Dendrogeomorphology Pilot Study, Tittabawassee River Floodplain, Michigan

FINAL

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Limno-Tech, Inc.

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1. INTRODUCTION

Soils in the floodplain adjacent to the Tittabawassee River have been found to contain dioxins and furans at varying levels under preliminary sampling conducted by the Michigan DEQ (MDEQ, 2002). The role of the floodplain in the redistribution and/or burial of existing contaminants within the floodplain soil and the potential exchange of contaminants with the river during floods is currently unknown. However, understanding the movement of sediment within the floodplain and the potential role of sediments and floodplain soils as an ongoing source of solids loading during flood events is an important element of the overall understanding of solids transport in the river-floodplain system.

This report describes the results of the dendrogeomorphic tree root/tree age pilot study to evaluate sediment deposition in the floodplains adjacent to the Tittabawassee River. In dendrogeomorphic studies long-term deposition rates and historic changes in these rates are estimated from tree age and the extent of root burial. The pilot study represents a preliminary field effort initiated in the spring of 2004 to measure historical sediment deposition patterns. The goal of this report is to test whether the method can be successfully applied under conditions in the Tittabawassee River floodplain and to document baseline conditions in the floodplain at the start of the long-term study. This preliminary data assessment also serves to detect data problems and identify sources of variability, error and potential confounding factors in anticipation of potential future floodplain studies. This work complements other on-going studies of sediment deposition in the floodplain.

The remainder of this report is divided into two sections. Section 2 describes the specific design elements for the dendrogeomorphic deposition rate pilot study, and Section 3 presents preliminary results.

The study was conducted in accordance with the Quality Assurance Project Plan (QAPP) (CH2MHILL, 2004). The QAPP outlines quality assurance procedures to ensure that the data collected are complete, representative, comparable, and of a known and documented quality.

2. PROCEDURES AND PILOT STUDY DESIGN

2.1. General Approach

Dendrogeomorphology is a subfield of dendrochronology, which is the basic science of dating the growth layers of woody plants in order to exploit any associated environmental information such as accumulation processes (Shroder, 1980). Lateral tree roots form just below the ground surface during germination (see Figure 1). The botanical centers of these roots are valuable as distinctive markers, indicating the original ground surface level. In combination with the age of the tree obtained from increment core analysis, it is possible to determine the rates of historical sedimentation by calculating the depth from the original lateral root mass to the present soil surface (Hupp and Carey, 1990). Net sedimentation rates can be calculated by dividing the depth of sedimentation by the tree age. Areas of significant sedimentation can be identified by the presence of trees with buried trunk buttresses or basal flares, which often give the appearance of posts in the ground (Phipps *et al*., 1995).

This study design was modeled on previous investigations on various floodplains throughout the country where dendrogeomorphic methods were successfully used (in combination with other floodplain studies) to provide insight into sediment exchange between a river and its floodplain and sediment transport within the floodplain (e.g., WRP Technical Note SD-CP-4.1, 1993; Steiger *et al*., 2003; Shroder, 1980; Phipps, *et al*., 1995; Hupp and Morris, 1990; . Hupp and Bazemore, 1993; Heimann and Roell, 2000). In these studies, sampling locations were distributed throughout the floodplain (e.g., Heimann and Roell, 2000), on a regular grid or in transects (Kleiss, 1996), and study length ranged from a single event to 4 years. The combination of methods yielded results relating to the following properties of floodplains:

- event, short, and long-term sediment accumulation rates by floodplain subareas (Kleiss, 1996),
- sediment chemistry associated with overbank deposition (Steiger *et al*., 2003; Goodson *et al*., 2003),
- correlations between hydrodynamics and sediment deposits and chemistry (e.g., Goodson *et al*., 2003),
- sediment and nutrient retention efficiency (Kronvang, 2003),
- spatial trends of sediment deposition, such as correlation with distance to the river and elevation (Maas and Makaske, 2002),
- spatial redistribution patterns of contaminants (Rowan and Walling, 1992),
- estimates of soil erosion rates (Du *et al*., 1998).

As stated above, the original lateral roots provide an indication of the surface level at the time of germination. Sedimentation after seedling establishment can result in the formation of adventitious roots (roots in the sediment layer), which may be mistaken for the lateral roots because they also grow horizontally (Phipps *et al*., 1995). To avoid this difficulty, only trees that are known not to grow such roots were selected for the study. These species are: swamp white oak, burr oak, black and green ash, elm, hackberry and black walnut.

Recommended sample sizes in existing literature range from 2 to 13 trees per site, and commonly consist of 6 to 8 trees. In addition, to determine changes in accretion rates over time, several classes of tree age are required. A sample covering a variety of age classes can be achieved by including half of the trees from the dominant canopy (tallest trees) and the other half from the subcanopy (below the dominant canopy) (Heimann, 2004; Phipps *et al*., 1995). For this study, 3 trees were selected from the canopy and 3 from the subcanopy at each location forming a group of 6 trees within a dendrogeomorphic study zone.

Trees were selected in close proximity to locations of other ongoing floodplain studies. A dendrogeomorphic study zone was defined as a group of trees within 500 feet or less of each other. To ensure that deposition rate estimates are comparable within a group, all trees were selected from approximately the same elevation contour to capture random, local variability.

Dendrogeomorphic measurements were made at the following three sites in the fall of 2004 (number of study zones and trees in parenthesis):

1. Dow Property near Caldwell Boat Launch (3 zones, 18 trees)
2. Dow property near Rockwell Drive (3 zones, 18 trees)
3. Imerman Park (3 zones, 17 trees)

Three dendrogeomorphic zones were positioned at increasing distance from the river at these three locations, as listed in Table 1. Portable GPS units were used to determine the coordinates of each tree.

