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# Tree-ring analysis of sub-fossil kauri (*Agathis australis*) from the Harding's Farm, Hilliam Road, near Dargaville, Northland

**Gretel Boswijk**

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***The University of Auckland***

*Tree-ring Laboratory, School of Geography and Environmental Science, Private Bag 92019, Auckland, New Zealand*

# Tree-ring analysis of sub-fossil kauri (*Agathis australis*) from the Harding's Farm, Hilliam Road, near Dargaville, Northland

*This is a technical archive report describing recent dendrochronological analysis of sub-fossil kauri from the Okapakapa swamp, on Robert and Donna Harding's farm, Hilliam Road, near Dargaville. Although the primary application of data derived from this analysis is for palaeoclimate reconstruction, no attempt is made to provide discussion of standardisation techniques used to enhance the climate signal for dendroclimatology or offer any dendroclimatological interpretation. The report is concerned only with the development of tree-ring chronologies. Discussion and interpretation of data are limited to setting any chronologies in a broad environmental context.*

**Summary**

Tree-ring analysis of sub-fossil (swamp) kauri from the Okapakapa swamp, Harding's farm, near Dargaville, was undertaken to develop tree-ring chronologies for palaeoclimate research. Thirteen samples were obtained from logs recently extracted from the swamp by Nelson Parker of 'Nelson's Kaihu Kauri' and Milton Randell. Tree-sequences were produced for ten samples. Two site chronologies were constructed: ***Harding1*** (five samples) and ***Harding2*** (three samples). The site chronologies were compared against the database of modern and swamp kauri chronologies. ***Harding1*** was dated to AD 124 – 1152. This was significant as ***Harding1*** assisted in linking 'floating' chronologies from Northland and Waikato to the calendar dated kauri master chronology, with calendar dates being applied back to 315 BC. A one-ring difference between two swamp kauri chronologies (***Maitahi*** and ***Whangape***) prior to 315 BC currently prevents calendar dates being applied to all swamp kauri chronologies. ***Harding2*** crossmatched with swamp kauri chronologies at 6425 – 7454 KS (ca. 1470 – 435 BC). It replicated the entire length of a tree-sequence, **POU001**, and long sections of other chronologies from Northland and Waikato, including ***Maitahi*** and ***Whangape***. As such, it is likely to be important in resolving the ring-error that currently exists between the latter two chronologies. Two Harding tree-sequences did not crossmatch to either Harding site chronology, or against any other swamp kauri chronologies or tree-sequences. Radiocarbon ($^{14}$C) dates for these samples indicate that the trees were all older than the current range of sub-fossil kauri chronologies, and that kauri were present in the locality during the past 7000 years.

# Tree-ring analysis of sub-fossil kauri (*Agathis australis*) from the Harding's Farm, Hilliam Road, near Dargaville, Northland

## Introduction

Samples of recently extracted sub-fossil (swamp) kauri (*Agathis australis*) were supplied by Nelson Parker, of 'Nelson's Kaihu Kauri' for a Marsden funded tree-ring based palaeoclimatology project: *El Nino history as recorded in kauri tree-rings* (UOA108). Almost all the kauri had been extracted from the Okapakapa swamp on Robert and Donna Harding's farm, Hilliam Road, near Dargaville (Figure1; Figure 2), by Nelson Parker and Milton Randell (kauri log digging specialist). One sample was from a site near Notorious Road, approximately 1 km from the Harding site. The Harding wood is one of several assemblages of swamp kauri from sites in the upper North Island where Holocene age kauri has been collected. The site was visited and a transect survey of the peat-bog profile was undertaken. A peat-sediment core was obtained from the same locality for palynological and sedimentological analysis. The results of the survey and peat core work are not discussed here.

### *Okapakapa Swamp*

The Okapakapa swamp is located between Hilliam Road, Mahuta Road and Notorious Road, at the northern end of the north Kaipara Peninsula (Figure 1). The western end of the swamp formed between hills of pliestocene age sand, which are up to 100 meters high. The swamp is drained by the Okapakapa stream, which outlets into the Wairoa River. The kauri were recovered from peat deposits on the edge of the swamp and from a side spur in the upper reaches of the swamp. According to Milton Randell and Nelson Parker, the land had not previously been dug over by gum diggers, or for log recovery. They also observed that the 'feel' of the wood, and the 'fluffiness' of the kauri when cut suggested that the wood was 'young' (i.e. had not been buried for a long time.) In-situ upright stumps near the surface also suggest that the site may have been forested until relatively recently.

**Figure 1: Location of Okapakapa swamp (white box), Harding's farm, Northland (260-P08 850775)**
The circle in the lower left map indicates the approximate position where the photograph in Figure 2 was taken.

**Figure 2: Okapakapa Swamp, Harding's Farm**
Milton Randell's digger is in the foreground. View to the south. November 2002

## Dendrochronology

Dendrochronology or tree-ring analysis is based on the measurement and comparison of patterns of tree-growth. The principles and methodology of tree-ring analysis are described in detail by Stokes and Smiley (1968), Fritts (1976) and Baillie (1982). In brief, each year trees lay down a growth ring, formed in the cambium directly under the bark. In many species, including kauri and silver pine, these annual rings are clearly defined by a boundary formed at the end of the growing season, which separates one growth season from the next. The width of the annual ring is limited by climatic conditions, as well as being influenced by local environmental factors, previous growth years and genetic make-up of the tree. Because growth conditions change from year to year, ring-width also varies, creating a pattern of wide and narrow rings which unique in time, but common to trees that have grown at the same time under similar conditions. Therefore it is possible to compare the growth patterns of different trees and identify those which are contemporary. Comparison of many different living kauri from several sites throughout the upper North Island indicate that these trees have a common growth pattern in their rings (Fowler *et al* 2004).

## Methods

The kauri had been extracted from the swamp and removed to Nelson's Kaihu Kauri, State Highway 12, Kaihu, near Dargaville, where it was stacked in woodpiles. Thirteen cross-sections were cut by Nelson Parker, using a chainsaw (Figure 2). The site has been assigned a site-code 'HARD" and all the wood was labelled with a prefix 'HAR', since the Okapakapa swamp was located on the Harding's farm. This includes the sample from near Notorious Road (sample HAR011).

**Figure 2: Nelson Parker cutting 'biscuits' from the Harding kauri**
HAR007 is being cut. HAR008 is on the far left (end log).

The cross-sections were photographed and dimensions recorded prior to the samples being prepared for analysis (Appendix 1: Figure A1). Up to five radii were cut from the slices so that multiple measurements from a sample could be made, ensuring that the complete ring-sequence of a sample was obtained. The cross-sectional surface of the samples was sanded using progressively finer sandpaper to clearly reveal the ring sequence. Ring-widths were measured using a binocular microscope and travelling stage linked to a computer. The measurements were recorded in 'Dendro Input', a data capture program (Tyers 1999).

Crossmatching was undertaken using the CROS computer programs (Baillie and Pilcher 1973; Munro 1984), which are included in the Dendro for Windows suite (Tyers 1999). The ring-width series were compared against each other and the correlation coefficient (r) measured at every position of overlap. A Student's *t* value is calculated, to provide a measure of the probability of the *r* value arising by chance (Baillie 1982). All reported values are from CROS73.

All crossmatched radii from a sample were combined to produce a single tree-sequence that was subsequently used for inter-tree crossmatching. All Harding tree sequences (derived from single measurements or multiple radii) were compared against each other statistically and visually and those that crossmatched were averaged together to create a mean ring-width chronology (also refered to as a site chronology). This reduces the effect of local conditions on the ring-width data and strengthens the climate signal, on which crossmatching is dependant (Baillie 1982). Resulting site chronologies were compared against other sub-fossil kauri chronologies to establish if there was any overlap. Swamp kauri chronologies have been derived from sites in the Waikato Lowlands, and in the Dargaville region (Boswijk et al 2001, Fowler et al 2001,Boswijk and Palmer 2003, Boswijk 2004a, 2004b, Boswijk and Palmer 2004).

All suggested matches (between radii, between tree-sequences and for chronologies against chronologies) were checked visually using plotted ring-width graphs. Ring-width graphs also assist the identification and resolution of any ring problems. Kauri can occasionally produce 'false' rings (the annual ring is divided by an apparent boundary) or locally absent rings (the annual ring is not complete around the tree circumference). Where a ring was absent on one radius, but present on other same-tree series, inspection of the sample usually located the ring merging into the ring boundary for the previous year. This allowed a measured value for the ring to be inserted into the series. If a ring was wholly absent from a radius, a zero value was inserted. If the location of missing rings could not be reliably resolved, the radius sequence was truncated.

Occasionally radii or tree-sequences from different samples may be very highly correlated. If supported by close visual agreement this may indicate that they are derived from the same source tree. In these cases, samples were relabelled (wood and data files) to indicate same-tree provenance. Tree-sequences were remade, incorporating all radii considered to be from the same source tree.

### *Dating*

Tree-ring dating is accurate to the last growth ring present on a sequence. If a radii/tree-sequence includes the final growth ring, at the bark-edge surface, the year of death can be identified. The season of death can also be determined depending on whether the ring is complete (died after the end of the growing season) or incomplete (died during the growing season).

At present the modern kauri master curve does not extend past AD 911[1]. If the Harding kauri crossmatch to the modern kauri master, calendar years (AD/BC) can be applied to the relevant site chronology/tree-sequences. If the sub-fossil kauri do not match to the modern calendar dated chronology, identifying an approximate date for the wood is dependant on establishing linkages to existing floating chronologies which have been radiocarbon dated. Floating sub-fossil chronologies have been radiocarbon dated to between ca. 3500 – 1300 years before present (BP) (Boswijk *et al* 2005). However, to allow newly crossmatched material to be aligned relative to existing sub-fossil chronologies in a consistent manner, avoiding continual revision of start and end dates, an arbitrary floating Kauri Scale (KS) has been devised. The sub-fossil kauri chronologies are within a period which has kauri scale 'dates' of 6167 – 8662 KS. Any Harding samples crossdated against the floating sub-fossil chronologies will be assigned KS dates.

## Results

Thirteen samples were collected from Nelson's Kaihu Kauri. One sample, **HAR002**, was not analysed as it was from the same tree as **HAR003**. Radii from twelve samples were measured and tree-sequences were produced for ten samples. Of these, **HAR001**, **HAR005**, **HAR006** and **HAR007** all had the final growth ring at the bark edge surface. However, the outer rings of **HAR001** were excluded due to the effects of wedging, suppression and locally absent rings. The centre of **HAR005** had rotted, so that an unknown number of rings had been lost. **HAR006** had a 150 year period of suppressed growth and locally absent rings on all radii. The radii and tree-sequence were separated into inner and outer sections. **HAR007** was the longest series with 1030 rings, plus an additional ½ ring which was the final growth ring at bark edge. This sample had clearly visible heartwood-sapwood transition and bark edge around much of the sample (Figure 4). **HAR003** and **HAR008** had wide rings from pith, and distinctive wedging. On **HAR003**, the growth rate decreased after ca. 200 rings. The inner rings of **HAR008** were notable as they had dark latewood. Tree-sequences could not be made for **HAR009** and **HAR012**. Both samples had narrow rings, numerous missing rings and false rings, which hindered crossmatching between radii. The outer 76 rings of **HAR013** were truncated as the ring pattern was not considered reliable. **HAR013d** ended at bark-edge, but this was ca. 60 years earlier than the outermost ring on **HAR013F**. Full details of all the samples (dimensions, number of rings, average growth rates etc.) are listed in Table 1.

