our projects and programmes wherever possible.

We make the results of our work available through the Research Report Series, and through journal publications and monographs. Our newsletter *Research News*, which appears twice a year, aims to keep our partners within and outside English Heritage up-to-date with our projects and activities.

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