United States Department of Agriculture
Forest Service

Pacific Northwest
Research Station

General Technical Report
PNW-GTR-871

June 2013

A Photographic Guide to *Acacia koa* Defects

Eini C. Lowell, Janice K. Wiedenbeck,
and Betsy S. Porterfield

Authors

Eini C. Lowell is a research forest products technologist, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main St., Suite 400, Portland, OR 97205. **Janice K. Wiedenbeck** is a research forest products technologist and **Betsy S. Porterfield** is an information technology specialist, Northern Research Station, 241 Mercer Springs Road, Princeton, WV 24740.

Cover photographs: Eini C. Lowell, Suzie Lee, and Janice K. Wiedenbeck.

Abstract

Lowell, Eini C.; Wiedenbeck, Janice K.; Porterfield, Betsy S. 2013. A photographic guide to *Acacia koa* defects. Gen. Tech. Rep. PNW-GTR-871. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 99 p.

Acacia koa (A. Gray), native to the Hawaiian Islands, has both cultural and economic significance. Koa wood is world-renowned for its extensive use in furniture, tone wood for musical instruments, and other items of cultural importance. Old-growth koa is decreasing in supply, yet dead and dying koa is still being harvested for manufacture of products. Knowledge of wood quality in the trees available for harvest is limited and colloquial in nature. We selected logs from four geographically dispersed sites on the Island of Hawaii. Defects on the face and end surfaces of each log were measured and photographed. The four most commonly occurring defects found were seam, branch, decay (log face), and heart rot. Sawing patterns were recorded so that corresponding defects on lumber could be measured and impact on volume recovery calculated for a specific defect. Included is a pictorial accounting that captures the defect indicators on the exterior of the log and the interior manifestation of the defects as seen in the lumber sawn from the log.

Keywords: *Acacia koa*, Hawaiian woods, log defect, wood quality, lumber defect.

Contents

Introduction

Koa (*Acacia koa* A. Gray) wood is a culturally important and economically valuable hardwood species in the Hawaiian Islands. It is native to Hawaii, found primarily on the larger of the islands, and occurs nowhere else in the world (Baker et al. 2009, Whitesell 1990). It has been, and continues to be, an important timber species for the manufacture of wood products in Hawaii. Koa wood is used for a variety of products from traditional items such as canoes and fine musical instruments (e.g., ukuleles) to flooring. The wood has a cultural significance to Hawaiians—many people would like to own a koa piece of heirloom quality.

Koa wood is prized worldwide for its extensive use in furniture and has gained a reputation for its uses as tone wood for musical instruments. The quality (and value) of the wood is ultimately defined by the consumer. Wood quality is determined by heartwood color, grain figure (e.g., curl), and the size of defect-free sections. The highest grade, dark-colored wood is used for musical instruments. If the wood has figure[1] it increases in value. Cabinetmakers may use intermediate-colored koa and lighter, less figured wood may be used in flooring. Small pieces of koa can be used in niche market applications such as door knobs, bowls, jewelry boxes, hairbrushes, or picture frames.

Larger and older trees do not always produce the highest value wood. Value is based on the level of all three quality attributes (color, figure, clear area size) as they relate to the raw material requirements of the product(s). For example, plain koa, or lumber without any color or figure attributes, might be sold for $15 to $20/board foot (bf). Full curl lumber can bring between $80 and $120/bf, and musical-grade koa runs up to $150/bf (Woodshop News 2009).

Old-growth koa, used in the manufacture of traditional Hawaiian wood products, is dwindling in supply, with limited amounts available in coming years. Much of the koa being processed comes from standing dead or downed trees and logs that have been on the ground for some time (relic logs). While these trees/logs are being sought out and swept up with the expectation that high-value wood with good color and figure will be recovered, the felling, bucking, and transporting of these massive logs can be dangerous, costly, and sometimes unproductive.

Because of the value of koa wood, understanding how log defects affect wood quality and value is critical for those involved in buying or selling koa trees or logs and for those who process koa logs into lumber. Conversations with those who study and work with koa wood enabled us to compose a list of defects that appear

[1] "Traditionally refers to distinctive wood grain patterns … [but] more recently the term has been used in a broader sense to include other distinctive wood appearance factors, such as color" (Wiedenbeck et al. 2003).

most frequently. An existing guide (Burgan et al. 1971; also see appendix) is limited in scope and sample size. Many of the defects identified in our conversations were not included in this 1971 study, or, if they were, had results based on very few samples. Regional experts felt that rotten knots and bark seams were the most difficult defects for log traders to assess in terms of their impacts on both scale volume and value recovery.

The purpose of this study, jointly funded by the Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife and the U.S. Forest Service, was to (1) develop a better understanding of relationships between key tree and log attributes and the potential for efficient wood utilization and value recovery for *Acacia koa*, and (2) develop a photographic guide to koa log defects that captures the defect indicators on the outside of the log and the interior manifestation of the defects as seen in the lumber sawn from the log.

Methods

Log and lumber defect data were collected at four locations on the Island of Hawaii (fig. 1). These locations were chosen based on recommendations of local agency representatives. Active koa sales, site differences, and defect knowledge all influenced site selection. Two locations were on the east side of the island. The Department of Hawaiian Home Lands site was at about 6,000 ft on Keanakolu Road off Saddle Road. Standing trees were selected from an existing sale for nondestructive stress wave testing prior to felling and processing (Wiedenbeck and Lowell 2011). The second site on the east side was on privately owned land near the town of Ookala. Because of manufacturing time constraints, only two logs were chosen from the Ookala log deck for diagramming and processing. On the west side of the island, samples were selected from log decks at two sites. A wood products manufacturer in Honaunau had logs available from standing dead trees harvested off nearby private land. A second private landowner had relic logs and young-growth logs from dead trees available for processing. Table 1 summarizes site, sample, and processing data.

The measurements taken on the logs included large-end diameter and small-end diameter inside bark; log length; location of pith; and type, location, and size information on every log defect (what we term “defect mapping”). The log data collection sheet is illustrated in figure 2. Diagrams of the sawing pattern (fig. 3) were made as logs were being milled and each piece of merchantable wood was labeled with the log number and a unique board number that could be referenced back to the sawing diagram. Logs were often rotated or larger pieces cut for further milling to obtain the best lumber grade from the log. Although 4/4 (nominal 1-in thick), 8/4 (nominal 2-in thick), cants, and veneer flitches were the preferred products to mill,