[1] This equates to the calendar years AD 911/12, as the austral growing season crosses the change of year. The convention is to date the annual ring by the year growth started.

**Figure 4: HAR007 which had visible heartwood sapwood transition and bark edge surface.**
H/S marks the heartwood-sapwood transition.

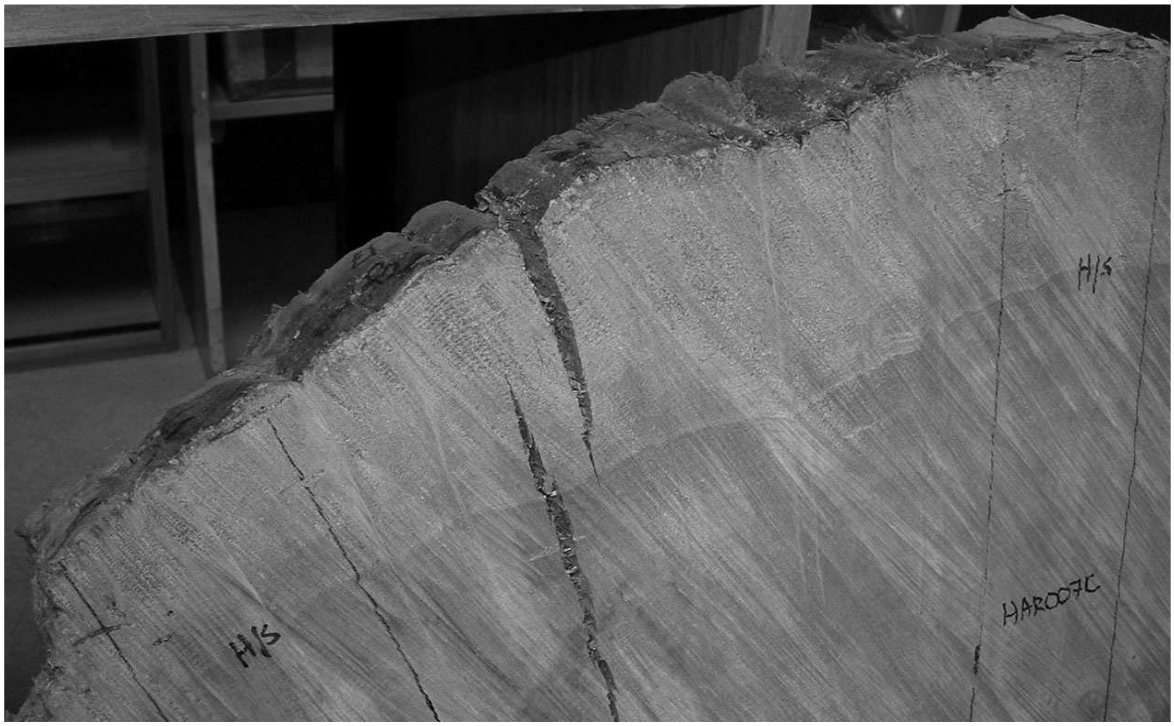


**Table 1: Details of the Harding samples**

**Key**:
**Sample:** HAR*** = tree-sequence used for chronology building; radii are listed below
**Length:** radii length, measured from pith to edge, or edge to edge.
**Pith:** C = centre; <5 = less than five to pith; 5-10 = 5 – 10 rings to pith; >10 = more than 10 rings to pith
**Rings:** **n*+ **n** = *extra inner rings* + measured rings; h = heartwood; **n** +*n** = measured rings + *extra outer rings*; h = heartwood rings; s = sapwood rings; b= bark edge. Extra rings were either unmeasured or excluded from the series due to irresolvable problems.
**Bark:** b = bark edge; bw = final ring complete (died winter); +½Bs = + ½ unmeasured ring to bark edge (died spring/summer).
**AGR:** average growth rate (mm per annum)
**Date:** according to position in chronology or tree-sequence. May be calendar (AD/BC); relative (rel = relates to position within the tree-sequence only) or Kauri Scale (KS) (crossmatched to floating sub-fossil chronologies)
**Absent rings**: indicates years – calendar, KS or rel – where there were locally absent rings on a series (i.e. rings not present on the measured radius).

| Sample | Length | Pith | Rings | Bark | AGR | Date | Chronology | Absent rings | Comment |
|---|---|---|---|---|---|---|---|---|---|
| **HAR001** | | | **226 *+117*** | +½Bs | **2.65** | **6641-6866 KS** | ***Harding2*** | | |
| HAR001a | 505 mm | >10 | 101 *+192* | | 1.63 | 6662 – 6762 KS | | 6757 KS | Outer rings on all radii quite variable |
| HAR001b | 600 mm | >10 | 150 *+147* | +½Bs | 1.94 | 6652 – 6801 KS | | 6746 KS | with wedging, suppresion and locally |
| HAR001c | 644 mm | >10 | 210 *+123* | +½Bs | 1.91 | 6641 – 6851 KS | | | absent rings. Difficult to resolve |
| HAR001d | 715 mm | >10 | 219 *+117* | +B | 2.09 | 6648 – 6866 KS | | 6685 KS; 6785 KS | problems satisfactorily. E was |
| HAR001e | 760 mm | >10 | 350 | | 2.03 | 1 – 350 | | | excluded due to multiple missing rings |
| **HAR002** | **-** | **-** | **-** | **-** | **-** | **-** | | | Not measured – same tree as HAR003/010 |
| **HAR003** | | | **523** | | **1.66** | **AD 504 AD1026** | ***Harding1*** | | Same tree as HAR002/HAR010 |
| HAR003b | 630 mm | >10 | 336 | | 1.86 | AD 572 – AD 907 | | | Log still standing upright and sticking |
| HAR003c | 830 mm | >10 | 469 | | 1.72 | AD 542 –AD 1010 | | | out of peat, rather than prostrate like deeper logs and stumps |
| **HAR004** | | | **348 *+62h*** | | **1.55** | **AD 805 –AD 1152** | ***Harding1*** | | Died some time after AD 1214 |
| HAR004a | 882 mm | <5 | 347 *+62h* | | 1.55 | AD 806 –AD 1152 | | | |
| HAR004b | 882 mm | >10 | 300 *+64h* | | 1.55 | AD 848 –AD 1147 | | | |
| HAR004c | 882 mm | C | 193 | | 1.51 | AD 805 – AD 997 | | | |
| HAR004d | 882 mm | <5 | 224 | | 1.42 | AD 808 –AD 1031 | | | |
| **HAR005** | | | **563** | **+Bw** | **1.57** | **AD 124 – AD 686** | ***Harding1*** | | Died winter AD 687 |
| HAR005a | 0 x 0 | >10 | 563 | +Bw | 1.40 | AD 124 – AD 686 | | AD 257; AD 289; AD 331; AD 381; AD 385; AD 386; AD 394; AD 504 | |
| HAR005b | 920 mm | >10 | 546 | +Bw | 1.61 | AD 141 – AD 686 | | AD 331 | |
| HAR005c | 1015 mm | >10 | 505 | +Bw | 1.99 | AD 182 – AD 686 | | | |
| HAR005d | 920 mm | >10 | 515 | +Bw | 1.71 | AD 172 – AD 686 | | AD 379; AD 380; AD 382; AD 386; AD 394; AD 399; AD 404 | |
| **HAR006i** | | | **199** | | **1.17** | **AD 200 – AD 398** | ***Harding1*** | | All radii have suppressed growth and |
| **HAR006o** | | | **294** | +½Bs | **1.46** | **AD 546 – AD 839** | | | locally absent rings between AD399- |
| HAR006ai | 590 mm | >10 | 199 | | 1.02 | AD 200 – AD 398 | | | 545 inclusive. Each series was cut in |
| HAR006ao | | | 221 | +B | 1.24 | AD 546 – AD 766 | | | to two sections. HAR006 died during |
| HAR006bi | 773 mm | >10 | 188 | | 1.23 | AD 211 – AD 398 | | | AD 840/41 growing season. |
| HAR006bo | | | 294 | +B | 1.52 | AD 546 – AD 839 | | | |
| HAR06ci | 765 mm | >10 | 150 | - | 1.46 | AD 244 – AD 393 | | | |
| HAR06co | | | 288 | +½Bs | 1.62 | AD 552 – AD 839 | | | |
| **HAR007** | | | **1030** | **+½Bs** | **0.79** | **6425 – 7454 KS** | ***Harding2*** | | |
| HAR007a | 578 mm | >10 | 690 | | 0.80 | 6556 – 7245 KS | | | |
| HAR007b | 875 mm | >10 | 1029 | +½Bs | 0.84 | 6425 – 7454 KS | | 7048 KS; 7053 KS; 7081 KS; 7401 KS | |
| HAR007c | 903 mm | >10 | 1026 | | 0.86 | 6425 – 7450 KS | | 6952 KS; 6985 KS; 7045 KS; 7048 KS; | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 7053 KS | |
| HAR007d | 760 mm | >10 | 968 | | 0.77 | 6434 – 7401 KS | 6936 KS; 6985 KS | |
| HAR007e | 522 mm | >10 | 857 | | 0.59 | 6446 – 7302 KS | 6831 KS; 6886 KS; 6957 KS; 6985 KS; 7048 KS; 7053 KS | |
| **HAR008** | | | **316** | **-** | **2.44** | **1-316 rel** | **Not crossmatched** | |
| HAR008a | 375 mm | C | 196 | | 1.84 | 1-196 rel | | |
| HAR008b | 810 mm | >10 | *277+17h* | | 2.67 | 40-316 rel | | |
| HAR008d | 0 x 0 | >10 | 148 | | 2.13 | 45-192 rel | | |
| **HAR009** | | | **-** | | **-** | **-** | **Not crossmatched** | Same tree as HAR012. |
| HAR009a | 380 mm | >10 | 668 | | 0.59 | 1-668 | 68 rel | |
| HAR009b | 646 mm | >10 | 822 *+17h* | | 0.77 | 1-822 | | |
| HAR009c | 0 mm | >10 | 693 | | 0.72 | 1-693 | 64 rel; 179 rel; 181 rel; 187 rel | |
| HAR009d | 540 mm | >10 | *99h*+ 774 | ?B | 0.58 | 1-774 | | |
| **HAR010** | | | **543** | **-** | **0.96** | **AD 610 – AD 1152** | ***Harding1*** | Head log from the same tree as HAR003. |
| HAR010a | 545 mm | <5 | 517 | | 1.04 | AD 612 – AD 1128 | AD 921; AD 1101 | Tree died some time after AD 1152. |
| HAR010b | 554 mm | >10 | 524 | | 1.00 | AD 629 – AD 1152 | | |
| HAR010c | 557 mm | <5 | 494 | | 1.13 | AD 611 – AD 1104 | | |
| HAR010d | 395 mm | C | 481 | | 0.80 | AD 610 – AD 1090 | AD 920; AD 921 | |
| **HAR011** | | | **300*+148h*** | | **0.93** | **1-300** | **Not crossmatched** | Short tree-sequence made but did not crossmatch to any other Hardings sequences or other kauri chronologies. From a log near Notorious Road, ca. 1km from Harding site. |
| HAR011a | 510 mm | >10 | 403 | | 1.29 | 1-403 | | |
| HAR011b | 700 mm | >10 | 448 | | 1.51 | 1-448 | | |
| **HAR012s** | | | **-** | | **-** | **-** | **Not crossmatched** | Same tree as HAR009. |
| HAR012a | 225 mm | C | 530 | | 0.41 | 1-530 | | |
| HAR012b | 435 mm | <5 | 832 | | 0.52 | 2-833 | 158 rel; 288 rel; 304 rel; 305 rel; 307 rel; 308 rel; 310 rel; 311 rel; 323 rel; 328 rel; 332 rel; 334 rel; 354 rel; 383 rel; 392 rel; 403 rel; 406 rel; 457 rel; 563 rel; 593 rel; 698 rel | |
| HAR012c | 478 mm | >10 | 823 | | 0.59 | 1-823 | | |
| HAR012d | 0 mm | >10 | 607 | | 0.76 | 120-726 | 475 rel; 699 rel | |
| HAR012e | 600 mm | | 926 | | 0.64 | 1-926 | 122 rel; 256 rel; 270 rel; 277 rel; 288 rel; 621 rel; 787 rel | |
| **HAR013** | | | **556 *+76*** | **+Bw** | **1.65** | **6696 – 7251 KS** | ***Harding2*** | |
| HAR013a | 563 mm | >10 | 337 | | 1.65 | 6789 – 7125 KS | | |
| HAR013bi | 871 mm | | *45h*+ 321 | | 2.30 | 6696 – 7016 KS | | |
| HAR013bo | | | *20h*+ 206 | | 0.52 | 7041 – 7246 KS | | |
| HAR013d | 1067 mm | >10 | 434 | | 2.27 | 6811 – 7244 KS | 7109; 7162 KS | |
| HAR013f | 950 mm | >10 | *74h*+ 548 *+76* | +Bw | 1.41 | 6704 – 7251 KS | | |