Table 1. Summary of Tittabawassee River Dendrogeomorphic Pilot Study

Location	Date of coring	Number of zones	Number of trees	Number of cores
Dow Property near Caldwell Boat Launch	11/24-12/2/04	3	18	54
Dow Property near Rockwell Drive	12/2-8/04	3	18	54
Imerman Park	12/8-17/04	3	17	50
Number of photographs	292			

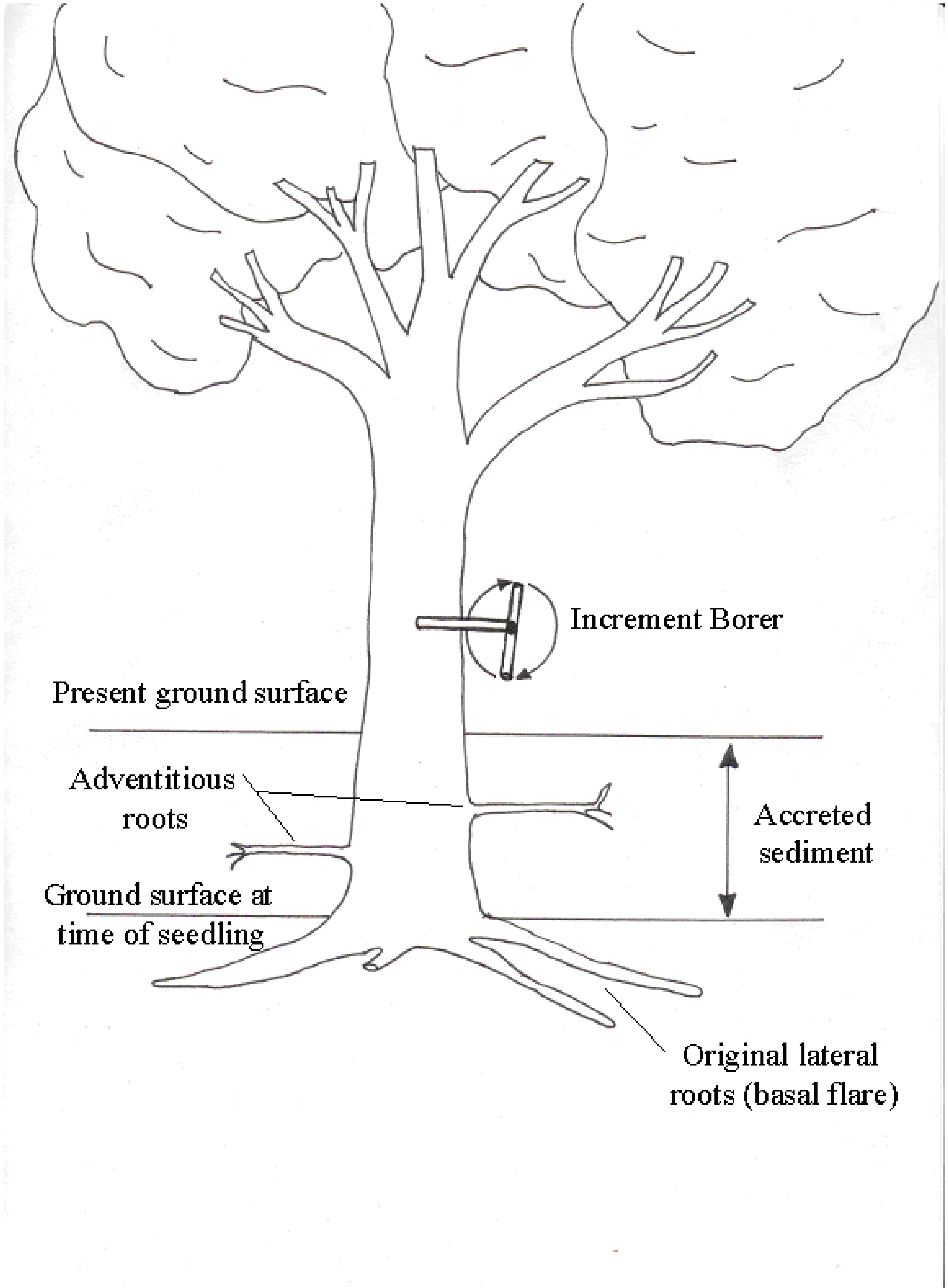

Figure 1. Diagram of Dendrogeomorphic Measurements

2.2. Procedures

The field procedures consisted of lateral root exposure with depth measurement and tree coring. Figures A-1 and A-2 in Appendix A show photographs demonstrating dendrogeomorphic measurements. Measurements and additional site-specific information were recorded in the field as shown on the field form in Appendix B.

2.2.1. Exposing the Lateral Roots

For each tree, three original lateral roots were exposed according to the following procedure:

1. All soil was excavated down to the top of the basal flare in a radius of 3-5 feet around entire tree starting on the outside and working towards the tree. To find a root, a metal rod was used to tamp around the tree base. Sound and resistance of tamping indicated when the tree root was found. When a root was found, it was followed to determine whether it came from the tree in question. If so, it was determined whether it broke off when standing on it. Adventitious roots are typically weak, break off/bend easily and grow out of a straight section of trunk, without flaring. If the root was solid and flare was evident, it was taken as a basal root.
2. The depth of 3 basal roots was measured from the top of the root to the soil surface where the soil was not disturbed. Measurements were made 3 ft away from trunk, avoiding the upward curve of the root. Photographs recorded the basal flare.

Accumulated sediment depth for a tree was estimated as the average of three depth basal root depth measurements (termed the "tree-average").

2.2.2. Coring the Tree

After exposing the lateral roots, cores were taken from the tree trunk just above the basal flare following instructions on the increment borer. Three cores were collected from each tree with two exceptions. Only two cores were collected from one of the trees (THT-02422) due to difficulties with coring. Another tree (THT-02410) was not cored or measured because of winter weather constraints. The cores were taken from three different orientations at 2-64 inches above the ground surface, with all except 18 cores taken within 20 inches of the ground. Each core was inserted into a plastic straw and the straw ends were stapled and sealed with tape. The straw protected the cores and prevented the cores from coiling while drying. The straw was labeled with core ID, date and time, and the outside end of the core was indicated. While awaiting shipment to the laboratory, the straws were opened on both ends (the cores were left inside) and were kept in a dry, warm, well-ventilated room to avoid molding and facilitate drying. Core pieces that broke off do not prevent age dating, so they were kept in the original order and orientation relative to all other pieces. The cores were then resealed in the straws and stored in a freezer. The tree cores were delivered to the Michigan State University Department of Plant Biology on February 2, 2004. Core mounting and the age-dating process is described in the laboratory report in Appendix C. The tree age was estimated as the average of the three dated cores.

2.3. Field Documentation and Photographs

All information pertinent to sampling activities was recorded in log books, which served as a daily record of events, observations, and measurements during field activities. At each tree, photographs were taken showing the tree and the exposed roots.

3. RESULTS

The following sections present the observations of tree root depth, tree age measurements, and estimated floodplain soil accumulation rates. Raw data are presented in Appnedix D.

3.1. Dendrogeomorphic Study Field Observations

Fifty four live trees were selected for dendrogeomorphic analysis from the following types: ash (25), black walnut (1), elm (12), hackberry (6), and oak (10). Core length ranged from 41% to 100% of the tree diameter. All sampled trees had at least one representative core taken, but there were 11 cores with lengths less than 50% of the tree diameter (no trees had more than one such core). Cracks and broken cores were common, but the pieces were kept together in the appropriate order to minimize any effect on dating.