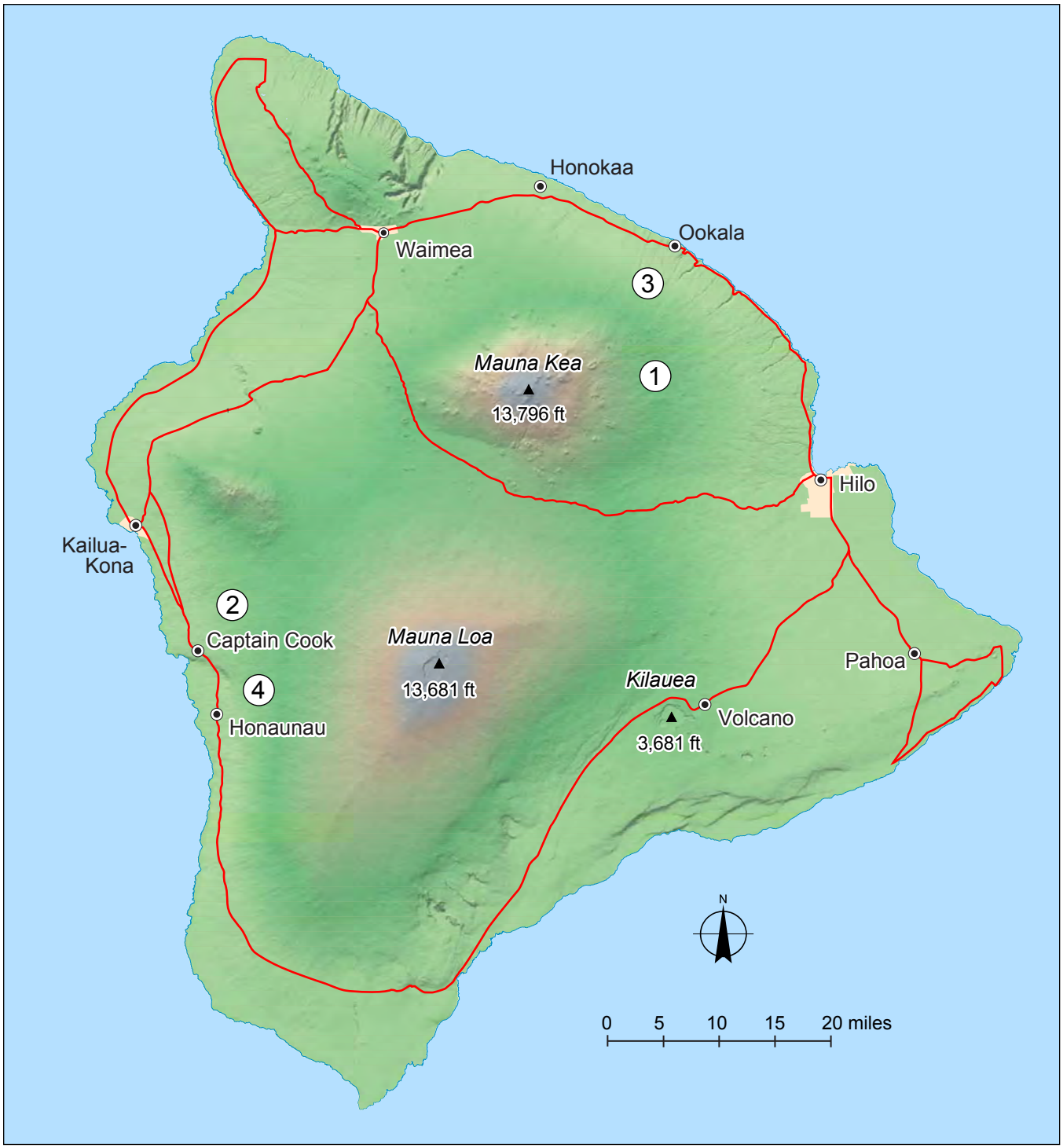


Figure 1—The Island of Hawaii showing locations of sample/processing sites as indicated by numbers. Numbers cross reference to table 1 site information.

Table 1—Study site and sample description[a]

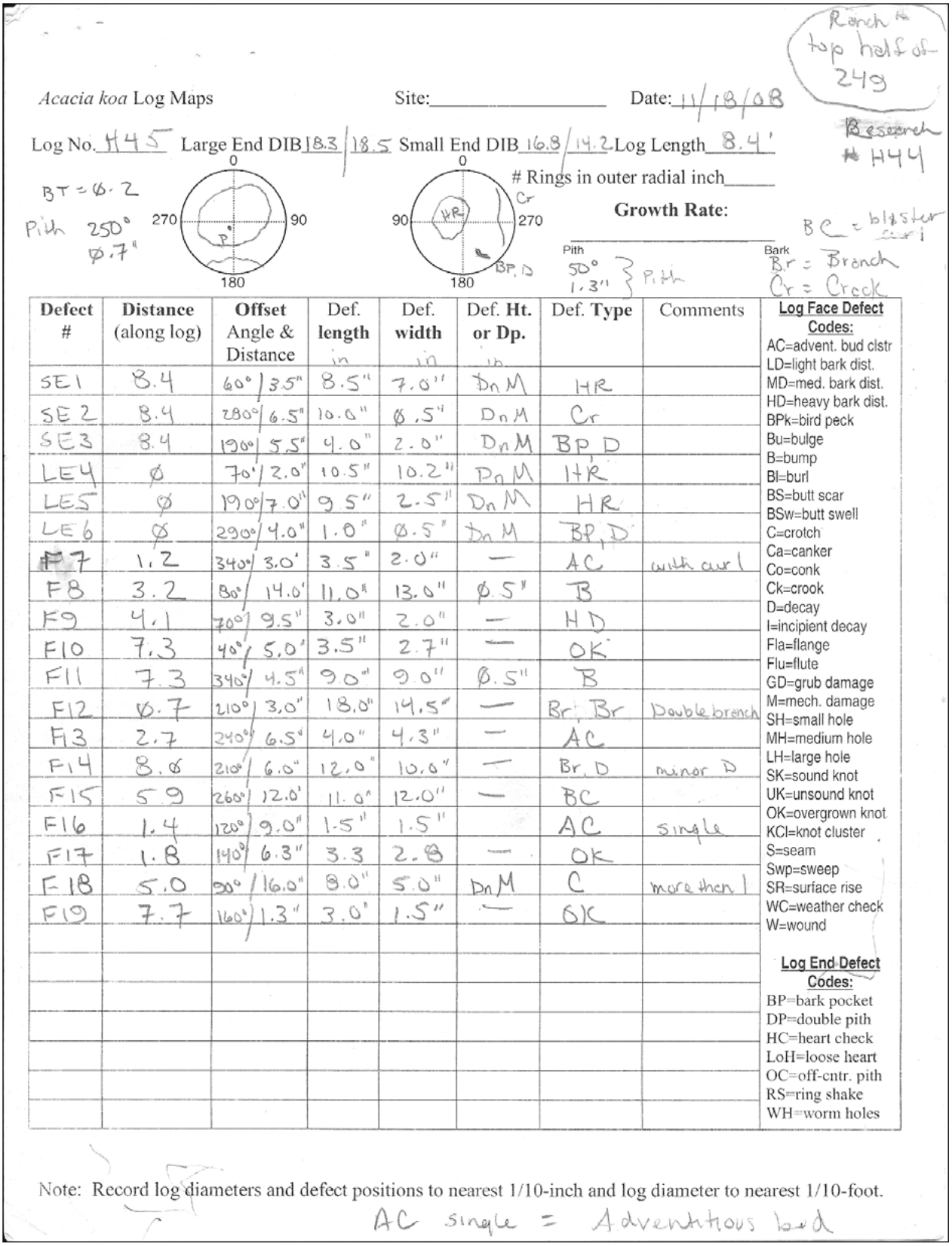
Site location	Elevation (approx.)	Mill site	Sawn logs	Tree/log condition	Mill type (kerf)	Products sawn
	Ft		*No.*			
Site 1: Keanakolu Road	6,000	Onsite	7	Standing dead, dying, and poor form	Wood Mizer LT 15 (1/8 in)	Predominantly 4/4- and 8/4-in-thick lumber with occasional 16/4-in cant
Site 2: Kealakekua	4,600 to 5,200[b] 3,600 to 3,800[c]	Onsite	9	6 relic (down) and 3 dead young growth	Wood Mizer (1/8 in)	4/4- and 8/4-in-thick lumber
Site 3: Ookala	4,400	Onsite	2	Standing dead or dying	Wood Mizer LT 40 (1/8 in)	4/4- and 8/4-in-thick lumber
Site 4: Honaunau	3,000 to 4,000	Offsite	9	Standing dead or dying	Select Sawmill (3/16 in)	Predominantly 4/4-with occasional 7/4- and 8/4-in-thick lumber