All the tree-sequences were compared against each other to identify those samples that were contemporary. Two separate groups were identified: ***Harding1*** and ***Harding2***. Two tree-sequences, **HAR008** and **HAR011** did not crossmatch with either group, or against each other.

## *Harding1*

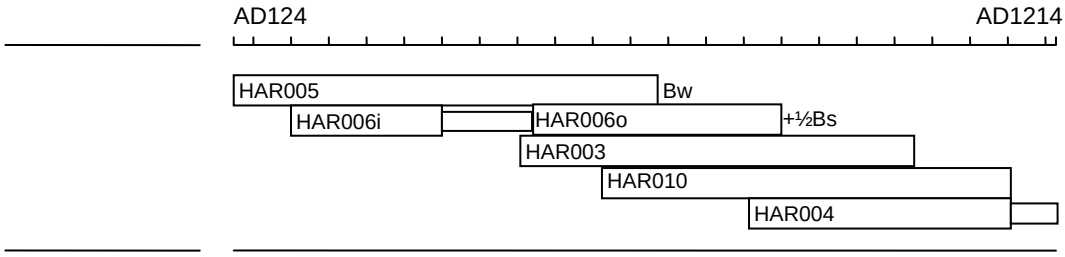
***Harding1*** is comprised of five tree-sequences (**HAR003**, **HAR004**, **HAR005**, **HAR006i** and **HAR006o**, and **HAR010**) (Table 2; Figure 5). This equates to four trees as **HAR003** and **HAR010** were from the same tree. The chronology is 1029 years long. Intra-tree crossmatching is listed in Appendix 2: Table A1. The composition of each tree-sequence is illustrated in Appendix 2: Figure A2. The chronology listing for ***Harding1*** is presented in Table A3.

**Table 2: Inter-tree crossmatching between Harding1 tree-sequences**
t and r values are listed (t = *n* / r = *n* )

| **Filenames** | **-** | **-** | **HAR003** | **HAR004** | **HAR005** | **HAR006i** | **HAR006o** | **HAR010** |
|---|---|---|---|---|---|---|---|---|
| - | *start* | *dates* | *AD 504* | *AD 805* | *AD 124* | *AD 200* | *AD 510* | *AD 610* |
| - | *dates* | *end* | *AD 1026* | *AD 1152* | *AD 686* | *AD 400* | *AD 839* | *AD 1152* |
| **HAR003** | *AD 504* | *AD 1026* | * | 6.52 / 0.41 | - | \ | 10.83 / 0.52 | 17.04 / 0.64 |
| **HAR004** | *AD 805* | *AD 1152* | * | * | \ | \ | - | 8.77 / 0.43 |
| **HAR005** | *AD 124* | *AD 686* | * | * | * | 8.00 / 0.50 | 11.40 / 0.67 | 3.30 / 0.36 |
| **HAR006i** | *AD 200* | *AD 400* | * | * | * | * | \ | \ |
| **HAR006o** | *AD 510* | *AD 839* | * | * | * | * | * | 15.24 / 0.71 |
| **HAR010** | *AD 610* | *AD 1152* | * | * | * | * | * | * |

n = 10 min t = 0.23 max t = 17.04 mean t = 7.85 s.d. = 5.02

**Figure 5: Composition of Harding1**
Wide bars represent measured sequences. Narrow bars indicate unmeasured/excluded rings. Bw = bark edge, last ring complete; +½ Bs = additional ½ ring at bark edge, tree died during the growing season.




### Calendar Dating *Harding1*

***Harding1*** was tested against all sub-fossil and modern kauri chronologies and crossmatched with two sub-fossil kauri chronologies (***Furniss1*** and ***Yakas1***) and **TIK001,** a tree sequence, at the kauri scale years 8015 – 9043 KS. Note that the ***Furniss1*** chronology has recently been extended by 360 years, through the addition of a new sample, **FNS100** (Boswijk *et al* 2005)

The crossmatching of ***Harding1*** to these chronologies was a significant finding, as the position of overlap for ***Harding1*** indicated that this chronology spanned much of the first millenium AD and should end early in the second millennium AD. Radiocarbon dates for ***Furniss1*** and **TIK001** indicated that these chronologies dated to the first millennium AD and ***Yakas1*** was thought to end probably in the 13$^{th}$ century AD. However, no crossmatching between ***Yakas1*** and the modern kauri record (at that time represented only by one series, **DSPL**, from AD 911 to 1268) had been previously identified, suggesting that the Yakas chronology was flawed in some way. Only a 426-year section of ***Yakas1,*** which had been independently replicated

completely by **TIK001** and in part by ***Furniss1***, was considered reliable by Boswijk and Palmer (2004). The recent addition of **FNS100** to the ***Furniss1*** chronology extended the period of replication by 222 years.

***Harding1*** replicated 850 years of ***Yakas1***. However, the chronologies went out of alignment by one year at 8701-8702 KS, indicating either a missing ring in ***Harding1*** or a false ring in ***Yakas1***. Close inspection of all the samples of the year in question, and decade prior and after, indicated that a false ring had been measured on a ***Yakas1*** sample (**YAK003**) and the error carried over to other crossmatched Yakas sequences through the insertion of a 'zero' value ring. In this case a 'boundary' had formed in the middle of the ring, so that there appeared to be two distinct rings, but the boundary disappeared further along the ring. The affected series were corrected and the ***Yakas1*** chronology rebuilt.

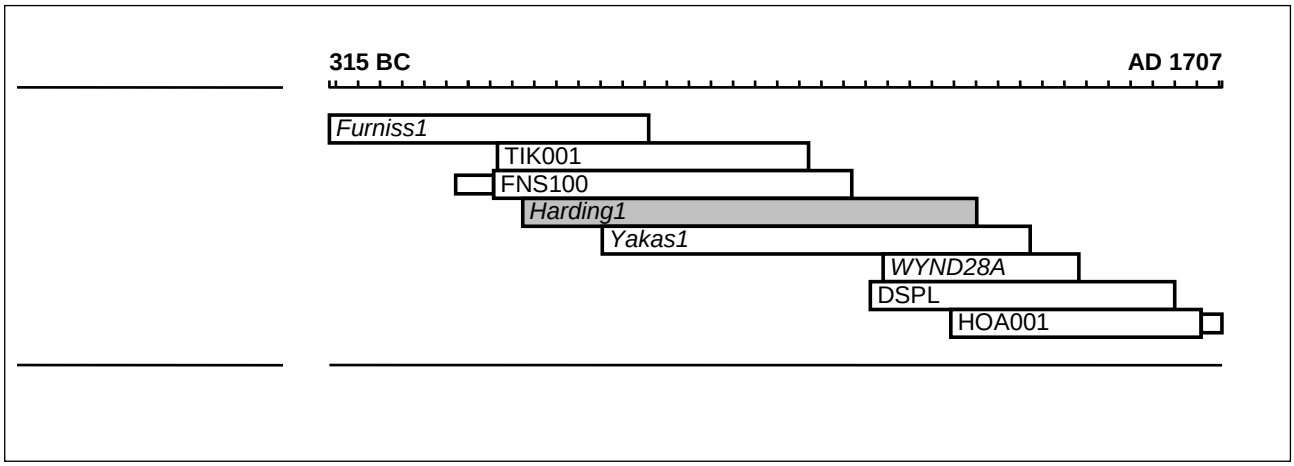
Both chronologies were compared to modern kauri chronologies, derived from living trees, and a new house-timber chronology (**WYND28a**; Lorrey *et al* 2004) and tree-sequence from a buried log (**HOA001**; Boswijk 2004b) recently added to the kauri database. Comparison of ***Yakas1*** against these, and **DSPL,** indicated that the ***Yakas1*** chronology dated to AD 304 – 1273. ***Harding1*** spans the period AD 124 – 1152, although comparison to **WYND28a** and **DSPL** shows only weak crossmatching (Table 3; Figure 6).

The absolute dating of ***Harding1*** and ***Yakas1*** enables calendar dates to be applied to the ***Furniss1*** chronology and **TIK001**. At present there is a one year difference between a Waikato chronology, ***Whangape*** (crossmatches to ***Furniss1***), and a contemporary chronology from the Dargaville region, ***Maitahi***, (Boswijk 2005), which prevents calendar dates being applied to the entire sub-fossil database. Once the ring discrepancy is resolved, all swamp kauri will be calendar dated.