Eleven trees had completely buried basal flares, 38 were partially buried, and 4 trees had less than 10% of their basal flare buried. All investigated trees indicated some positive amount of accretion (accretion can be due to either flood deposition, leaf litter accumulation or both). Individual root depth at 3 feet from the trunk varied from 0.35 inches to 27.5 inches. Most roots (80%) were less than one foot below ground surface. The within-tree average depth range of roots was 0.4-23 inches, with the standard deviation ranging 0.05-10.2 inches, corresponding to 7% to 85% of the respective means.

Tree age was determined based on three cores and the measurement error was a function of the presence or absence of pith (the center of a tree representing the reference from which tree rings are counted) in a given core and deviations between the three individual cores (details are given in the laboratory report in Appendix C). The average reported error on tree age was 5% of the estimated age (based on three tree cores). Tree age was approximately normally distributed between 30 and 108 years. Trees were selected from the subcanopy and canopy to span a range of ages, which in most cases resulted in a uniform distribution of ages among trees of the same group. The statistics are summarized in Table 2.

Table 2. Summary of Tree Observations

Category	Statistic as labeled
Number of trees of species: Ash Black walnut Elm Hackberry Oak, undifferentiated Oak, Burr Oak, Swamp	 25 (24 sampled) 1 12 6 4 1 5
Tree Age	30-108 years Mean error = 5% of estimated age
Core length relative to tree diameter.	41-100% 11 cores with < 50%
Number of trees with at least one good (dateable) core	53 (all trees)
Number of trees with basal flares above ground/ partially buried/<10% buried Dow property near Caldwell Boat Launch Dow Property near Rockwell Drive Imerman Park	4/38/11 1/16/1 0/11/7 3/11/3
Individual root depth range Within-tree root depth	0.35-27.5 in Tree-average: 0.4-23 in Tree-St.dev: 0.05-10.2 in

3.2. Estimated Dendrogeomorphic Soil Accumulation Rates

Dendrogeomorphic results (shown in Appendix D and summarized in Table 3) indicate that sedimentation rates for individual trees vary between 0.01 and 0.43 inches per year. The average rate by tree group ranges from 0.08 to 0.29 inches per year. The variability of the results assessed as a signal to noise ratio is defined as the ratio of the mean and the standard deviation. Generally, the greater the ratio, the more reliable the result. For dendrogeomorphic measurements, the mean sedimentation rate by tree group is at least twice greater than the standard deviation. For one group, however, the ratio is only 1.6. The 95% confidence intervals range from 31% to 74% of the group mean. These results suggest that selecting 6 trees is necessary and adequate to establish local sedimentation rates within a factor of 2 or less.

Table 3. Statistical Summary of Sedimentation Rates

Range	0.01 - 0.43 in/year
Standard deviation	0.09 in/year
Group mean range	0. 08 - 0.29 in/year
95% Confidence interval as percentage of group mean	31 - 74%
Group standard deviation range	0.03 - 0.16 in/year
Signal to Noise Ratio (average/standard deviation)	1.6 - 3.4

Figure 2. Average Sedimentation Rates at Dow Property Near Caldwell Boat Launch

Figure 3. Average Sedimentation Rates at Dow Property Near Rockwell Drive

Figure 4. Average Sedimentation Rates at Imerman Park

Figure 5. Tree-Average Sedimentation Rates at Dow Property Near Caldwell Boat Launch

Figure 6. Tree-Average Sedimentation Rates at Dow Property Near Rockwell Drive

Figure 7. Tree-Average Sedimentation Rates at Imerman Park

4. CONCLUSIONS AND RECOMMENDATIONS

The following subsections of this report present conclusions and recommendations.

4.1. Conclusions

Results of this preliminary investigation indicate that sedimentation rates are on the order of 0.08-0.29 inches per year, with local variation, particularly near the river. Rates of deposition measured to date decrease with greater distance from the river. Current data are insufficient to establish trends with river mile or elevation. Analyses of data available to date indicate that numerous factors may affect accretion rates. In addition to localized effects of floodwater currents, geomorphologic features of the floodplain, such as levees, depressions/wetlands, point bars and overbank deposits may also influence sedimentation.

A primary goal of this pilot study was to evaluate the utility of the dendrogeomorphic method for determining deposition rates. The dendrogeomorphic approach was found to be an effective method for evaluating historical rates of sediment accumulation on the floodplain along the Tittabawassee River. There appears to be a sufficient abundance of trees of appropriate species or varius ages in areas of interest along the floodplain to allow evaluation of the variance of accumulation rates across the floodplain. An evaluation of the data collected to date indicates that, in terms of sampling design, six trees per group are necessary and adequate for estimates of deposition within a factor of 2 or less.

4.2. Recommendations

Recommendations for potential future adjustments to the approach and additional studies include the following:

- Tree measurements appear to be reliable and provide information on localized patterns of deposition as well as temporal trends. Consequently, we recommend that the dendrogeomorphic study element should be retained for future studies.
- <u>Trends with River Mile</u>. At least 3 other sites are recommended at intermediate distances along the river to further delineate trends with distance.
- <u>Sedimentation as a Function of Geomorphology</u>. To distinguish the impact of various geomorphologic features on sedimentation rates, additional locations should be investigated with the goal of targeting individual features, including levees, overbank depositional areas, point bars, and control plots in upland areas outside of the floodplain.

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APPENDIX A:
PHOTOGRAPHS DEMONSTRATING DENDROGEOMORPHIC MEASUREMENTS

Figure A-1. Coring a tree with an increment corer.

Figure A-2. Exposing the roots of a tree.