[a] All sites are on the Island of Hawaii.
[b] Relic logs.
[c] Young-growth trees.

pieces that contained a single board foot were sometimes sawn and tallied. Flanges, and other naturally occurring variations in log shape, were sometimes cut and set aside to be sold as craft wood. All defects were measured and recorded (fig. 4) for each piece of lumber sawn. Photographs were taken of most defects identified on board diagrams. Lumber was tallied by mill personnel at each site.

Table 2 contains a summary of the defects found and mapped on our study logs. In total, 28 logs were defect mapped (27 of which were subsequently sawn) and 391 log defects were tallied, measured, and photographed. Of the 391 defects tallied, 64 were end defects found on the large end of the logs, 69 were end defects located on the small ends, and 258 (66 percent) were face defects (occurring along the sides of the logs). The four most commonly occurring defects found in our koa log sample were seam, branch, decay (log face), and heart rot, all occurring in over 55 percent of the study logs. This log defect tally substantiates the opinions expressed by koa experts in our prestudy discussions that rotten knots (which develop from branch defects over time) and bark seams are very important, highly variable defects that log buyers and sellers alike find challenging to evaluate.

Shading has been used in table 2 to show defects that are hard to distinguish from one another or of similar origin. In our original field tally, we tended to split similar defect types into multiple categories. These similarities and distinctions between and among defects are presented in the next section.



Acacia koa Log Maps Site:_____ Date: 11/18/08

Ranch = top half of 249

Research # H44

Log No. H45 Large End DIB 18.3 / 18.5 Small End DIB 16.8 / 14.2 Log Length 8.4'

Rings in outer radial inch_____

Growth Rate:

BT = 6.2
Pith 250° Ø.7"

0 / 90 / 180 / 270 (P)

0 / 90 / 180 / 270 (HR, Cr, BP, D)

Pith 50° 1.3" } Pith

BC = blaster cut

Bark
Br = Branch
Cr = Crack

Defect #	Distance (along log)	Offset Angle & Distance	Def. length in	Def. width in	Def. Ht. or Dp. in	Def. Type	Comments
SE1	8.4	60° / 3.5"	8.5"	7.0"	DnM	HR	
SE2	8.4	280° / 6.5"	10.0"	Ø.5"	DnM	Cr	
SE3	8.4	190° / 5.5"	4.0"	2.0"	DnM	BP, D	
LE4	Ø	70° / 2.0"	10.5"	10.2"	DnM	I+R	
LE5	Ø	190° / 7.0"	9.5"	2.5"	DnM	HR	
LE6	Ø	290° / 4.0"	1.0"	Ø.5"	DnM	BP, D	
F7	1.2	340° / 3.0'	3.5"	2.0"	—	AC	with curl
F8	3.2	80° / 14.0'	11.0"	13.0"	Ø.5"	B	
F9	4.1	70° / 9.5"	3.0"	2.0"	—	HD	
F10	7.3	40° / 5.0'	3.5"	2.7"	—	OK	
F11	7.3	340° / 4.5"	9.0"	9.0"	Ø.5"	B	
F12	Ø.7	210° / 3.0"	18.0"	14.5"	—	Br, Br	Double branch
F13	2.7	240° / 6.5"	4.0"	4.3"	—	AC	
F14	8.6	210° / 6.0"	12.0"	10.0"	—	Br, D	minor D
F15	5.9	260° / 12.0'	11.0"	12.0"	—	BC	
F16	1.4	120° / 9.0"	1.5"	1.5"		AC	single
F17	1.8	140° / 6.3"	3.3	2.8	—	OK	
F18	5.0	90° / 16.0"	8.0"	5.0"	DnM	C	more than 1
F19	7.7	160° / 1.3"	3.0"	1.5"	—	OK	

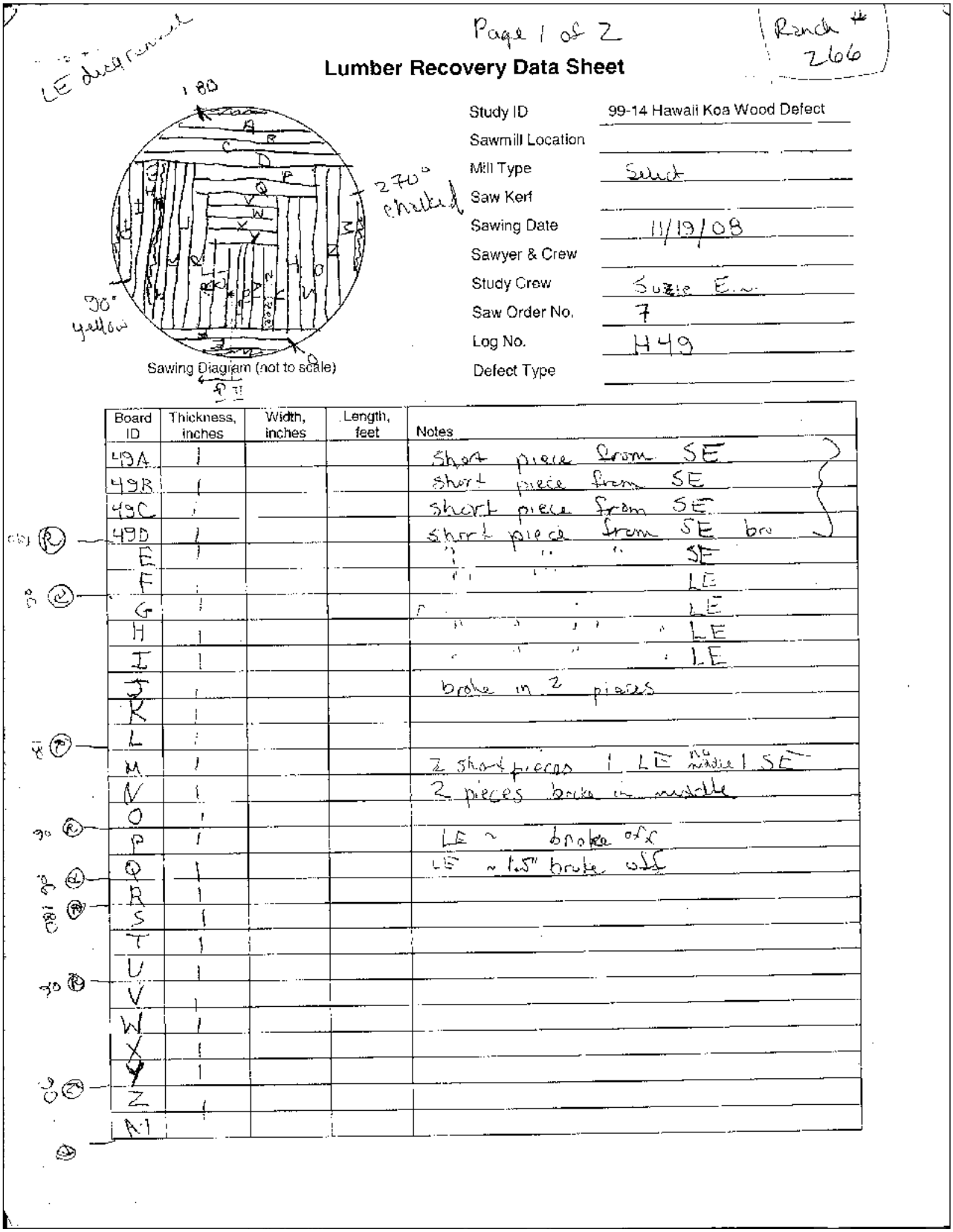
Log Face Defect Codes:
AC=advent. bud clstr
LD=light bark dist.
MD=med. bark dist.
HD=heavy bark dist.
BPk=bird peck
Bu=bulge
B=bump
Bl=burl
BS=butt scar
BSw=butt swell
C=crotch
Ca=canker
Co=conk
Ck=crook
D=decay
I=incipient decay
Fla=flange
Flu=flute
GD=grub damage
M=mech. damage
SH=small hole
MH=medium hole
LH=large hole
SK=sound knot
UK=unsound knot
OK=overgrown knot
KCl=knot cluster
S=seam
Swp=sweep
SR=surface rise
WC=weather check
W=wound