**Table 3: Crossmatching of *Harding1* and *Yakas1* to modern and sub-fossil chronologies.**
***Furniss1*** (chronology) and **TIK001** (tree-sequences) are swamp kauri records. **DSPL** is a logging relic. **WYND28A** is a house-timber chronology. **HOA001** is a buried kauri of recent age.

| **Filenames** | | | ***Harding1*** | ***Yakas1*** |
|---|---|---|---|---|
| | *start dates* | *dates end* | *AD124 AD1152* | *AD304 AD1273* |
| ***Northland*** | | | | |
| ***Harding1*** | *AD124* | *AD1152* | * | 23.09 / 0.62 |
| **TIK001** | *AD67* | *AD771* | 15.60 / 0.52 | 12.48 / 0.50 |
| **HOA001** | *AD1093* | *AD1660* | - | 7.50 / 0.49 |
| ***Waikato*** | | | | |
| ***Furniss1*** | *315BC* | *AD769* | 7.77 / 0.29 | 11.61 / 0.48 |
| ***Other*** | | | | |
| **DSPL** | *AD911* | *AD1600* | 3.22 / 0.21 | 4.55 / 0.23 |
| ***Wynd28a*** | *AD940* | *AD1383* | 2.38 / 0.16 | 7.27 / 0.37 |

**Figure 6: Calendar dated position of *Harding1* (shaded).**
***Furniss1*** , ***Yakas1*** (chronologies) and **TIK001,** (tree-sequence) are swamp kauri records. **WYND28A** is a house-timber chronology. **DSPL** is a logging relic. **HOA001** is a buried kauri of recent age. Wide bars indicate the measured length of the chronology/tree-sequence. Narrow bars are unmeasured/excluded rings.




## *Harding2*

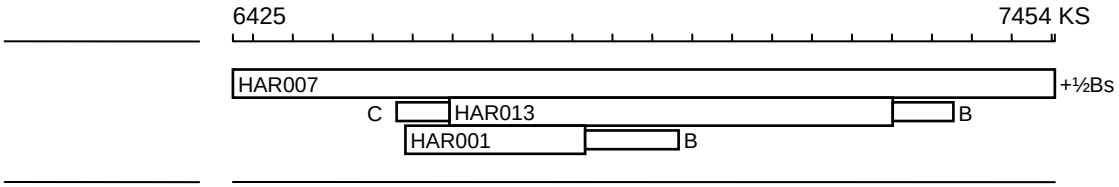
***Harding2*** is comprised of **HAR001**, **HAR007** and **HAR013** (Table 4, Figure 7). The chronology is 1030 years long, which represents the entire span of **HAR007**. Crossmatching between same-tree radii and between radii from different samples is presented in Appendix 2: Table A2. The composition of each tree-sequence is illustrated in Appendix 2: Figure A3. The chronology listing is presented in Table A3.

**Table 4: Inter-tree crossmatching between *Harding2* tree-sequences**
t and r values are listed (t = *n* / r = *n* )

| Filenames | - | - | **HAR001** | **HAR007** | **HAR013** |
|---|---|---|---|---|---|
| - | *start* | *dates* | 6641 | 6425 | 6696 |
| - | *dates* | *end* | 6866 | 7454 | 7251 |
| **HAR001** | *6641* | *6866* | * | 10.72 / 0.59 | 4.15 / 0.31 |
| **HAR007** | *6425* | *7454* | * | * | 10.30 / 0.40 |
| **HAR013** | *6696* | *7251* | * | * | * |

n = 3 min t = 4.15 max t = 10.72 mean t = 8.39 s.d. = 3.00

**Figure 7: Position of overlap between HAR001, HAR007 and HAR013**
Wide bars represent measured sequences. Narrow bars indicate unmeasured/excluded rings. B = bark edge; +½Bs = additional half ring at bark edge. Dates refer to Kauri Scale (KS). The application of KS dates is discussed below.



### Crossmatching *Harding2*

***Harding2*** was compared against all sub-fossil kauri chronologies/tree-sequences from the Waikato and Dargaville regions. It crossmatched to ***Yakas2,*** **POU001**, ***Pukekapia***, and ***Whangape***, at the date span 6425 – 7454 KS (Table 5; Figure 8)[2]. ***Harding2*** also had a 141 year overlap with the chronology, ***Maitahi***, which was statistically significant (t= 7.20/ 0.53) and visually very good. It should be noted that ***Harding2*** is based on one tree for the span of the overlap, as is ***Maitahi***. The Harding chronology ended prior to the period when a ring difference was thought to occur between ***Maitahi*** and ***Whangape*** (at 7510 – 7535 KS). However, comparison of the two northland chronologies to ***Whangape*** suggests that the latter chronology should be reviewed from 7410 KS to 7535 KS. This is discussed further in Boswijk (2005).

**Table 5: Crossmatching of *Harding2* and tree-sequences to other sub-fossil kauri chronologies and the POU001 tree-sequence**
*t* and *r* values are listed (t = *n* / r = *n* ). Dates refer to Kauri Scale (KS).

| **Filenames** | - | - | ***Harding2*** | **HAR001** | **HAR007** | **HAR013** |
|---|---|---|---|---|---|---|
| - | *start* | *dates* | *6425* | *6641* | *6425* | *6696* |
| - | *dates* | *end* | *7454* | *6866* | *7454* | *7251* |
| ***Northland*** | | | | | | |
| ***Yakas2*** | *6344* | *6970* | 15.54 / 0.56 | 7.46 / 0.45 | 13.92 / 0.51 | 7.13 / 0.40 |
| **POU001** | *6576* | *7150* | 14.72 / 0.53 | 4.56 / 0.29 | 9.93 / 0.38 | 14.30 / 0.56 |
| ***Waikato*** | | | | | | |
| ***Pukekapia*** | *6167* | *6969* | 9.16 / 0.37 | 4.41 / 0.29 | 9.51 / 0.38 | 6.65 / 0.38 |
| ***Whangape*** | 6711 | 7761 | 10.81 / 0.37 | - / - | 9.47 / 0.33 | 9.62 / 0.38 |

n = 16 min t = 1.20 max t = 15.54 mean t = 9.27 s.d. = 3.91

**Figure 8: Dated position of *Harding2* to other sub-fossil kauri chronologies and a tree-sequence**
***Yakas2*** chronology and **POU001** (tree-sequence) are from the Dargaville region. ***Pukekapia*** and ***Whangape*** are Waikato chronologies.

*Diagram removed due to problem converting to pdf*

### *HAR008 and HAR011*

**HAR008** and **HAR011** did not crossmatch to each other or to any other kauri chronologies. Therefore they remain undated (either calendrically or relative to floating chronologies). Both samples had 'difficult' ring patterns. **HAR008** was notable as it had wide rings from pith – the average growth rate for the tree-sequence was 2.44 mm per annum - and displayed a strong pattern of alternating wedging and suppression. It also had dark latewood bands and episodes where the latewood appeared to 'split out' creating a false ring, particularly in the inner rings. **HAR011** had obvious false rings, and the outer rings of both radii were quite wide. Although a 300 year tree-sequence was made from the reliable inner sections of both radii, it did not crossmatch to anything else. It is possible that the tree-sequences were flawed in some way, preventing crossmatching of these tree-sequences to other Harding's wood or other site chronologies. Alternatively the kauri may older than the current group of kauri chronologies.

[2] This is within the period 1470 – 435 BC, although precise calendar dates cannot be applied to the tree-sequences due to the ring issue described above.

### *Radiocarbon dating*

Radiocarbon dates were obtained for **HAR008**, **HAR009** and **HAR011**, to determine if these samples were contemporary with, or older than, the other sub-fossil kauri chronologies from Dargaville and Waikato. A block of 10 rings was taken from the each sample. **HAR010** was also sub-sampled for $^{14}C$ dating, as a secondary check for the dendrochronological dating of ***Harding1***. The wood samples were sent to the Radiocarbon Dating Laboratory at the University of Waikato. The radiocarbon results are listed in Table 6 below.

The calibrated date span for **HAR010** broadly agrees with the calendar date for the sampled rings (1011-1020 cal AD), supporting the crossdating of the ***Harding1*** chronology. The $^{14}C$ dates for **HAR008**, **HAR009** and **HAR011** indicate that these trees are all older than the current range of sub-fossil and modern kauri chronologies. In particular, the calibrated date range for **HAR009** (5316 – 5042 cal BC) indicated that the kauri tree was alive over 7000 years ago. This was a wholly unanticipated finding, as it was not expected that wood so old would be in the Harding assemblage.

**Table 6: Results from radiocarbon dating**
$^{14}C$ results are conventional age as per Sutiver and Polach (1977), based on the Libby half-life of 5568 years. $^{14}C$ dates were calibrated using Oxcal v3.9 (Bronk Ramsey 1995, 2001) using Southern Hemisphere atmospheric data from McCormac et al (2004).

| Sample | Rings sampled for 14C dating | Sample code | 14C result | Calibrated date range (2σ) |
|---|---|---|---|---|
| **HAR008** | 325-334 rel | WK15533 | 4582 ± 43 BP | 3368 – 3033 cal BC |
| **HAR009** | 654-663 rel | WK15534 | 6286 ± 50 BP | 5316 – 5042 cal BC |
| **HAR010** | AD 1011-1020 | WK15535 | 1034 ± 35 BP | 990 – 1150 cal AD |
| **HAR011** | 421-430 rel | WK15536 | 5006 ± 37 BP | 3906 – 3644 cal BC |

## Discussion

Analysis of kauri from the Harding's farm has contributed two new kauri chronologies to the suite of sub-fossil chronologies currently being developed for palaeoclimate research. In particular, ***Harding1*** has been a significant addition as it spans much of the first millennium AD and ends at AD 1152. It replicated over 800 years of the ***Yakas1*** chronology, the reliability of which had been previously questioned, and assisted in linking 'floating' sub-fossil chronologies from Northland and Waikato, to the modern, calendar dated record. ***Harding2*** has replicated the entire length of a tree-sequence, **POU001**, and long sections of other chronologies from Northland and Waikato.

The tree-ring chronologies, Harding1 and Harding2, and the radiocarbon dates for **HAR008**, **HAR009** and **HAR011** indicate that kauri was present in the locality for over 7000 years. (**HAR011** was from near Notorious Road, ca. 1 km from the Harding site). Unfortunately it is not possible to map whether there was any difference in location between trees dating to different time periods, which could aid understanding of the development of the peat bog, as the logs were already removed from the swamp when the kauri was sampled.

Over half the samples analysed had more than 500 rings, and are similar in length to contemporary tree-sequences from Adrian Yakas' farm (north of Dargaville) and Tikinui and Pouto, North Kaipara Peninsula. As the Harding's tree-sequences rarely represent the entire growth span of the tree, this also indicates that these kauri were easily achieving ages similar to modern kauri, which commonly reach ages over 600 years.

**HAR001**, **HAR005**, **HAR006**, **HAR007** and **HAR013** all retained the bark edge surface and the tree-sequences from three of these (**HAR005**, **HAR006**, and **HAR007**) included the final complete growth ring. There is no evidence of a single cataclysmic event that may have caused several trees to die at the same time in either ***Harding1*** or ***Harding2***, however sample depth in both chronologies is low (<4 trees).