APPENDIX B:
FIELD FORM FOR RECORDING DENDROGEOMORPHIC OBSERVATIONS AND MEASUREMENTS

Tree Location ID: | **Project Code: DWTR4-6** | **Date+Time:**

Field Personnel:

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Weather: ____________________________

Location Description: _________________

Associated Clay Pad Location ID: ___________

Tree species: ________________________________

Tree Photo IDs: _____________________________

Microsite Description

Approximate slope: _______

Aspect (direction slope faces): _________

Moisture:
Dry ______ Moist _______ Submerged ______ Snow/Ice _______

Tree Description

Species: __________________ Circumference at chest height____________

Lean direction (from North): ___________ Lean degree: _______________

Is the tree alive? ____

Distance from clay pad: ______________________________________

Tree Coring

Number of Cores (at least 3): ________

Core ID E.g.: Location ID + 01	Core height from a lateral root*	Core length (recovery) (ft)	Core orientation (degrees from N)	Circumference at core level (ft)	Core condition

* measure 1 m away from trunk (where sediment depth measured)

Lateral Root Exposure

Is the basal flare burried ("telephone pole" appearance)? ________

Number of roots exposed (at least 3): ________

Depth to roots at one meter from trunk:

____

____

____

____

____

____

Draw tree and indicate slope of ground surface, locations of cores and direction of photograph(s):

501 Avis Drive
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48108
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APPENDIX C:
LABORATORY REPORT ON AGE DATING OF TREE CORES

Estimates of Tree Age as Determined from Increment Cores using Dendrochronology
Final Report for CH2MHill

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Methodology

A total of 158 cores, representing 53 trees, were delivered by Mark Holland of CH2MHill on February 2, 2005. Cores were contained in plastic straws and labeled with both paper labels and writing on the straw identifying each sample. Upon arrival, the cores were dried in a drying oven at 100° C for a minimum of 24 h. Cores were then mounted in wood core mounts (Don Ficken, Fort Morgan, CO) using white glue and held in place until dry using cotton twine. Cores exhibiting twisting were straightened using steam prior to mounting. Detailed core identification numbers were transposed from the straws to the core mounts. Core 113004-TRP-02383-0.17-D2 was not mounted due to it being highly fragmented. After the glue dried, strings were removed, and the core mounts were cut to individual tree core lengths. Each core was surfaced using a belt sander with successively finer (180-220-320) grit belts, and then hand sanded with 400-grit aluminum oxide paper. In most cases, the individual core was skeleton-plotted on graph paper (10 divisions to the inch) using the method described in Stokes and Smiley (1968). The skeleton plots representing the three cores per tree were cross-dated to create a tree-specific chronology, and several tree specific chronologies were used to create a species-specific master chronology (ash = 4 trees, elm = 4 trees, swamp oak = 3 trees, hackberry = 2 trees). Burr oak cross dated with the ash chronology, and black walnut cross dated with the elm chronology. Individual trees were then cross dated against the master chronologies to determine pith dates (when pith was present) or the inner most ring fragment date. These dates are then recorded on the individual wood core mounts for trees with verified ring dates. In several instances, specifically within the ash samples, cross dating with the ash master chronology was so robust that only one core was skeleton-plotted. This core represented the one core of the triplet with the most growth rings or the one that contained the pith.

Data

The only reliable data in this study are dates representing the pith date or the inner most growth ring fragment. A pith date represents the true age of the tree at the height along the stem (bole) where the core was obtained. Ring dates without pith only represent the date of that growth increment and are not, in and of themselves, representative of the actual age of the tree at the sampling height. A total of 16 trees in the sample of 53 have pith dates. Pith dates are reported in column AD and inner most ring dates are reported in column AE of the excel file.

One or two estimates were required to estimate the age of each individual tree from the dated cores. If a core contained a pith date, then tree age was estimated by the number of years required for the tree to reach the height from which the core sample was taken. The closer the sample was taken from ground level (column T in excel file), the lower the error in estimating tree age. If the pith were not present in any of the three cores from an individual tree, then determining an estimate of pith date was required for a specific dated core. Distance to pith was determined by matching the arch of the inner most ring boundary with a circle of known diameter using a plastic template (Template Designs Circle Master Template No. TD 445, Alvin & Co., Inc. Windsor, CT). Radial distance was calculated from this diameter. These data are reported in column AI of the excel file. The number of annual growth rings anticipated to be present along the estimated radius was determined by comparison against a core from a tree of the same species and same class (canopy or subcanopy), if possible, that contained pith. The larger the estimated radius to pith distance, the greater the uncertainty in the estimated pith date. Then, using the estimated pith date, tree age was estimated in the same way described above for trees with a pith date.

The uncertainty in tree age is lowest in trees in which the sampled core contained pith and was taken closest to the ground. As distance increased between the ground surface and sampling point along the bole, and as radial distance increased from the inner most dated growth ring to estimated pith position, uncertainty in estimated tree age increases. Uncertainty of age also increases with an increased sample height due to the potential for suppressed growth below the sampling point. This suppression is impossible to account for without actual growth ring data below the point of sampling. Estimated tree age is reported in column AH in the excel file.