Log End Defect Codes:
BP=bark pocket
DP=double pith
HC=heart check
LoH=loose heart
OC=off-cntr. pith
RS=ring shake
WH=worm holes

Note: Record log diameters and defect positions to nearest 1/10-inch and log diameter to nearest 1/10-foot.

AC single = Adventitious bud

Figure 2—Sample log defect mapping data sheet.



Page 1 of 2

Ranch # 2166

Lumber Recovery Data Sheet

Sawing Diagram (not to scale)

Study ID	99-14 Hawaii Koa Wood Defect
Sawmill Location	
Mill Type	Select
Saw Kerf	
Sawing Date	11/19/08
Sawyer & Crew	
Study Crew	Suzie E.
Saw Order No.	7
Log No.	H49
Defect Type	

Board ID	Thickness, inches	Width, inches	Length, feet	Notes
49A	1			Short piece from SE
49B	1			short piece from SE
49C	1			short piece from SE
49D	1			short piece from SE bro
E	1			SE
F	1			LE
G	1			LE
H	1			LE
I	1			LE
J	1			broke in 2 pieces
K	1			
L	1			
M	1			2 short pieces 1 LE no middle 1 SE
N	1			2 pieces broke in middle
O	1			
P	1			LE ~ broke off
Q	1			LE ~ 1.5" broke off
R	1			
S	1			
T	1			
U	1			
V	1			
W	1			
X	1			
Y	1			
Z	1			
A1	1			

Figure 3—Example of the sawing diagram form used to record sawn lumber position and size.

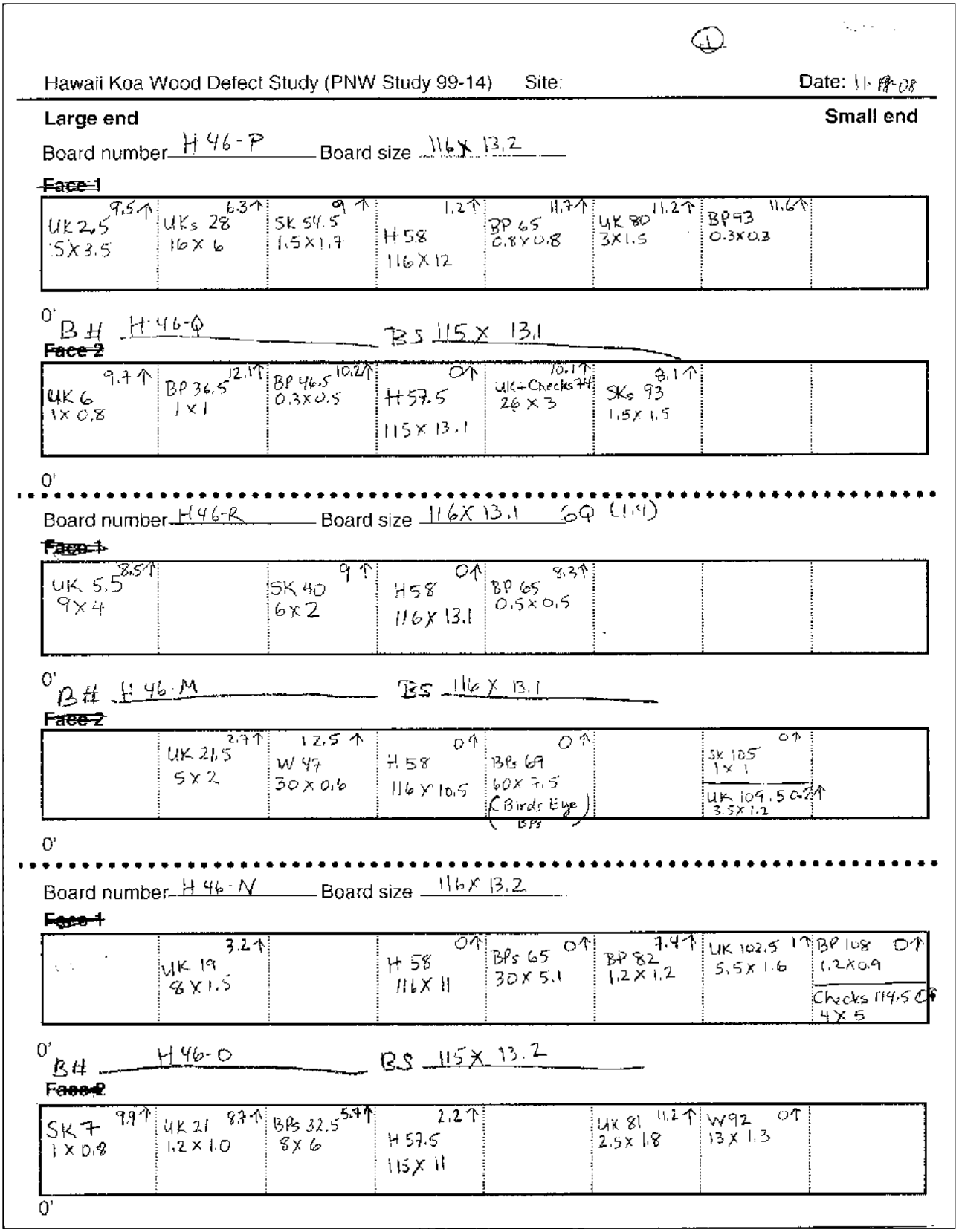


Figure 4—Example of the board defect diagramming sheet.