Of the ***Harding1*** group, **HAR005** died in winter AD 687 and **HAR006** sometime during spring or early summer of AD 840/841. There is no obvious indicator of a change in growth rate signifying stress for either tree, suggesting that the trees may have been blown over, or fell over.

All three tree-sequences from ***Harding2*** had bark edge. **HAR001** had wedging, suppression and locally absent rings in the outer 117 rings (after 6866 KS). Taking these additional rings into account, the tree died in, or after, 6983 KS. **HAR013** also had missing rings in the outer sections of the radii, so that the series had to be truncated by 76 rings. After producing relatively wide rings for 310 years, the growth rate decreased and the rings became narrow. **HAR007**, which is contemporary with both trees, does not exhibit any significant change after 6866 KS or 7251 KS (the end date of **HAR013**). This suggests a localised change in conditions which only affected the growth of some trees. **HAR007** is similar to **HAR005** and **HAR006**, in having no obvious indicator of a change in growth pattern in the years prior to the death of the tree.

The good preservation of sapwood and bark edge on at least part of the logs, suggests that the trees fell into existing peat bog. If the trees had died and stayed standing for some time before falling over, it would be expected that the bark would be lost and sapwood would rot and be attacked by insects, as can be seen on standing dead trees in Waipoua Forest. An exposed log left on the edge of a paddock at the Okapakapa swamp still retained bark, as well as different types of leaves which were pressed onto the bark surface (Figure 9). However, the trunks appear to have been only partially buried for some time, as almost all had eroded on one side (as can be seen in figure 2).

**Figure 9: Kauri bark with different types of leaves, Okapakapa swamp, Harding's farm, November 2002**

## Conclusion

The Harding's kauri has been a very useful addition to the swamp kauri collection held at the Tree-ring Laboratory at The University of Auckland. The development of two 1000+ year chronologies has been a significant contribution to the development of multi-millennial kauri chronologies. ***Harding2*** replicated a long section the kauri record between about 1470 – 435 BC. ***Harding1*** (AD 124 – 1152) contributed to bridging the gap between the modern, calendar-dated kauri chronologies and 'floating' sub-fossil kauri chronologies. The dating of several samples to the final growth ring indicates that trees were dying at different times, although sample depth is low in each group.

## Acknowledgments

Nelson Parker is thanked for his generosity in providing the kauri samples, and cutting them from the logs, at his premises at Kaihu. Robert and Donna Harding are thanked for access to the Okapakapa swamp. The wood was cut into radial strips and prepared for analysis by Peter Crossley. The Harding samples were collected by John Ogden, Anthony Fowler, Gretel Boswijk and Drew Lorrey, and analysed by Gretel Boswijk, as part of the *El Nino history as recorded in kauri tree-rings* project, supported by the Royal Society of New Zealand Marsden fund (UOA108). All the wood and offcuts are archived in the Tree-ring Laboratory Woodstore, School of Geography and Environmental Science, University of Auckland.

## Addendum

Since this report was drafted the ring issue between the Maitahi and Whangape chronologies has been resolved (Boswijk 2005), and calendar dates applied to all crossmatched sub-fossil kauri. The ***Harding2*** chronology has been calendar-dated to 1466 – 437 BC. The calendar dates for each tree-sequence are listed in Table 7 below.

**Table 7: Updated details for Harding2 tree-sequence and radii**

| | | |
|---|---|---|
| **HAR001** | **1250 BC-1025 BC** | +117 rings +½Bs - tree died in or after 907/6 BC |
| HAR001a | 1229 BC-1129 BC | |
| HAR001B | 1239 BC-1090 BC | |
| HAR001C | 1250 BC-1040 BC | |
| HAR001D | 1243 BC-1025 BC | |
| **HAR007** | **1466 BC-437 BC** | +½Bs - tree died in 436/5 BC |
| HAR007A | 1335 BC-646 BC | |
| HAR007b | 1465 BC-437 BC | |
| HAR007c | 1466 BC-441 BC | |
| HAR007d | 1457 BC-490 BC | |
| HAR007e | 1445 BC-589 BC | |
| **HAR013** | **1195 BC-640 BC** | +76 rings +Bw - tree died in or after 563 BC |
| HAR013a | 1102 BC-766 BC | |
| HAR013B | 1195 BC-875 BC | |
| HAR013BO | 850 BC-645 BC | |
| HAR013d | 1080 BC-647 BC | |
| HAR013f | 1187 BC-640 BC | |

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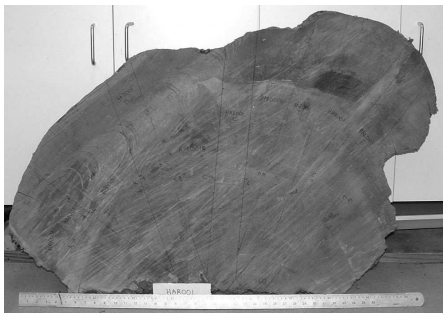
## Appendix 1:

**Figure A1: Harding kauri cross-sections**
Black lines mark where radii were cut.

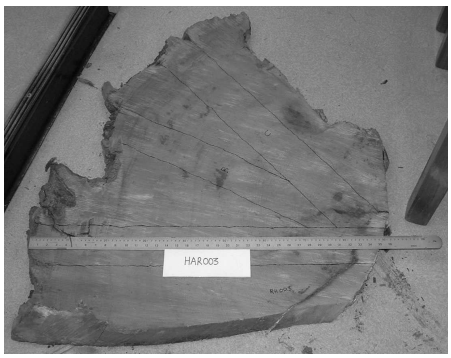
**HAR001**



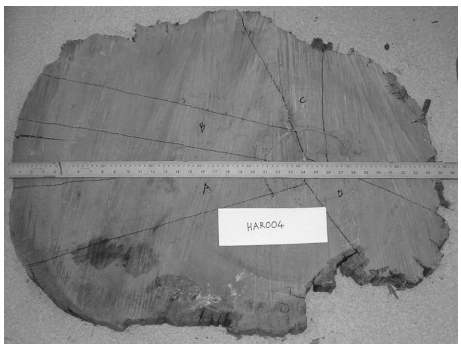
**HAR002**

No image

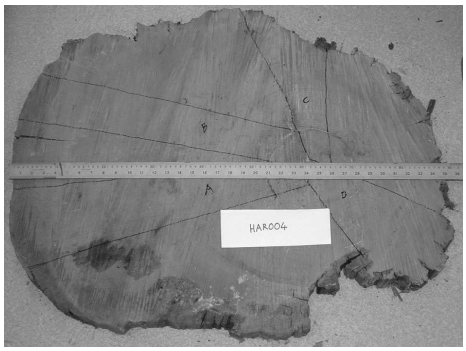
**HAR003**




**HAR004**

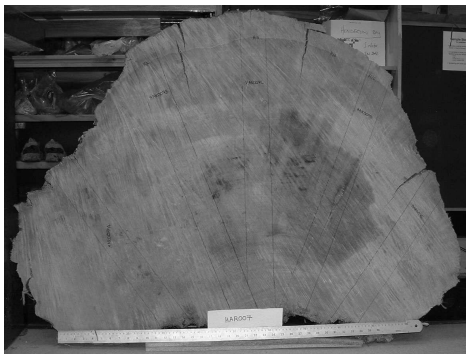



**HAR005**




**HAR006**


**HAR007**

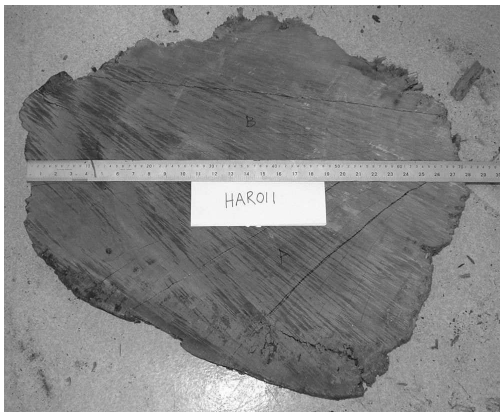


**HAR 008**

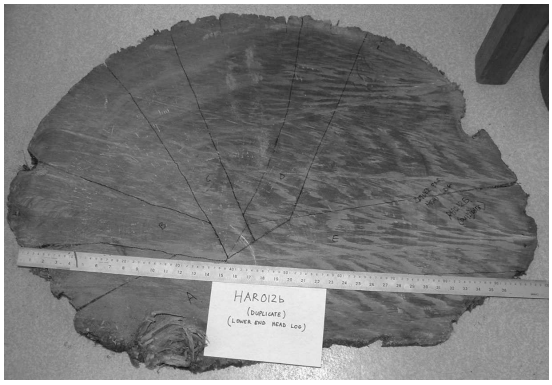
**HAR009**


**HAR010**


**HAR011**




**HAR012**


**HAR013**

# Appendix 2:

**Tale A1: Table A1: Intra-tree (shaded) and inter-tree crossmatching for *Harding1* radii**

| Filenames | HAR 003a | HAR 003b | HAR 003c | HAR 004a | HAR 004b | HAR 004c | HAR 004d | HAR 05a | HAR 005b | HAR 005c | HAR 005d | HAR 006ai | HAR 006ao | HAR 006bi | HAR 006bo | HAR 006ci | HAR 006co | HAR 010a | HAR 010b | HAR 010c | HAR 010d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HAR003a** | * | 16.09 | 23.10 | 6.19 | 5.72 | 5.53 | 6.54 | - | - | - | - | \ | 6.40 | \ | 8.57 | \ | 8.76 | 12.34 | 13.94 | 13.14 | 12.25 |
| **HAR003b** | * | * | 17.58 | - | 4.12 | - | 3.75 | - | - | - | - | \ | 6.45 | \ | 9.56 | \ | 7.31 | 9.27 | 9.48 | 9.62 | 10.05 |
| **HAR003c** | * | * | * | 4.52 | 4.43 | 4.05 | 5.57 | - | - | - | - | \ | 7.19 | \ | 8.18 | \ | 8.11 | 13.41 | 15.19 | 13.26 | 12.57 |
| **HAR004a** | * | * | * | * | 32.90 | 11.43 | 19.05 | \ | \ | \ | \ | \ | \ | \ | - | \ | - | 6.27 | 8.33 | 5.89 | 6.18 |
| **HAR004b** | * | * | * | * | * | 12.37 | 16.95 | \ | \ | \ | \ | \ | \ | \ | \ | \ | \ | 5.63 | 7.55 | 5.49 | 5.02 |
| **HAR004c** | * | * | * | * | * | * | 11.97 | \ | \ | \ | \ | \ | \ | \ | - | \ | - | 3.01 | 3.95 | - | - |
| **HAR004d** | * | * | * | * | * | * | * | \ | \ | \ | \ | \ | \ | \ | - | \ | - | 3.70 | 5.45 | 4.21 | 4.64 |
| **HAR005a** | * | * | * | * | * | * | * | * | 19.98 | 8.01 | 11.15 | - | 9.05 | - | 7.95 | 3.13 | 7.62 | - | - | - | - |
| **HAR005b** | * | * | * | * | * | * | * | * | * | 8.21 | 14.38 | 6.10 | 11.74 | 5.06 | 9.35 | 4.94 | 9.50 | - | 3.10 | - | - |
| **HAR005c** | * | * | * | * | * | * | * | * | * | * | 7.05 | - | 9.24 | - | 10.82 | - | 10.60 | 3.69 | 3.23 | - | - |
| **HAR005d** | * | * | * | * | * | * | * | * | * | * | * | 4.79 | 7.56 | 3.27 | 9.85 | 3.70 | 9.16 | - | 3.44 | - | - |
| **HAR006ai** | * | * | * | * | * | * | * | * | * | * | * | * | \ | 21.53 | \ | 24.12 | \ | \ | \ | \ | \ |
| **HAR006ao** | * | * | * | * | * | * | * | * | * | * | * | * | * | \ | 17.52 | \ | 18.00 | 7.59 | 9.60 | 7.48 | 8.60 |
| **HAR006bi** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | \ | 19.28 | \ | \ | \ | \ | \ |
| **HAR006bo** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | \ | 25.67 | 10.13 | 13.67 | 10.20 | 10.79 |
| **HAR006ci** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | \ | \ | \ | \ | \ |
| **HAR006co** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 12.04 | 14.40 | 12.26 | 12.69 |
| **HAR010a** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 26.68 | 19.88 | 26.05 |
| **HAR010b** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 30.34 | 24.61 |
| **HAR010c** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | 22.48 |
| **HAR010d** | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |

n = 146 min t = -0.27 max t = 32.90 mean t = 8.26 s.d. = 6.76

**Figure A2: Composition of *Harding1* tree-sequences**

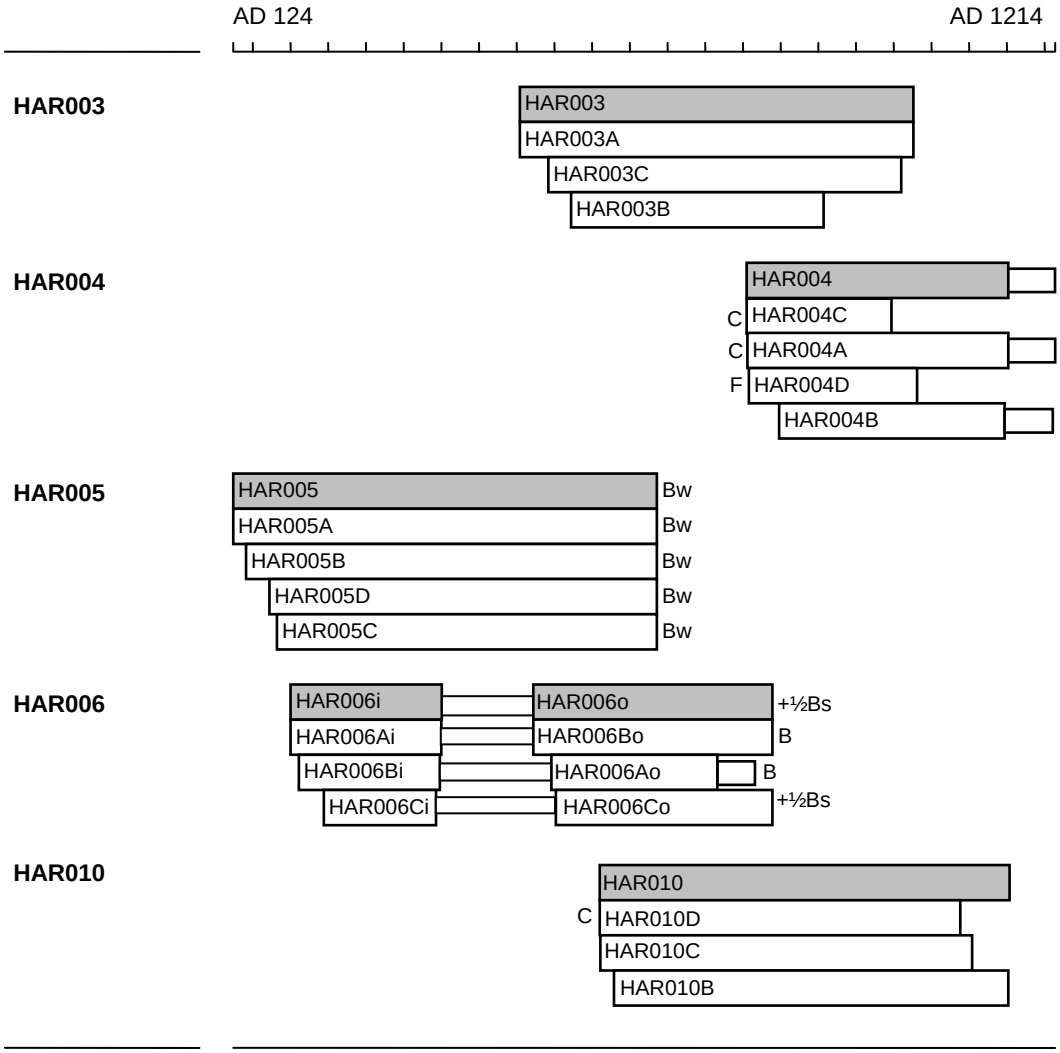


**Table A2: Intra-tree (shaded) and inter-tree crossmatching for *Harding2* radii**

| **Filenames** | **-** | **-** | **HAR001a** | **HAR001b** | **HAR001c** | **HAR001d** | **HAR007a** | **HAR007b** | **HAR007c** | **HAR007d** | **HAR007e** | **HAR013a** | **HAR013b** | **HAR013b** | **HAR013d** | **HAR013f** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *-* | *start* | *dates* | *6662* | *6652* | *6641* | *6648* | *6556* | *6426* | *6425* | *6434* | *6446* | *6789* | *6696* | *7041* | *6811* | *6704* |
| *-* | *dates* | *end* | *6762* | *6801* | *6851* | *6866* | *7245* | *7454* | *7450* | *7401* | *7302* | *7125* | *7016* | *7246* | *7244* | *7251* |
| **HAR001a** | 6662 | 6762 | * | 10.64 | 5.98 | 3.71 | 5.68 | 5.79 | 5.71 | 6.81 | 5.16 | \ | - | \ | \ | 3.50 |
| **HAR001b** | 6652 | 6801 | * | * | 13.10 | 10.46 | 10.85 | 8.44 | 8.87 | 10.03 | 9.69 | \ | - | \ | \ | 4.43 |
| **HAR001c** | 6641 | 6851 | * | * | * | 13.74 | 10.29 | 7.87 | 8.40 | 8.83 | 8.08 | - | - | \ | - | 3.87 |
| **HAR001d** | 6648 | 6866 | * | * | * | * | 8.15 | 7.08 | 6.91 | 7.24 | 7.94 | - | 3.55 | \ | - | 5.54 |
| **HAR007a** | 6556 | 7245 | * | * | * | * | * | 10.85 | 15.84 | 18.67 | 11.59 | 5.58 | 5.13 | - | - | 5.06 |
| **HAR007b** | 6426 | 7454 | * | * | * | * | * | * | 30.86 | 25.69 | 33.60 | 5.62 | 4.04 | 7.56 | 4.69 | 9.27 |
| **HAR007c** | 6425 | 7450 | * | * | * | * | * | * | * | 35.63 | 32.43 | 6.94 | 4.26 | 7.26 | 4.82 | 9.76 |
| **HAR007d** | 6434 | 7401 | * | * | * | * | * | * | * | * | 34.22 | 7.08 | 3.93 | 9.62 | 5.27 | 10.03 |
| **HAR007e** | 6446 | 7302 | * | * | * | * | * | * | * | * | * | 4.99 | - | 6.24 | 4.02 | 7.68 |
| **HAR013a** | 6789 | 7125 | * | * | * | * | * | * | * | * | * | * | 9.05 | 7.77 | 10.40 | 16.23 |
| **HAR013b** | 6696 | 7016 | * | * | * | * | * | * | * | * | * | * | * | \ | 7.79 | 13.79 |
| **HAR013bo** | 7041 | 7246 | * | * | * | * | * | * | * | * | * | * | * | * | 5.47 | 11.29 |
| **HAR013d** | 6811 | 7244 | * | * | * | * | * | * | * | * | * | * | * | * | * | 10.75 |
| **HAR013f** | 6704 | 7251 | * | * | * | * | * | * | * | * | * | * | * | * | * | * |

n = 82 min t = -0.56 max t = 35.63 mean t = 8.95 s.d. = 7.46

**Figure A3: Composition of *Harding2* tree-sequences**

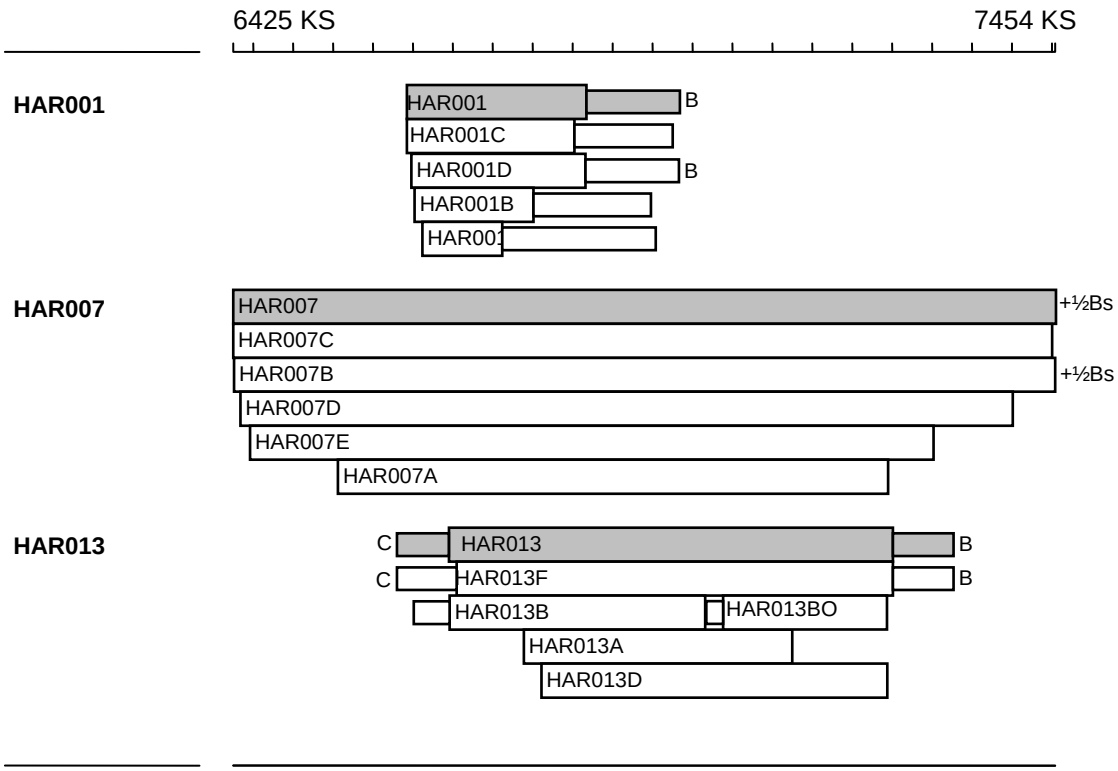


**Table A3: Chronology Listings for *Harding1* and *Harding2***

***Harding1* Okapakapa swamp near Dargaville**
1029 years length dated AD124 to AD1152
Average ring width 139.58 Sensitivity 0.30