APPENDIX D:
DENDROGEOMORPHIC MEASUREMENT RESULTS

Table D-1. Dendrogeomorphic Measurement Results

Core Sample ID	Tree Location ID	Date	Location	Tree Species	Depth to roots at one meter from trunk (in) (location does not necessarily correlate with core sample)	Field Core #	Core Recovery Length (in)	Pith present?	Pith date	Inner-most ring date	Estimated pith date	estimated tree age (Years)	Tree Ring Notes
112404-TRP-02374-2.50-D1	MIC-02374	11/24/2004	Dow Prp CBL	Elm	12	1	15.60	no	na	1953			
112404-TRP-02374-2.33-D2	MIC-02374	11/24/2004	Dow Prp CBL	Elm	12	2	15.60	no	na	1941	1939±1		compared to 02376 D2 for rings to pith est.
112404-TRP-02374-2.42-D3	MIC-02374	11/24/2004	Dow Prp CBL	Elm	14	3	15.60	no	na	1942		71±2	
112904-TRP-02375-5.33-D1	MIC-02375	11/29/2004	Dow Prp CBL	Elm	15	1	12.00	no	na	1940	1937±1		
112904-TRP-02375-4.83-D2	MIC-02375	11/29/2004	Dow Prp CBL	Elm	11.5	2	12.00	yes	1936	1936			
112904-TRP-02375-5.17-D3	MIC-02375	11/29/2004	Dow Prp CBL	Elm	11.5	3	10.00	no	na	1953		85±6	
112404-TRP-02376-2.00-D1	MIC-02376	11/24/2004	Dow Prp CBL	Ash	20	1	8.91	yes	1957	1957			
112404-TRP-02376-1.75-D2	MIC-02376	11/24/2004	Dow Prp CBL	Ash	11	2	8.91	no	na	1957	1956		
112404-TRP-02376-1.67-D3	MIC-02376	11/24/2004	Dow Prp CBL	Ash	20	3	8.91	no	na	nr		51±3	
112904-TRP-02377-1.58-D1	MIC-02377	11/29/2004	Dow Prp CBL	Ash	9.5	1	2.50	yes	1957	1957			
112904-TRP-02377-1.46-D2	MIC-02377	11/29/2004	Dow Prp CBL	Ash	24	2	3.00	yes	1956	1956			
112904-TRP-02377-1.83-D3	MIC-02377	11/29/2004	Dow Prp CBL	Ash	6.5	3	2.50	yes	1958	1958		55±2	
112904-TRP-02378-2.92-D1	MIC-02378	11/29/2004	Dow Prp CBL	Ash	24	1	3.13	no	na	1953	1947±1		compared to 02376 D3 for rings to pith est.
112904-TRP-02378-3.08-D2	MIC-02378	11/29/2004	Dow Prp CBL	Ash	24	2	3.00	no	na	1954	1947±2		no bark, broken off at 1978
112904-TRP-02378-3.25-D3	MIC-02378	11/29/2004	Dow Prp CBL	Ash	21	3	3.38	no	na	1953		68±4	
112904-TRP-02379-2.00-D1	MIC-02379	11/29/2004	Dow Prp CBL	Ash	11	1	8.88	no	na	1958	1952±1		
112904-TRP-02379-2.25-D2	MIC-02379	11/29/2004	Dow Prp CBL	Ash	19	2	9.38	no	na	1957	1952±1		
112904-TRP-02379-2.33-D3	MIC-02379	11/29/2004	Dow Prp CBL	Ash	18	3	9.25	no	na	1954	1952±1	56±3	
120204-TRP-02380-0.71-D1	MIC-02380	12/2/2004	Dow Prp CBL	Ash	5	1	4.50	no	na	nr			
120204-TRP-02380-0.83-D2	MIC-02380	12/2/2004	Dow Prp CBL	Ash	10	2	5.25	no	na	nr			
120204-TRP-02380-0.90-D3	MIC-02380	12/2/2004	Dow Prp CBL	Ash	17	3	6.00	yes	1951	1951		57±3	
113004-TRP-02381-0.46-D1	MIC-02381	11/30/2004	Dow Prp CBL	Elm	5	1	4.25	no	na	nr			
113004-TRP-02381-0.71-D2	MIC-02381	11/30/2004	Dow Prp CBL	Elm	4	2	4.13	no	na	1957	1953±2		severely suppressed in 1980-90s
113004-TRP-02381-0.58-D3	MIC-02381	11/30/2004	Dow Prp CBL	Elm	3	3	4.00	no	na	1970	1957±4	53±3	severely suppressed in 1980-90s
120104-TRP-02382-1.13-D1	MIC-02382	12/1/2004	Dow Prp CBL	Burr Oak	5.5	1	15.25	no	na	1925	1918±3		
120104-TRP-02382-1.00-D2	MIC-02382	12/1/2004	Dow Prp CBL	Burr Oak	2.75	2	11.25	no	na	1934			
120104-TRP-02382-1.00-D3	MIC-02382	12/1/2004	Dow Prp CBL	Burr Oak	12	3	15.00	no	na	1921		90±4	
120104-TRP-02382-1.00-D3	MIC-02382	12/1/2004	Dow Prp CBL	Burr Oak	10.5	Root Measurement							
120104-TRP-02382-1.00-D3	MIC-02382	12/1/2004	Dow Prp CBL	Burr Oak	12								
113004-TRP-02383-0.21-D1	MIC-02383	11/30/2004	Dow Prp CBL	Elm	4.5	1	2.63	no	na	1970	1967±1		
113004-TRP-02383-0.17-D2	MIC-02383	11/30/2004	Dow Prp CBL	Elm	6.5	2	2.00	na	na	nr	na		core badly broken up, could not mount
113004-TRP-02383-0.54-D3	MIC-02383	11/30/2004	Dow Prp CBL	Elm	3.625	3	2.00	no	na	1973	1967±2	37±2	
120204-TRP-02384-0.54-D1	MIC-02384	12/2/2004	Dow Prp CBL	Oak	7.25	1	5.00	yes	1923	1923			4 missing rings, suppressed 1979-2004
120204-TRP-02384-0.58-D2	MIC-02384	12/2/2004	Dow Prp CBL	Oak	15.5	2	7.00	no	na	1924			suppressed 1979-2004
120204-TRP-02384-0.67-D3	MIC-02384	12/2/2004	Dow Prp CBL	Oak	27.5	3	6.50	no	na	1928		83±2	4 missing rings, suppressed 1979-2004
113004-TRP-02385-1.75-D1	MIC-02385	11/30/2004	Dow Prp CBL	Ash	6	1	15.50	no	na	1957	1949±5		
113004-TRP-02385-2.29-D2	MIC-02385	11/30/2004	Dow Prp CBL	Ash	8.625	2	14.63	no	na	1956	1949±5		
113004-TRP-02385-2.50-D3	MIC-02385	11/30/2004	Dow Prp CBL	Ash	4.25	3	15.38	no	na	1967		60±7	
113004-TRP-02386-0.50-D1	MIC-02386	11/30/2004	Dow Prp CBL	Ash	9	1	10.00	no	na	1944	1929±5		suppressed 1952-1965
113004-TRP-02386-0.67-D2	MIC-02386	11/30/2004	Dow Prp CBL	Ash	12.5	2	9.13	no	na	1935	1928±2		suppressed 1954-1964
113004-TRP-02386-0.96-D3	MIC-02386	11/30/2004	Dow Prp CBL	Ash	9	3	9.88	no	na	nr		79±3	

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Table D-1. Dendrogeomorphic Measurement Results (cont.)