Table 2—Defects found and mapped on koa logs at the four study sites and percentage of all study logs containing each type of defect

Type of defect	Occurrences per log				Occurrences (all sample sites)	Percentage of logs (out of 28) where defect was found
	Site 1 (eight logs)	Site 2 (nine logs)	Site 3[a] (two logs)	Site 4 (nine logs)		
	Average No.				*No.*	*Percent*
Branch	0.00	1.44	1.00	1.89	32	57
Double pith	0.38	0.33	0.00	0.33	9	32
Heavy distortion	0.25	0.44	0.50	0.44	11	28
Overgrown knot	0.13	0.33	1.00	**1.11**	16	28
Adventitious cluster	0.13	0.44	0.50	**1.89**	23	25
Crotch	0.38	0.22	0.50	0.22	8	25
Medium distortion	0.00	**0.78**	0.50	0.22	10	14
Light distortion	0.00	0.22	0.50	0.00	3	7
Sound knot	0.13	0.00	0.00	0.00	1	3
Unsound knot	0.13	0.00	0.00	0.00	1	3
Decay	0.88	**1.67**	1.50	0.67	31	64
Heart rot	1.00	1.00	1.50	1.22	31	57
Bark pocket	0.13	0.22	0.50	0.67	10	28
Incipient decay	0.00	0.00	0.50	0.00	1	3
Flange	0.50	0.44	0.00	0.33	11	25
Flute	**0.88**	0.00	0.00	0.00	7	14
Seam	**3.63**	1.33	1.00	1.89	60	61
Crack	0.00	1.67	1.00	1.33	29	43
Ring shake	0.13	0.89	0.00	0.78	16	36
Heart check	0.13	0.56	0.00	1.00	15	28
Check	0.00	0.00	0.00	0.11	1	3
Split	0.13	0.00	0.00	0.00	1	3
Large hole	0.50	0.89	1.50	0.33	18	39
Medium hole	0.00	0.00	0.00	0.11	1	3
Small hole	0.00	0.00	0.00	0.11	1	3
Beetle damage	0.00	0.11	0.00	0.00	1	3
Cat face	0.25	0.11	1.00	0.33	8	25
Mechanical damage	0.25	0.22	0.00	0.56	9	21
Wound	0.00	0.11	0.50	0.11	3	11
Bump	0.00	0.33	0.50	0.78	11	32
Bulge	0.25	0.22	0.50	0.22	7	25
Surface rise	0.13	0.00	0.00	0.00	1	3
Sweep	0.00	0.44	0.00	0.00	4	11
Total	10.32	14.41	14.50	16.65	391	

Note: Color shading indicates related defects as described in the text. Bold font indicates defects that have a rate of occurrence that is at least 0.5 higher than the rates at the other two study sites (this excludes site 3 owing to small sample size).

[a] The number of study logs at site 3 was small (two logs) compared to the other three sites.

In considering the distribution of defects encountered in the study logs from the four sites, it is worth recalling the basic characteristics of these log sets. The koa trees that were evaluated at sites 1 and 4 were similar in that the trees being harvested were dead or dying. The site 2 koa trees that we studied were either "relic" logs that had been laying on the ground for months to years or recently fallen (dead) young-growth logs. The logs studied at site 3 (only two logs) were from standing dead and dying trees that were located down a steep gulch—thus, during earlier logging operations when there were many more koa trees to choose from, these hard-to-get-to trees had been left.

Koa Defects

As noted previously, 66 percent of the defects tallied in this study of 28 koa logs were face defects while 34 percent were log-end defects. Face defects may be detectable when viewing the standing tree; therefore, understanding the nature of log-face defects can be helpful in making decisions about if, when, and how to harvest a mature koa tree. End defects become evident as the tree is bucked into logs. By observing the presence and severity of end defects, the sawmill operator can determine how much of the log to remove before sawing so that time and resources are not spent sawing log sections that will not yield products of value. The trading of trees and logs in the supply chain becomes more efficient if all parties involved have a good understanding of the quality and product potential of koa trees and logs.

In table 2, related defects are shown with the same color shading. In most cases, a given color-coded group may include both log-face and log-end defects. In fact, sometimes a specific defect type may be found to occur both on faces and ends of logs. Sometimes a defect is named differently based strictly on where it occurs on the log—for example, "butt rot" versus "decay" versus "heart rot" are all a form of wood deterioration caused by decay fungi. The minimum average number of defects on a log was slightly more than 10 while the maximum was close to 17. Average for all logs was close to 14 defect occurrences per log. Following, we define and describe the related (groups of) defect types found in our koa study logs.

Branch and Crotch/Double Pith/Overgrown Knot, Sound Knot, Unsound Knot/Heavy, Medium, and Light Distortion/Adventitious Branch and Branch Clusters

Branch and crotch—

The most frequently occurring group of defect types in koa is the branch group. Branch defects, with the exception of the crotch and double pith defects, are defects that are found on the faces of logs. The term branch is used when the defect was a

live branch that was recently sawn off (e.g., during harvesting). If the log surface shows any evidence of rot at the site where the branch was cut off, then it may be termed an unsound knot. In contrast, if no rot is present, it may be characterized as a sound knot. When the branch is a major branch at the end of the log, it is considered a crotch. The pocket formed between the main stem and the major branch ("the crotch") is a location where moisture collects and decay can develop. Ingrown bark will occur in this pocket as well. The crotch defect is a very important defect in koa owing to the large branches common in old-growth trees.

Double pith—
Double pith is noted on the log ends and is indicated by two (or more) sets of concentric growth rings around multiple piths indicating the presence of a significant branch or perhaps a second leader affecting the bole. Double pith zones often include ingrown bark, and significant stresses brought about by the orientation of rings in this region can increase physiological stresses leading to more shakes, splits, and checks.

Overgrown knot, sound knot, unsound knot—
"Overgrown knot" refers to a branch defect that was overgrown with bark within the last few years. An overgrown knot may also be called a "heavy (bark) distortion." Knot (sound and unsound) is more appropriately used to describe the defect in the lumber sawn from the log section that contains the branch.

Heavy, medium, and light distortion—
Heavy, medium, and light distortions are defect indicators in which the pattern of the bark is irregular, providing a clue as to the type of overgrown defect and number of years that clear wood has been deposited over the top of the defect. Heavy distortions, when they are indicative of overgrown knots, will show a bark pattern that consists of continuous concentric circles of bark that entirely interrupt the normal longitudinal orientation of the normal pattern of fissures in the bark. Heavy branch distortions indicate that the branch was relatively recent and thus the knots will show up in lumber cut from the outer part of the log as well as the inner heart region. Medium bark distortions show concentric circles, but the circles are interrupted in one or more places by "flat bark plates" (Rast et al. 1991). Light distortions of the bark are indicative of an overgrown knot and show only a slight curvature, which can be difficult to see. Medium and light bark distortions associated with overgrown branches provide evidence as to how much clear wood overlies the branch (knot) defect.