| Year | Mean ring width | | | | | | | | | | Number of tree-sequences | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AD 124 | | | | 212 | 151 | 206 | 307 | 195 | 190 | 97 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 138 | 224 | 72 | 120 | 72 | 112 | 104 | 164 | 107 | 170 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 215 | 143 | 125 | 148 | 196 | 242 | 205 | 148 | 133 | 85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AD 151 | 195 | 261 | 306 | 261 | 132 | 192 | 230 | 95 | 128 | 73 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 163 | 153 | 213 | 107 | 183 | 219 | 111 | 185 | 236 | 100 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 128 | 94 | 219 | 215 | 195 | 125 | 245 | 195 | 173 | 144 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 177 | 154 | 197 | 241 | 111 | 227 | 127 | 155 | 247 | 147 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 183 | 172 | 182 | 223 | 185 | 201 | 118 | 207 | 175 | 176 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| AD 201 | 143 | 123 | 158 | 111 | 132 | 92 | 109 | 128 | 139 | 198 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 171 | 180 | 163 | 203 | 67 | 172 | 141 | 127 | 110 | 84 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 123 | 143 | 158 | 161 | 165 | 97 | 137 | 71 | 105 | 94 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 112 | 164 | 164 | 49 | 92 | 126 | 97 | 123 | 53 | 84 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 107 | 82 | 115 | 97 | 108 | 99 | 99 | 149 | 76 | 130 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 251 | 95 | 132 | 91 | 95 | 71 | 83 | 64 | 133 | 35 | 113 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 137 | 66 | 147 | 122 | 91 | 104 | 120 | 99 | 154 | 130 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 176 | 104 | 113 | 145 | 157 | 162 | 184 | 199 | 84 | 196 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 206 | 197 | 149 | 91 | 94 | 128 | 114 | 111 | 68 | 87 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 108 | 76 | 122 | 57 | 94 | 114 | 81 | 162 | 152 | 166 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 301 | 205 | 61 | 147 | 160 | 117 | 171 | 145 | 173 | 116 | 122 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 66 | 135 | 154 | 142 | 109 | 169 | 156 | 214 | 157 | 153 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 119 | 148 | 193 | 78 | 125 | 86 | 159 | 164 | 223 | 187 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 98 | 165 | 137 | 150 | 85 | 154 | 111 | 96 | 124 | 146 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 144 | 141 | 132 | 146 | 80 | 114 | 131 | 119 | 119 | 166 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 351 | 191 | 65 | 129 | 115 | 89 | 114 | 83 | 124 | 93 | 116 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 61 | 72 | 104 | 102 | 95 | 95 | 81 | 54 | 82 | 57 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 71 | 104 | 87 | 73 | 60 | 42 | 39 | 59 | 34 | 37 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 47 | 25 | 50 | 40 | 25 | 18 | 48 | 39 | 61 | 52 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 44 | 28 | 38 | 28 | 32 | 20 | 45 | 34 | 14 | 48 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 401 | 32 | 36 | 17 | 6 | 47 | 58 | 41 | 68 | 76 | 104 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 114 | 69 | 84 | 91 | 94 | 102 | 60 | 110 | 112 | 110 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 182 | 63 | 124 | 117 | 185 | 106 | 155 | 170 | 200 | 65 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 115 | 191 | 170 | 259 | 198 | 264 | 274 | 159 | 199 | 278 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 316 | 200 | 207 | 232 | 118 | 157 | 121 | 236 | 231 | 191 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AD 451 | 195 | 51 | 134 | 182 | 85 | 150 | 162 | 213 | 234 | 88 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 181 | 127 | 210 | 300 | 323 | 72 | 165 | 213 | 267 | 370 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 224 | 249 | 201 | 247 | 300 | 268 | 168 | 175 | 247 | 189 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 222 | 257 | 324 | 249 | 296 | 270 | 272 | 233 | 167 | 171 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 232 | 305 | 215 | 292 | 336 | 154 | 208 | 306 | 362 | 225 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| AD 501 | 286 | 353 | 309 | 161 | 157 | 138 | 219 | 203 | 180 | 127 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| - | 158 | 122 | 173 | 112 | 142 | 132 | 161 | 116 | 175 | 158 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 145 | 146 | 151 | 189 | 203 | 149 | 140 | 123 | 169 | 157 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 172 | 126 | 112 | 142 | 196 | 135 | 160 | 176 | 201 | 196 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 216 | 229 | 231 | 228 | 197 | 182 | 178 | 205 | 202 | 106 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 551 | 200 | 178 | 159 | 128 | 184 | 134 | 231 | 214 | 250 | 214 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 250 | 172 | 169 | 183 | 190 | 229 | 195 | 229 | 218 | 212 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 155 | 223 | 266 | 232 | 180 | 204 | 253 | 238 | 258 | 266 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 288 | 236 | 364 | 330 | 312 | 230 | 273 | 266 | 283 | 200 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 261 | 235 | 239 | 196 | 271 | 218 | 191 | 240 | 266 | 185 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 601 | 257 | 245 | 249 | 194 | 226 | 203 | 257 | 265 | 255 | 247 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| - | 271 | 282 | 243 | 279 | 196 | 212 | 195 | 194 | 282 | 183 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 227 | 198 | 256 | 270 | 203 | 213 | 236 | 119 | 145 | 151 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 141 | 191 | 184 | 96 | 202 | 150 | 223 | 108 | 202 | 121 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| - | 255 | 245 | 298 | 240 | 259 | 162 | 264 | 257 | 144 | 231 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| AD 651 | 234 | 114 | 156 | 197 | 269 | 245 | 217 | 167 | 222 | 230 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 189 | 140 | 148 | 178 | 142 | 189 | 169 | 85 | 174 | 165 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 168 | 141 | 83 | 147 | 150 | 188 | 162 | 177 | 163 | 124 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 181 | 212 | 166 | 219 | 190 | 136 | 175 | 148 | 134 | 158 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 3 |
| - | 82 | 169 | 190 | 124 | 194 | 149 | 187 | 205 | 116 | 132 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 701 | 158 | 183 | 102 | 134 | 76 | 167 | 142 | 176 | 166 | 146 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 206 | 101 | 100 | 102 | 170 | 137 | 153 | 167 | 62 | 113 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 83 | 149 | 167 | 92 | 137 | 150 | 147 | 103 | 72 | 80 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 62 | 95 | 132 | 96 | 164 | 73 | 109 | 84 | 86 | 141 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 155 | 87 | 163 | 74 | 121 | 106 | 135 | 125 | 155 | 123 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 751 | 161 | 64 | 103 | 100 | 145 | 102 | 130 | 105 | 115 | 139 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 99 | 145 | 150 | 101 | 101 | 111 | 136 | 174 | 47 | 84 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 69 | 124 | 133 | 107 | 128 | 109 | 105 | 118 | 159 | 124 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 116 | 166 | 167 | 104 | 108 | 95 | 162 | 76 | 120 | 148 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 144 | 164 | 141 | 168 | 133 | 144 | 131 | 43 | 99 | 123 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 801 | 90 | 138 | 160 | 83 | 136 | 125 | 79 | 125 | 141 | 97 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| - | 127 | 82 | 133 | 118 | 115 | 135 | 160 | 144 | 142 | 96 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 155 | 104 | 182 | 163 | 131 | 129 | 128 | 149 | 136 | 195 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| - | 82 | 146 | 98 | 139 | 157 | 117 | 130 | 157 | 170 | 117 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| - | 99 | 161 | 107 | 182 | 125 | 140 | 125 | 217 | 201 | 135 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 851 | 157 | 137 | 171 | 89 | 154 | 142 | 79 | 150 | 206 | 124 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 145 | 98 | 165 | 149 | 124 | 132 | 157 | 62 | 106 | 108 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 146 | 87 | 127 | 78 | 98 | 114 | 89 | 198 | 126 | 118 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 89 | 140 | 145 | 221 | 146 | 154 | 164 | 119 | 129 | 103 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 105 | 157 | 74 | 118 | 106 | 127 | 118 | 178 | 94 | 203 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 901 | 72 | 104 | 114 | 122 | 119 | 82 | 93 | 113 | 37 | 124 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 73 | 110 | 88 | 138 | 108 | 119 | 114 | 79 | 76 | 74 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 48 | 101 | 116 | 72 | 132 | 88 | 123 | 105 | 120 | 152 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 56 | 93 | 82 | 153 | 105 | 137 | 98 | 127 | 158 | 142 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 94 | 129 | 61 | 84 | 68 | 142 | 127 | 117 | 57 | 53 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 951 | 66 | 73 | 74 | 80 | 75 | 54 | 66 | 73 | 90 | 92 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 88 | 82 | 131 | 110 | 139 | 89 | 95 | 71 | 156 | 180 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 125 | 110 | 82 | 87 | 107 | 78 | 53 | 86 | 47 | 44 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 42 | 74 | 91 | 41 | 90 | 94 | 109 | 88 | 91 | 91 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 82 | 132 | 127 | 111 | 100 | 60 | 103 | 112 | 78 | 93 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| AD 1001 | 47 | 102 | 58 | 75 | 62 | 130 | 125 | 135 | 110 | 129 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 124 | 108 | 104 | 113 | 86 | 84 | 110 | 58 | 109 | 93 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 107 | 121 | 83 | 106 | 91 | 105 | 121 | 153 | 80 | 160 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 |
| - | 148 | 98 | 86 | 51 | 153 | 145 | 106 | 96 | 86 | 101 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 81 | 90 | 29 | 147 | 144 | 105 | 183 | 120 | 128 | 149 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 1051 | 144 | 148 | 79 | 151 | 150 | 143 | 108 | 132 | 67 | 145 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 147 | 156 | 152 | 137 | 105 | 84 | 116 | 110 | 120 | 102 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 118 | 122 | 59 | 149 | 126 | 141 | 106 | 126 | 61 | 144 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 116 | 112 | 131 | 154 | 119 | 127 | 93 | 88 | 77 | 99 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 149 | 148 | 54 | 108 | 117 | 74 | 93 | 59 | 86 | 119 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 1101 | 45 | 76 | 46 | 107 | 103 | 67 | 99 | 95 | 76 | 84 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 74 | 82 | 58 | 97 | 76 | 106 | 111 | 86 | 131 | 43 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 89 | 88 | 157 | 179 | 129 | 169 | 131 | 121 | 88 | 72 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 46 | 70 | 97 | 130 | 103 | 90 | 47 | 138 | 138 | 50 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 134 | 92 | 105 | 60 | 143 | 62 | 91 | 39 | 51 | 94 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AD 1151 | 76 | 59 | | | | | | | | | 2 | 2 | | | | | | | |