Core Sample ID	Tree Location ID	Date	Location	Tree Species	Depth to roots at one meter from trunk (in) (location does not necessarily correlate with core sample)	Field Core #	Core Recovery Length (in)	Pith present?	Pith date	Inner-most ring date	Estimated pith date	estimated tree age (Years)	Tree Ring Notes
113004-TRP-02387-0.54-D1	MIC-02387	11/30/2004	Dow Prp CBL	Swamp Oak	5.25	1	3.00	yes	1976	1976			1 misssing ring, 2003 or 2004
113004-TRP-02387-0.50-D2	MIC-02387	11/30/2004	Dow Prp CBL	Swamp Oak	7	2	3.00	no	na	1976			1 misssing ring, 2003 or 2004
113004-TRP-02387-0.67-D3	MIC-02387	11/30/2004	Dow Prp CBL	Swamp Oak	5.5	3	3.00	no	na	1976		30±2	
120104-TRP-02388-0.58-D1	MIC-02388	12/1/2004	Dow Prp CBL	Swamp Oak	7	1	5.00	no	na	1958	1957		
120104-TRP-02388-0.67-D2	MIC-02388	12/1/2004	Dow Prp CBL	Swamp Oak	7	2	4.50	no	na	1959			
120104-TRP-02388-0.75-D3	MIC-02388	12/1/2004	Dow Prp CBL	Swamp Oak	6	3	4.50	no	na	1965		51±2	
120104-TRP-02389-1.25-D1	MIC-02389	12/1/2004	Dow Prp CBL	Ash	7.75	1	15.25	no	na	1932	1930±1		
120104-TRP-02389-1.25-D2	MIC-02389	12/1/2004	Dow Prp CBL	Ash	9	2	14.25	no	na	1940			
120104-TRP-02389-1.29-D3	MIC-02389	12/1/2004	Dow Prp CBL	Ash	9.25	3	13.50	no	na	1932		79±3	
120204-TRP-02390-0.94-D1	MIC-02390	12/2/2004	Dow Prp CBL	Ash	3.5	1	9.50	no	na	1916			supperssed 1929-1940
120204-TRP-02390-1.08-D2	MIC-02390	12/2/2004	Dow Prp CBL	Ash	7	2	10.50	no	na	1914	1902±4		suppressed 1925-1936
120204-TRP-02390-1.00-D3	MIC-02390	12/2/2004	Dow Prp CBL	Ash	9	3	10.75	no	na	nr		108±8	
113004-TRP-02391-0.63-D1	MIC-02391	11/30/2004	Dow Prp CBL	Ash	3.5	1	10.50	no	na	1972			
113004-TRP-02391-0.92-D2	MIC-02391	11/30/2004	Dow Prp CBL	Ash	5.5	2	10.25	no	na	1972			
113004-TRP-02391-0.67-D3	MIC-02391	11/30/2004	Dow Prp CBL	Ash	3.75	3	10.38	no	na	1967	1959±2	48±3	
120804-TRP-02392-0.19-D1	FRE-02392	12/8/2004	Dow Prp R.Dr.	Oak	7	1	3.75	yes	1955	1955			5 missing rings suppressed 1974-1986
120804-TRP-02392-0.25-D2	FRE-02392	12/8/2004	Dow Prp R.Dr.	Oak	8	2	4.00	yes	1955	1955			2 missing rings 1991, 1997
120804-TRP-02392-0.58-D3	FRE-02392	12/8/2004	Dow Prp R.Dr.	Oak	5	3	3.50	no	na	1960		52±1	
120804-TRP-02393-0.50-D1	FRE-02393	12/8/2004	Dow Prp R.Dr.	Oak	6	1	6.25	no	na	1958			
120804-TRP-02393-0.58-D2	FRE-02393	12/8/2004	Dow Prp R.Dr.	Oak	10	2	6.75	no	na	1952			
120804-TRP-02393-0.63-D3	FRE-02393	12/8/2004	Dow Prp R.Dr.	Oak	6	3	8.00	yes	1950	1950		57±1	
120804-TRP-02394-0.92-D1	FRE-02394	12/8/2004	Dow Prp R.Dr.	Swamp Oak	4	1	10.00	yes	1958	1958			
120804-TRP-02394-0.83-D2	FRE-02394	12/8/2004	Dow Prp R.Dr.	Swamp Oak	7.5	2	10.25	no	na	1959			
120804-TRP-02394-0.71-D3	FRE-02394	12/8/2004	Dow Prp R.Dr.	Swamp Oak	2	3	8.00	no	na	1960		55±2	
120804-TRP-02395-0.50-D1	FRE-02395	12/8/2004	Dow Prp R.Dr.	Swamp Oak	4	1	4.00	no	na	1966			3 missing rings, suppressed 1979-2004
120804-TRP-02395-0.42-D2	FRE-02395	12/8/2004	Dow Prp R.Dr.	Swamp Oak	7	2	4.25	no	na	1958	1954±1		
120804-TRP-02395-0.58-D3	FRE-02395	12/8/2004	Dow Prp R.Dr.	Swamp Oak	3	3	4.00	no	na	1963		55±3	
120704-TRP-02396-1.00-D1	FRE-02396	12/7/2004	Dow Prp R.Dr.	Oak	3	1	9.00	no	na	1960	1951±2		
120704-TRP-02396-1.04-D2	FRE-02396	12/7/2004	Dow Prp R.Dr.	Oak	2.5	2	11.00	no	na	1959			
120704-TRP-02396-1.21-D3	FRE-02396	12/7/2004	Dow Prp R.Dr.	Oak	2	3	11.50	no	na	1966		61±4	
120804-TRP-02397-0.44-D1	FRE-02397	12/8/2004	Dow Prp R.Dr.	Swamp Oak	3	1	4.75	no	na	1985			
120804-TRP-02397-0.54-D2	FRE-02397	12/8/2004	Dow Prp R.Dr.	Swamp Oak	3	2	4.25	no	na	1980	1976±1		estimated on 2395 D2 121
120804-TRP-02397-0.58-D3	FRE-02397	12/8/2004	Dow Prp R.Dr.	Swamp Oak	4.5	3	4.00	no	na	1982		33±3	
120604-TRP-02398-0.33-D1	FRE-02398	12/6/2004	Dow Prp R.Dr.	Elm	2	1	2.00	no	na	1982			
120604-TRP-02398-0.42-D2	FRE-02398	12/6/2004	Dow Prp R.Dr.	Elm	5	2	2.00	no	na	1976			
120604-TRP-02398-0.50-D3	FRE-02398	12/6/2004	Dow Prp R.Dr.	Elm	13	3	2.50	yes	1972	1972		34±2	
120204-TRP-02399-1.17-D1	FRE-02399	12/2/2004	Dow Prp R.Dr.	Black Walnut	7	1	10.00	no	na	1955			miss ID as ash
120204-TRP-02399-1.04-D2	FRE-02399	12/2/2004	Dow Prp R.Dr.	Black Walnut	6	2	13.25	yes	1949	1949			miss ID as ash
10000-TRP-02399-0.00-D	FRE-02399	12/2/2004	Dow Prp R.Dr.	Black Walnut	5.5	3	11.00	no	na	1956		58±3	miss ID as ash
120204-TRP-02400-0.90-D1	FRE-02400	12/2/2004	Dow Prp R.Dr.	Ash	7.5	1	8.75	no	na	1969	1953±5		compared to sample 69 to est. pith
120204-TRP-02400-0.88-D2	FRE-02400	12/2/2004	Dow Prp R.Dr.	Ash	8.5	2	8.25	no	na	nr			
120204-TRP-02400-0.75-D3	FRE-02400	12/2/2004	Dow Prp R.Dr.	Ash	17	3	6.50	no	na	nr		48±8	

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Table D-1. Dendrogeomorphic Measurement Results (cont.)