Adventitious branch and branch clusters—
Adventitious branch and adventitious branch clusters are indicators of current or overgrown branch "sprouts," or epicormic branches. These defects, whether single or occurring in groups, look like a cluster of small buds that have been overgrown. Some of these adventitious defects will show a bud trace that goes all the way to the pith. Others are more localized and seem to originate from latent bud cells in the periphery of the stem.

Seams/Shake/Cracks and Splits/Checks

Seams—
Seams, which generally run along the log's length (but can also spiral up the log face) may be caused by several sources including lightning, wind, frost, and damage caused by falling trees (Carpenter et al. 1989). Seams may be open or overgrown with callus tissue. They may contain ingrown bark. Some seams show relatively clean wood separation, but others may have significant areas of torn fibers. Although seams may be seen on the log end, they typically are more evident and more significant on the face (surface) of the log.

Shake—
Shake is a tangential separation of wood that occurs within a given annual growth ring or at the boundary between two adjacent growth rings. Shakes that are seen on the ends of the log and follow around a substantial portion of the growth ring are termed "ring shakes." Owing to the architecture of wood, fractures in a growth ring readily spread up or down the wood section longitudinally; therefore, ring shake can be a very serious defect.

Cracks and splits/checks—
Cracks and splits are essentially the same defect type, but the term "crack" may be used when the radial separation of the wood fibers along the log is wider. Both cracks and splits will penetrate into the heartwood and even to the pith center of the log. They usually result from a traumatic stress such as occurs when a tree is felled (Carpenter et al. 1989). Checks, in contrast, are not as long and often are a surface phenomenon related to the radial separation of wood fibers that is caused by drying stresses. However, a type of check that occurs in the heart-center region of the log is called a heart check. Cracks and splits are considered log-face defects because they can affect a significant length of the log and are readily seen on the log face. Checks may occur either on the face or end of the log.

Decay/Heart Rot and Butt Rot/Incipient Decay/Bark Pocket

Decay—

Decay is the general term for wood degradation that is caused by the presence of fungi. It typically is evidenced by a change of wood color or texture, and sometimes fungal hyphae can be spotted. Decayed wood often is soft, lower in density, and has compromised mechanical properties. In living trees and logs from recently felled trees, extensive areas of decay are most frequently associated with heartwood because the environment of the heartwood region, in which the cells are no longer metabolically alive, is more conducive to fungal colonization (Boddy 2001). The exception to this would be tree species that have enhanced heartwood durability based on the types and amounts of extractives present. Koa does not possess this natural durability trait. The sapwood of downed trees becomes quickly susceptible to fungal propagation until the moisture content is reduced below 30 percent. Sapwood decay that results from delayed manufacture is typically a defect seen on the log faces but can be seen on the ends of logs too. Sapwood decay that results from an injury to the living tree is typically localized (compartmentalized) and may be evidenced by a bark distortion/defect indicator on the face of the log.

Heart rot and butt rot—

Heart rot is a type of decay that is found in the heartwood and is often, but not always, pith centered. It is usually associated with a broken out branch, tree top, or wound. Heart rot is a log-end defect that can be very significant, especially in logs from older trees. Butt rot is a term that refers to decay at the base of the tree—in the butt section of the bottom log. Butt rot may be located either in the sapwood or the heartwood zones and thus, on the log, may be identified as either a log-face or log-end defect.

Incipient decay—

Incipient decay is the earliest form of decay and usually is indicated by a change in wood color but not in wood density (i.e., a region having incipient decay will not exhibit softness). Incipient decay will typically not be evident on the faces of a log but might be evident on log ends.

Bark pocket—

Bark pockets are not decay, but they are often associated with decay regions, and, similar to decay, they are unsound defects. Wounds, broken out limbs, and tree tops, sites of fungal attack leading to decay, often develop ingrown bark at the same location in the tree.

Flute/Flange

Flutes and flanges are both tree/log form "defects" in which the tree bole, at its base, exhibits protrusions out from the normal cylindrical form. These protrusions start at the base and extend up the butt log, in rare cases extending into the second log. Flanges are distinguished from flutes in their shape, with flanges having a more triangular shape and flutes being rounded undulations of the tree bole at its base (Carpenter et al. 1989). When the undulations or folds of a flute extend more than just an inch or two out from the normal cylinder of the log, ingrown bark may be found in the lumber sawn from this log section. Flanges and flutes can be seen on both the log faces and the log ends depending on where the tree is bucked relative to the protrusions.

Large, Medium, and Small Hole/Insect Damage

Holes in logs are distinguished, for log-grading purposes, by their size. Knowing the origin of the hole (e.g., broken out limb, bird peck damage, beetle damage) can be very helpful in estimating the underlying wood quality. Large holes are larger than ½ inch in diameter (Carpenter et al. 1989). Medium holes range from 3/16 to ½ inch in diameter. Small holes are most often caused by the activity of one or another species of insects (e.g., small beetles, termites, ants) in which case they may be referred to as holes or insect damage. Holes can occur on the ends of logs if a beetle enters the log after it is bucked, but they typically are log face defects.

Wound/Cat Face/Mechanical Damage/Butt Scar

Wounds may be caused by a multitude of agents—both natural and human induced. Some of the most common sources include impact from another tree, lightning (in which case the wound may appear as a seam), fire, impact from heavy equipment, and animal contact or herbivory. Wounds are most often considered when they affect the bole of the tree, but damage to root systems also affect tree growth and quality. Wounds that occur on the tree bole may be recent or older, in which case they may be partially or substantially overgrown. Recent wounds typically expose just the sapwood component of the bole and appear sound (Carpenter et al. 1989). Older wounds usually exhibit evidence of decay as the wounding of the tree presents a vulnerability that may lead to insect or fungal colonization. Many overgrown spot wounds (as opposed to lightning strikes) that have been surrounded by callus wood growth are called "cat faces" as they assume an oval facelike form. Mechanical damage refers to a fresh wound that is equipment or human caused. A butt scar is simply a wound at the base of the butt log. Wounds and scars are defects that are seen on the log face.

Bump/Surface Rise/Bulge

A bump is a raised area on the surface of the tree or log that is covered over with bark. A bump is an indicator of an overgrown defect such as a broken out limb or a wound. A less distinct raised area having a height to length ratio of 1 to 12 or less is classified as a surface rise (Carpenter et al. 1989). A bulge is a defect in which the bole appears generally swollen. Carpenter et al. (1989) described the look as being that of a barrel. Bulges are frequently associated with regions of internal decay. Bumps, surface rises, and bulges are log face defects.

Sweep/Crook

Sweep and crook are tree/log form defects. Sweep refers to a linear form in which the tree bole or log curves gradually away from the straight alignment. Crook refers to a form in which the bole or log juts abruptly in a different direction. Trees often crook in a different direction in the region of a major branch so crook and branch defects commonly occur proximal to each other. Sweep and crook are neither face nor end defects but rather form defects that lead to a reduction in the amount of lumber volume recovered.

Lumber Attributes

Wood quality is represented by color, figure (e.g., curl), and size, not just of the log, but of clear cuttings (free of defects) from lumber as well. Value is based on the level of all three quality attributes as they relate to the product raw material requirements.