***Harding2* Okapakapa swamp nr Dargaville**
1030 years length undated; relative dates - 6425 to 7454 KS (Kauri scale)
Average ring width 115.66 Sensitivity 0.33

| Year | Mean ring width | | | | | | | | | | Number of tree-sequences | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6425 KS | | | | | 145 | 70 | 123 | 63 | 83 | 37 | | | | | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 52 | 71 | 81 | 97 | 144 | 89 | 134 | 123 | 148 | 186 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 164 | 103 | 133 | 150 | 195 | 209 | 90 | 221 | 223 | 190 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6451 KS | 248 | 128 | 184 | 190 | 131 | 162 | 184 | 93 | 158 | 134 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 140 | 120 | 106 | 40 | 113 | 83 | 94 | 107 | 102 | 69 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 105 | 71 | 82 | 140 | 96 | 147 | 131 | 103 | 80 | 56 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 99 | 149 | 100 | 143 | 54 | 109 | 87 | 97 | 105 | 95 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 138 | 143 | 150 | 86 | 70 | 63 | 59 | 99 | 97 | 113 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6501 KS | 103 | 57 | 86 | 89 | 120 | 118 | 56 | 94 | 119 | 53 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 88 | 75 | 133 | 108 | 125 | 103 | 126 | 137 | 106 | 73 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 83 | 65 | 103 | 79 | 115 | 111 | 71 | 93 | 105 | 63 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 114 | 83 | 104 | 101 | 98 | 72 | 99 | 72 | 98 | 99 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 34 | 67 | 54 | 85 | 115 | 58 | 82 | 58 | 125 | 113 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6551 KS | 161 | 133 | 110 | 97 | 87 | 110 | 41 | 90 | 70 | 144 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 112 | 142 | 163 | 98 | 77 | 59 | 109 | 98 | 32 | 80 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 42 | 97 | 101 | 73 | 89 | 43 | 89 | 91 | 78 | 87 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 60 | 38 | 96 | 35 | 81 | 57 | 75 | 105 | 88 | 54 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 57 | 64 | 93 | 89 | 61 | 69 | 101 | 31 | 108 | 111 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6601 KS | 74 | 112 | 78 | 120 | 105 | 93 | 67 | 87 | 59 | 101 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 84 | 114 | 55 | 114 | 80 | 106 | 109 | 74 | 148 | 126 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 123 | 81 | 116 | 143 | 97 | 170 | 154 | 67 | 104 | 70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 84 | 102 | 95 | 61 | 110 | 102 | 120 | 132 | 67 | 129 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 180 | 205 | 83 | 201 | 184 | 183 | 203 | 180 | 144 | 95 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 6651 KS | 138 | 139 | 69 | 116 | 133 | 151 | 199 | 62 | 186 | 201 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 179 | 147 | 146 | 166 | 162 | 66 | 141 | 105 | 105 | 149 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 82 | 124 | 155 | 162 | 64 | 214 | 208 | 120 | 181 | 139 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 111 | 153 | 108 | 123 | 80 | 175 | 119 | 61 | 93 | 86 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 91 | 127 | 94 | 144 | 139 | 139 | 129 | 117 | 136 | 96 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 6701 KS | 93 | 130 | 98 | 99 | 111 | 98 | 146 | 134 | 69 | 121 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 106 | 151 | 66 | 126 | 83 | 136 | 60 | 132 | 134 | 126 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 112 | 100 | 88 | 109 | 136 | 68 | 125 | 67 | 131 | 113 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 137 | 121 | 118 | 154 | 120 | 140 | 66 | 122 | 131 | 102 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 163 | 76 | 124 | 125 | 124 | 48 | 132 | 151 | 145 | 168 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 6751 KS | 142 | 156 | 133 | 155 | 119 | 163 | 57 | 176 | 155 | 199 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 157 | 195 | 189 | 124 | 189 | 105 | 159 | 162 | 160 | 211 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 176 | 249 | 175 | 191 | 182 | 237 | 236 | 190 | 229 | 186 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 150 | 204 | 185 | 259 | 233 | 279 | 213 | 351 | 282 | 214 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 262 | 172 | 202 | 211 | 126 | 285 | 206 | 231 | 208 | 254 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 6801 KS | 201 | 235 | 210 | 207 | 191 | 172 | 236 | 267 | 212 | 208 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 207 | 212 | 149 | 249 | 168 | 217 | 270 | 186 | 98 | 134 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 72 | 156 | 126 | 209 | 229 | 234 | 239 | 155 | 210 | 240 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 108 | 188 | 250 | 276 | 231 | 194 | 141 | 185 | 96 | 221 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 217 | 234 | 228 | 168 | 188 | 106 | 192 | 165 | 246 | 172 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 6851 KS | 192 | 146 | 175 | 91 | 150 | 157 | 106 | 174 | 174 | 211 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| - | 119 | 210 | 184 | 210 | 228 | 176 | 214 | 149 | 136 | 137 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 2 |
| - | 55 | 103 | 86 | 96 | 132 | 89 | 183 | 79 | 135 | 121 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 131 | 76 | 154 | 125 | 145 | 121 | 159 | 139 | 189 | 184 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 144 | 212 | 115 | 226 | 146 | 180 | 124 | 166 | 160 | 123 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 6901 KS | 219 | 100 | 175 | 133 | 166 | 138 | 173 | 108 | 197 | 178 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 218 | 199 | 125 | 134 | 115 | 123 | 97 | 155 | 169 | 187 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 210 | 181 | 225 | 99 | 247 | 217 | 271 | 162 | 263 | 154 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 153 | 173 | 202 | 250 | 212 | 161 | 156 | 131 | 82 | 185 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 147 | 189 | 210 | 163 | 175 | 190 | 140 | 210 | 166 | 143 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6951 KS | 123 | 108 | 129 | 151 | 188 | 136 | 142 | 137 | 108 | 190 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 102 | 256 | 156 | 185 | 176 | 163 | 147 | 104 | 143 | 138 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 159 | 220 | 177 | 119 | 170 | 107 | 130 | 65 | 178 | 99 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 184 | 158 | 197 | 174 | 78 | 169 | 125 | 229 | 131 | 200 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 145 | 228 | 155 | 222 | 165 | 158 | 128 | 177 | 137 | 166 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7001 KS | 188 | 152 | 138 | 114 | 156 | 173 | 163 | 122 | 138 | 122 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 136 | 103 | 116 | 111 | 78 | 112 | 137 | 115 | 128 | 53 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 100 | 93 | 135 | 84 | 110 | 59 | 67 | 61 | 75 | 62 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 85 | 45 | 77 | 46 | 50 | 88 | 31 | 128 | 123 | 53 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 94 | 74 | 100 | 78 | 63 | 94 | 107 | 37 | 84 | 55 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7051 KS | 78 | 86 | 41 | 79 | 74 | 61 | 98 | 36 | 88 | 49 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 84 | 79 | 74 | 87 | 53 | 108 | 43 | 81 | 66 | 47 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 42 | 56 | 37 | 77 | 50 | 72 | 56 | 48 | 60 | 79 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 43 | 117 | 104 | 112 | 77 | 103 | 120 | 109 | 109 | 119 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 118 | 140 | 138 | 100 | 90 | 60 | 96 | 120 | 79 | 89 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7101 KS | 94 | 43 | 90 | 76 | 136 | 113 | 170 | 69 | 109 | 99 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 120 | 139 | 58 | 105 | 103 | 84 | 140 | 93 | 136 | 99 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 86 | 80 | 133 | 83 | 135 | 146 | 87 | 117 | 80 | 131 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 76 | 106 | 79 | 148 | 66 | 86 | 78 | 128 | 132 | 77 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 125 | 99 | 159 | 71 | 114 | 101 | 124 | 124 | 109 | 170 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7151 KS | 107 | 162 | 130 | 150 | 142 | 139 | 143 | 86 | 74 | 67 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 70 | 62 | 97 | 56 | 66 | 45 | 72 | 54 | 101 | 81 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 67 | 79 | 87 | 53 | 94 | 40 | 81 | 86 | 98 | 63 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 87 | 79 | 48 | 72 | 42 | 41 | 60 | 39 | 58 | 62 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 62 | 94 | 61 | 90 | 43 | 55 | 36 | 78 | 75 | 36 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7201 KS | 74 | 50 | 77 | 82 | 73 | 77 | 114 | 69 | 66 | 52 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 61 | 63 | 46 | 73 | 58 | 68 | 57 | 68 | 74 | 54 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 63 | 69 | 73 | 57 | 83 | 36 | 84 | 57 | 65 | 71 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 79 | 65 | 67 | 59 | 91 | 64 | 76 | 78 | 72 | 91 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| - | 59 | 84 | 72 | 52 | 70 | 72 | 79 | 83 | 49 | 68 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 7251 KS | 97 | 121 | 115 | 91 | 84 | 100 | 118 | 48 | 65 | 86 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 77 | 90 | 100 | 88 | 32 | 66 | 67 | 37 | 77 | 71 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 76 | 61 | 88 | 45 | 104 | 79 | 97 | 58 | 75 | 101 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 101 | 51 | 117 | 115 | 90 | 84 | 41 | 90 | 92 | 81 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 65 | 112 | 43 | 111 | 148 | 84 | 122 | 83 | 167 | 152 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7301 KS | 52 | 129 | 163 | 101 | 116 | 112 | 57 | 90 | 95 | 82 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 108 | 94 | 68 | 103 | 70 | 109 | 118 | 123 | 24 | 106 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 133 | 123 | 96 | 143 | 124 | 100 | 74 | 55 | 35 | 53 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 50 | 68 | 70 | 56 | 83 | 42 | 56 | 79 | 70 | 70 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 80 | 55 | 74 | 62 | 74 | 85 | 56 | 90 | 62 | 85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7351 KS | 114 | 110 | 132 | 66 | 116 | 122 | 91 | 121 | 120 | 75 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 144 | 145 | 103 | 132 | 83 | 128 | 57 | 166 | 164 | 87 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 114 | 65 | 103 | 107 | 81 | 82 | 73 | 104 | 75 | 113 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 66 | 117 | 104 | 126 | 98 | 104 | 101 | 96 | 121 | 93 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 102 | 48 | 82 | 104 | 78 | 49 | 103 | 75 | 79 | 62 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7401 KS | 55 | 80 | 117 | 46 | 80 | 77 | 37 | 88 | 88 | 108 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 82 | 77 | 72 | 69 | 82 | 52 | 81 | 68 | 62 | 98 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 65 | 51 | 75 | 81 | 110 | 30 | 73 | 49 | 107 | 98 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 104 | 34 | 92 | 105 | 106 | 122 | 75 | 151 | 151 | 119 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| - | 127 | 173 | 125 | 87 | 110 | 110 | 83 | 76 | 102 | 118 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 7451 KS | 193 | 170 | 159 | 77 | | | | | | | 1 | 1 | 1 | 1 | | | | | | |