Core Sample ID	Tree Location ID	Date	Location	Tree Species	Depth to roots at one meter from trunk (in) (location does not necessarily correlate with core sample)	Field Core #	Core Recovery Length (in)	Pith present?	Pith date	Inner-most ring date	Estimated pith date	estimated tree age (Years)	Tree Ring Notes
120304-TRP-02401-0.38-D1	FRE-02401	12/3/2004	Dow Prp R.Dr.	Ash	4.5	1	5.25	yes	1949	1949			
120304-TRP-02401-0.79-D2	FRE-02401	12/3/2004	Dow Prp R.Dr.	Ash	9	2	5.50	no	na	nr			
120304-TRP-02401-0.29-D3	FRE-02401	12/3/2004	Dow Prp R.Dr.	Ash	6.5	3	6.00	yes	1949	1949		58±1	1 missing ring
120304-TRP-02402-0.63-D1	FRE-02402	12/3/2004	Dow Prp R.Dr.	Elm	7	1	1.75	no	na	1963			2 missing rings 1996. 1997
120304-TRP-02402-0.67-D2	FRE-02402	12/3/2004	Dow Prp R.Dr.	Elm	13	2	1.75	yes	1960	1960			2 missing rings 1996. 2002
120304-TRP-02402-0.42-D3	FRE-02402	12/3/2004	Dow Prp R.Dr.	Elm	12	3	1.75	no	na	1978		47±3	
120304-TRP-02403-0.52-D1	FRE-02403	12/3/2004	Dow Prp R.Dr.	Ash	10.5	1	9.60	no	na	1947	1946		
120304-TRP-02403-0.64-D2	FRE-02403	12/3/2004	Dow Prp R.Dr.	Ash	9.5	2	8.64	no	na	nr			
120304-TRP-02403-0.35-D3	FRE-02403	12/3/2004	Dow Prp R.Dr.	Ash	12	3	9.00	no	na	1947		58±1	
120604-TRP-02404-0.58-D1	FRE-02404	12/6/2004	Dow Prp R.Dr.	Elm	11	1	8.00	no	na	1940			1 missing ring 1984
120604-TRP-02404-0.33-D2	FRE-02404	12/6/2004	Dow Prp R.Dr.	Elm	17	2	9.00	no	na	1945			
120604-TRP-02404-0.58-D3	FRE-02404	12/6/2004	Dow Prp R.Dr.	Elm	16	3	8.00	yes	1938	1938		70±2	
120704-TRP-02405-0.58-D1	FRE-02405	12/7/2004	Dow Prp R.Dr.	Hackberry	3	1	3.00	no	na	nr			
120704-TRP-02405-0.42-D2	FRE-02405	12/7/2004	Dow Prp R.Dr.	Hackberry	4	2	3.50	yes	1948	1948			suppression starting 1967-1992 14 missing rings
120704-TRP-02405-0.42-D3	FRE-02405	12/7/2004	Dow Prp R.Dr.	Hackberry	5	3	3.50	no	na	1951		62±2	2 missing rings in 1990's
120704-TRP-02406-0.25-D1	FRE-02406	12/7/2004	Dow Prp R.Dr.	Ash	26	1	9.00	no	na	nr			
120704-TRP-02406-0.33-D2	FRE-02406	12/7/2004	Dow Prp R.Dr.	Ash	16	2	9.00	no	na	1946	1935±5		compared to sample 69 to est. pith
120704-TRP-02406-0.50-D3	FRE-02406	12/7/2004	Dow Prp R.Dr.	Ash	17	3	9.50	no	na	nr		71±7	
120604-TRP-02407-0.50-D1	FRE-02407	12/6/2004	Dow Prp R.Dr.	Ash	15	1	9.00	no	na	1952			
120604-TRP-02407-0.58-D2	FRE-02407	12/6/2004	Dow Prp R.Dr.	Ash	7	2	8.50	no	na	1945	1944		
120604-TRP-02407-0.50-D3	FRE-02407	12/6/2004	Dow Prp R.Dr.	Ash	23	3	8.50	no	na	1948		61±2	
120604-TRP-02408-0.17-D1	FRE-02408	12/6/2004	Dow Prp R.Dr.	Elm	9	1	7.50	no	na	1939			
120604-TRP-02408-0.58-D2	FRE-02408	12/6/2004	Dow Prp R.Dr.	Elm	15	2	8.25	no	na	1940			
120604-TRP-02408-0.42-D3	FRE-02408	12/6/2004	Dow Prp R.Dr.	Elm	4.5	3	7.50	yes	1928	1928		79±2	1 missing ring late 1990's
120604-TRP-02409-0.25-D1	FRE-02409	12/6/2004	Dow Prp R.Dr.	Ash	12	1	8.00	no	na	1957	1943±5		compared to sample 69 to est. pith
120604-TRP-02409-0.50-D2	FRE-02409	12/6/2004	Dow Prp R.Dr.	Ash	22	2	8.00	no	na	1960	1943±5		compared to sample 69 to est. pith
120604-TRP-02409-0.25-D3	FRE-02409	12/6/2004	Dow Prp R.Dr.	Ash	22	3	8.00	no	na	1956		62±8	
121704-TRP-02411-0.85-D1	THT-02411	12/17/2004	Imerman	Ash	11.4	1	7.56	no	na	1967	1966±1		
121704-TRP-02411-0.90-D2	THT-02411	12/17/2004	Imerman	Ash	10.8	2	8.52	no	na	nr			
121704-TRP-02411-0.90-D3	THT-02411	12/17/2004	Imerman	Ash	14.4	3	7.44	no	na	nr		39±3	
121704-TRP-02412-1.20-D1	THT-02412	12/17/2004	Imerman	Hackberry	12	1	7.32	no	na	1974			
121704-TRP-02412-0.85-D2	THT-02412	12/17/2004	Imerman	Hackberry	8.4	2	8.40	no	na	1969			
121704-TRP-02412-1.10-D3	THT-02412	12/17/2004	Imerman	Hackberry	11.4	3	8.04	yes	1968	1968		42±2	
121704-TRP-02413-0.95-D1	THT-02413	12/17/2004	Imerman	Ash	11.4	1	9.12	no	na	1972	1965±3		compared to sample 42 to est. pith
121704-TRP-02413-0.90-D2	THT-02413	12/17/2004	Imerman	Ash	9	2	9.00	no	na	nr			
121704-TRP-02413-1.15-D3	THT-02413	12/17/2004	Imerman	Ash	14.4	3	9.36	no	na	1972	1965±4	43±7	compared to sample 42 to est. pith
121704-TRP-02414-0.55-D1	THT-02414	12/17/2004	Imerman	Ash	19.2	1	8.88	yes	1967	1967			
121704-TRP-02414-1.00-D2	THT-02414	12/17/2004	Imerman	Ash	12	2	9.72	no	na	1971			
121704-TRP-02414-0.80-D3	THT-02414	12/17/2004	Imerman	Ash	19.8	3	8.64	no	na	1972		40±2	
121704-TRP-02415-0.90-D1	THT-02415	12/17/2004	Imerman	Elm	0.45	1	12.60	yes	1968	1968			
121704-TRP-02415-1.00-D2	THT-02415	12/17/2004	Imerman	Elm	0.35	2	12.72	yes	1969	1969			
121704-TRP-02415-0.90-D3	THT-02415	12/17/2004	Imerman	Elm	0.4	3	12.60	yes	1968	1968		39±2	