The heartwood color of mature koa trees can be various shades of red, light brown, deep chocolate brown, and reddish brown with reddish brown being the most common (Skolmen 1974) and dark brown being the most highly valued. The sapwood is relatively narrow and yellowish white to pale brown (Gerry 1955, Skolmen 1974). Koa wood can have distinctive figure, which may include banding that runs parallel with the wood grain or the highly prized curly figure that is generally perpendicular to the grain.

Synopsis

This publication expands on the data and guidelines published by Burgan et al. (1971, see appendix). A broader range of log defect types were observed in the 28 study logs examined here than had previously been cited by Burgan et al. (1971). It was common to find more than one defect type in a log section. Sometimes these co-occurrences were random, but other times the occurrence of proximally located log defects represented a logical correlation. For example, the crotch defect was frequently found with decay/rot. The fork of the limb is a site where water can collect

and injuries can occur, both of which contribute to the development of decay/rot. Thus, in some cases, it is difficult to attribute log volume loss to any one external defect indicator.

Log defects can manifest themselves in more than one lumber defect. Lumber recovery (gross cubic volume) from the study logs illustrates the variation that can be found in the resource. For example, among the relic logs found in this guide, recovery ranged from 35 to 83 percent. Although some differences in recovery may be attributed to milling equipment, the broad recovery range demonstrates the variability of quality in relic logs. The sawing diagram in figure 3 demonstrates the amount of time and effort processors put into producing koa lumber in order to maximize volume and quality.

Although this study expands knowledge of external log defects found in koa, the co-occurrence of log and lumber defects associated with a single external indicator illustrates the difficulty in developing a measurement system to accurately reflect products recovered.

Photographic Guide

In the series of figures that constitutes the photographic guide to *Acacia koa* defects (table 3, figs. 5 through 59), we identify the defect of interest and the condition of the tree from which the log containing the defect was found. Log size statistics are given as well as the dimensions of the defect. The first picture of the defect series is of the defect as it appears on the outside of the log. Log ends (usually the large end of the log) are pictured with sawlines superimposed to identify the sawn position of the boards pictured on the page. Each of these is color-coded to match the frame color of the corresponding board defect picture in the series. The number in the board caption identifies the log from which it was sawn and the saw order position. Each of the board pictures contains a defect or feature associated with the external defect. For each defect occurrence on a board, the dimensions are noted and the percentage of the board affected by this defect has been calculated. In many cases, it was not possible to show every piece of lumber having defect(s) associated with the defect indicator on the log. Consequently, we have included a listing of additional lumber defects (if any) and the total defect volume (cubic inches) in each log that is attributable to this external defect. The lumber recovery percentage from each log also is provided because, by itself, the information on the associated defect amounts contained in the lumber that is attributable to a given external defect is incomplete. This is because a particular defect type, for example, heart rot, may lead to lumber recovery losses if it is particularly severe (i.e., log sections that are not sawn into lumber).

There were many instances in which multiple log defects occurred proximal to one another such that it became difficult to discern which of the defects found on a particular board section were associated with a given external defect. We feel confident, however, that the defect series included in this photographic guide are made up of defect sets that belong together—many other good picture sets were discarded because of uncertainty as to whether the pictured defects belonged together. Also, note that an external log defect may often manifest itself internally as several different types of defects. For example, a branch may be observed internally as a sound knot, unsound knot, decay, or bark inclusion. The reader should take into consideration that figures are not to scale and, because the lumber defect picture data were taken in the field under operational constraints, lumber defects in a series may not appear to be positioned similarly from one board to the next and the degree of camera zoom may vary.

Branch

Branch defects, with the exception of the crotch and double pith defects, are defects that are found on the faces (sides) of logs. The term "branch" is synonymous with "limb" and is used when the defect was a live branch that was recently sawn off (e.g., during harvesting). Lumber defects associated with branch defects on the log include sound and unsound knots (both face and spike knot orientation), bark pockets, decay, and holes.

Log grading rule interpretation—
Branch defects (i.e., sound and unsound knots and live limbs) are always treated as defects in hardwood log grading (Rast et al. 1973).

Table 3—Comprehensive list of defects and lumber attributes included in the photographic guide of selected external defect indicators and associated internal defects in koa including relevant information for interpreting the influence of the defect on lumber recovery: defect type, tree quality, log small- and large-end diameters, log length and gross cubic volume, defect sizes, the amount of lumber affected by the defect, and overall lumber recovery from the log[a]

Figure No.	Defect type	Tree quality class[b]	Log SED[c]	Log LED[d]	Log length	Smalian cubic volume	Defect dimensions on log[e]	Total board volume recovered from log	Percent lumber volume recovered from log	Total lumber volume affected[f]	Percent lumber volume affected by defect	Boards affected
			----------*In*----------				*Ft3*	*In*	*Ft3*		*Ft3*	*No.*
Log face defects:												
5	Adventitious branch	SDD	15.5	18.4	101	13.30	3.5 x 2.7	8.8	66	0.1	1.1	4
6	Adventitious branch cluster	SDD	19.4	19.4	117	20.01	1 x 1	14.2	71	0.0	0.0	7
7	Adventitious branch cluster	SDD	19.4	19.4	117	20.01	1.3 x 1.7	14.2	71	0.0	0.0	4
8	Branch	AD/SD	23.3	27	76	21.39	12 x 6 x 4.5	12.3	57	0.4	3.0	10
9	Branch	SDD	8.6	13.9	92	5.59	3.2 x 1.7	2.5	45	0.1	5.5	4
10	Branch	SDD	14.2	17.3	89	10.13	26 x 15	5.6	55	0.2	3.8	7
11	Branch	R	14.4	16.2	133	14.20	16 x 13	10.9	77	0.1	0.5	4
12	Branch	R	12.7	14.5	114	9.63	7 x 5.5 x 1.5	7.2	75	0.0	0.3	4
13	Branch	R	12.7	14.5	114	9.63	9 x 8 x 2.5	7.2	75	0.0	0.3	3
14	Branch and decay	SDD	26.2	25.4	164	49.63	8 x 8 x 1.3	26.0	52	0.1	0.5	5
15	Branch and decay	SDD	18.4	20.7	113	19.70	9 x 8 x 2.5	12.5	63	0.1	1.0	5
16	Branch (double)	SDD	15.5	18.4	101	13.29	18 x 14.5	8.8	66	0.1	0.8	5
17	Branch	SDD	13	18	138	15.46	4 x 3	10.0	64	0.0	0.1	3
18	Branch (crotch)	SDD	13	18	138	15.46	12 x 10	10.0	64	0.2	1.6	8
19	Branch and decay	SDD	19.4	19.4	118	20.19	18 x 9	14.2	70	0.1	0.8	6
20	Bulge	AD/SD	20/21.4	33.8	72	32.49	19 x 13 x 2.5	20.0	61	0.0	0.2	5
21	Bump	SDD	18.4	20.7	113	19.70	8 x 6	12.5	63	0.0	0.1	2
22	Cat face	SDD	28.2	30.5	104	40.78	20 x 11	27.6	68	0.0	0.2	2
23	Cat face	SDD	18.4	20.7	113	19.70	33 x 18 x 1.5	12.5	63	1.3	10.0	7
24	Crack	SDD	26.2	31.3	116	43.92	116 x 3.5	29.6	67	0.2	0.8	5
25	Crack and wound	SDD	26.2	31.3	116	43.92	36 x 11 x 1 48 x 11x 2	29.6	67	0.5	1.6	8