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120904-TRP-02416-0.83-D1	THT-02416	12/9/2004	Imerman	Ash	10	1	9.50	no	na	1960	1952±3		compared to sample 42 to est. pith
120904-TRP-02416-0.71-D2	THT-02416	12/9/2004	Imerman	Ash	8	2	9.00	no	na	1965			
120904-TRP-02416-0.71-D3	THT-02416	12/9/2004	Imerman	Ash	11	3	8.50	no	na	1956		56±6	not possible to estimate pith due to geometry
120904-TRP-02417-0.25-D1	THT-02417	12/9/2004	Imerman	Elm	2	1	7.00	yes	1958	1958			
120904-TRP-02417-0.67-D2	THT-02417	12/9/2004	Imerman	Elm	5	2	6.00	no	na	1970			
120904-TRP-02417-0.67-D3	THT-02417	12/9/2004	Imerman	Elm	4.5	3	7.00	no	na	1968		47±1	
120904-TRP-02418-0.40-D1	THT-02418	12/9/2004	Imerman	Elm	6	1	6.00	yes	1956	1956			
120904-TRP-02418-0.50-D2	THT-02418	12/9/2004	Imerman	Elm	6.5	2	4.00	no	na	1972			
120904-TRP-02418-0.54-D3	THT-02418	12/9/2004	Imerman	Elm	2.5	3	4.25	no	na	1967		44±1	
120904-TRP-02419-0.67-D1	THT-02419	12/9/2004	Imerman	Ash	6	1	6.75	no	na	1959	1956±1		
120904-TRP-02419-0.63-D2	THT-02419	12/9/2004	Imerman	Ash	12.5	2	8.50	no	na	1961			
120904-TRP-02419-0.73-D3	THT-02419	12/9/2004	Imerman	Ash	4.25	3	9.00	no	na	1963		51±2	
120904-TRP-02420-0.33-D1	THT-02420	12/9/2004	Imerman	Ash	8	1	3.50	no	na	nr			
120904-TRP-02420-0.17-D2	THT-02420	12/9/2004	Imerman	Ash	8	2	4.25	no	na	nr			
120904-TRP-02420-0.33-D3	THT-02420	12/9/2004	Imerman	Ash	9.5	3	4.50	yes	1965	1965		41±1	
120904-TRP-02421-0.96-D1	THT-02421	12/9/2004	Imerman	Ash	5.5	1	10.75	no	na	1954			inner rings decayed
120904-TRP-02421-0.94-D2	THT-02421	12/9/2004	Imerman	Ash	6	2	14.00	no	na	1964			
120904-TRP-02421-0.88-D3	THT-02421	12/9/2004	Imerman	Ash	11	3	12.00	no	na	1955	1948±3	60±7	inner rings decayed, 42 for ref.
120804-TRP-02422-1.29-D1	THT-02422	12/8/2004	Imerman	Hackberry	9	1	11.50	no	na	1932	1939±1		compare to 88 to est. pith
120804-TRP-02422-1.06-D2	THT-02422	12/8/2004	Imerman	Hackberry	4	2	13.00	no	na	1938			1 missing ring 2002
	THT-02422	12/8/2004	Imerman	Hackberry	6	3	NA					71±6	
120904-TRP-02423-0.79-D1	THT-02423	12/9/2004	Imerman	Ash	12	1	12.75	no	na	1918	1914±1		
120904-TRP-02423-0.85-D2	THT-02423	12/9/2004	Imerman	Ash	7	2	8.75	no	na	1923			
120904-TRP-02423-0.58-D3	THT-02423	12/9/2004	Imerman	Ash	12	3	12.75	no	na	na		94±4	only short inner segment of core
120804-TRP-02424-1.29-D1	THT-02424	12/8/2004	Imerman	Hackberry	3	1	10.00	no	na	1947			
120804-TRP-02424-0.92-D2	THT-02424	12/8/2004	Imerman	Hackberry	5	2	10.00	no	na	1940			
120804-TRP-02424-1.04-D3	THT-02424	12/8/2004	Imerman	Hackberry	5.5	3	10.00	no	na	1938	1935	72±3	
120804-TRP-02425-0.63-D1	THT-02425	12/8/2004	Imerman	Hackberry	3.5	1	3.50	yes	1941	1941			scar 1944, suppressed 1954-1966, 1993-1998
120804-TRP-02425-0.42-D2	THT-02425	12/8/2004	Imerman	Hackberry	12	2	3.25	no	na	ns			
120804-TRP-02425-0.50-D3	THT-02425	12/8/2004	Imerman	Hackberry	9	3	3.50	no	na	ns		66±2	
120804-TRP-02426-0.25-D1	THT-02426	12/8/2004	Imerman	Hackberry	8	1	2.25	no	na	ns			
120804-TRP-02426-0.21-D2	THT-02426	12/8/2004	Imerman	Hackberry	8	2	2.75	no	na	ns			
120804-TRP-02426-0.38-D3	THT-02426	12/8/2004	Imerman	Hackberry	7	3	2.50	yes	1960	1960		45±1	suppressed growth 1982-1995
120804-TRP-02427-0.71-D1	THT-02427	12/8/2004	Imerman	Elm	13	1	6.00	no	na	1949			
120804-TRP-02427-0.33-D2	THT-02427	12/8/2004	Imerman	Elm	11	2	6.00	no	na	1947			
120804-TRP-02427-0.58-D3	THT-02427	12/8/2004	Imerman	Elm	4	3	5.25	yes	1942	1942		65±2	

Core ID Notes
- date is 6 digits (month, day, year)
- medium is TRP = terrestrial plant
- station# is numeric portion of Tree Location ID
- depth = core distance above ground surface in feet
- duplicate# is D# = replicate number of tree core sample