Table 3—Comprehensive list of defects and lumber attributes included in the photographic guide of selected external defect indicators and associated internal defects in koa including relevant information for interpreting the influence of the defect on lumber recovery: defect type, tree quality, log small- and large-end diameters, log length and gross cubic volume, defect sizes, the amount of lumber affected by the defect, and overall lumber recovery from the log[a] (continued)

Figure No.	Defect type	Tree quality class[b]	Log SED[c]	Log LED[d]	Log length	Smalian cubic volume	Defect dimensions on log[e]	Total board volume recovered from log	Percent lumber volume recovered from log	Total lumber volume affected[f]	Percent lumber volume affected by defect	Boards affected
			----------*In*----------				*Ft3*	*In*	*Ft3*		*Ft3*	*No.*
26	Decay	R	21.4	25.2	88	21.86	44 x 22	3.4	16	0.9	25.1	5
27	Decay	R	12.7	14.5	114	9.63	40 x 16	7.2	75	0.3	4.0	2
28	Decay	R	37.3	37.5	67	42.60	36 x 29	32.6	77	0.7	2.3	7
29	Distortion (medium)	AD/SD	16.6	20.2	96	14.91	11 x 11	7.5	50	0.0	0.3	1
30	Distortion (medium)	SDD	18.4	20.7	113	19.70	2.5 x 1.5	12.5	63	0.0	0.1	3
31	Distortion (medium)	SDD	13	18	138	15.46	4 x 1.5	10.0	64	0.0	0.2	5
32	Distortion (heavy)	SDD	13	18	138	15.46	4 x 3.5	10.0	64	0.0	0.1	3
33	Distortion (heavy), overgrown knot	SDD	13	18	138	15.46	3.8 x 2.6	10.0	64	0.0	0.3	4
34	Hole (large)	AD/SD	17.7	20.5	114	19.00	2 x 1	12.5	66	0.0	0.1	2
35	Hole (large)	R	14.4	16.2	133	14.20	4.5 x 1.5 x 2	10.9	77	0.1	0.7	4
36	Hole (large) and bark pocket	SDD	18.4	20.7	113	19.70	3 x 1.5	12.5	63	0.1	1.0	1
37	Holes (small), insect damage	R	13.8	13.4	86	7.23	36 x 16	5.7	79	0.4	7.2	9
38	Holes (small), insect damage	Y	7.1	7.7	101	2.52	38 x 13	2.1	84	0.5	21.2	5
39	Mechanical damage	Y	7.8	9.7	101	3.56	6.5 x 4 x .2	2.5	70	0.0	0.0	1
40	Seam	AD/SD	23.3	27	74	21.39	10 x 5.2 x 6.5	12.3	57	0.2	1.3	6
41	Seam	R	37.3	37.5	67	42.60	64 x 8 x 2.8	32.6	77	0.4	1.2	4
42	Seam	R	37.3	37.5	67	42.60	62 x 4.5 x 5	32.6	77	0.5	1.5	5
43	Seam	SDD	28.2	30.5	104	40.78	18 x 2	27.6	68	0.1	0.5	8
44	Wound (cat face)	SDD	8.6	13.9	92	5.59	6 x 3.5 x 1	2.5	45	0.0	1.6	2

Table 3—Comprehensive list of defects and lumber attributes included in the photographic guide of selected external defect indicators and associated internal defects in koa including relevant information for interpreting the influence of the defect on lumber recovery: defect type, tree quality, log small- and large-end diameters, log length and gross cubic volume, defect sizes, the amount of lumber affected by the defect, and overall lumber recovery from the log[a] (continued)

Figure No.	Defect type	Tree quality class[b]	Log SED[c]	Log LED[d]	Log length	Smalian cubic volume	Defect dimensions on log[e]	Total board volume recovered from log	Percent lumber volume recovered from log	Total lumber volume affected[f]	Percent lumber volume affected by defect	Boards affected
			----------*In*----------				*Ft3*	*In*	*Ft3*		*Ft3*	*No.*
Log end defects:												
45	Crotch	AD/SD	17.7	20.5	114	19.00	9 x 3 x 6	12.5	66	0.1	1.1	6
46	Crotch	AD/SD	20.0/21.4	33.8	70	32.49	14.2 x 10.5 x 10	20.0	61	0.6	2.8	13
47	Crotch	SDD	8.6	13.9	92	5.59	5 x 4 x 52	2.5	45	0.0	1.0	2
48	Crotch	R	17.7	22.7	88	16.57	9 x 12 x 14	6.8	41	1.3	19.2	7
49	Flute	SDD	29.5	34.6	98	46.04	2 x 4 x 18	31.1	67	0.0	0.1	3
50	Heart check and split	SDD	26.2	31.3	116	43.92	(8 x 0.2) (16 x 2.5)	29.6	67	0.2	0.7	6
51	Heart rot	AD/SD	16.6	20.2	96	14.91	14.5 x 9 x 42	7.5	50	1.1	14.5	7
52	Heart rot	AD/SD	20.7	21.8	86	17.66	15.5 x 12	6.7	38	1.1	17.1	5
53	Heart rot	SDD	29.5	34.6	98	46.04	24.2 x 25.2 x 53	31.1	67	8.0	25.7	38
54	Heart rot	SDD	15.5	18.4	101	13.29	10.5 x 10.2	8.8	66	0.7	7.6	11
55	Heart rot	SDD	26.2	31.3	116	43.92	16.5 x 9 x 18	29.6	67	0.6	2.0	11
56	Ring shake	R	13.8	13.4	86	7.23	5 x 1	5.7	79	0.1	1.9	6
57	Ring shake	SDD	26.2	25.4	164	49.63	4 x 2.5	26.0	52	0.4	1.6	7
Lumber attributes:												
58	Color attributes	Y	7.8	9.7	101	3.56	n/a	2.5	70	n/a	n/a	n/a
59	Curl	R	21.2	25.2	88	21.69	18 x 15	3.4	16	0.1	3.2	8

[a] Defects are grouped by where they were found on the log with log face defects (along the sides of the log) appearing first in the table, log-end defects following, and lumber attributes (not defects) at the bottom of the table.

[b] Tree quality class codes: AD/SD = alive declining or standing dead old-growth tree, R = relic (dead on ground for several years), Y = young growth (<15 years old).

[c] Log SED = log small-end diameter inside bark.

[d] Log LED = log large-end diameter inside bark.

[e] Defect dimensions may include either two or three measurements depending on whether a defect depth (either into the log or out from the log surface) could be measured or estimated. When only two measurements are provided, these measurements approximate the length and width measurements of a rectangle that would encase the defect.

[f] This volume can include several types of internal (lumber) defects that can be associated with a given log defect.

Log Face Defects

Log face defects are defects that occur most obviously and most commonly along the side surfaces of the logs.

Adventitious Branch and Branch Clusters

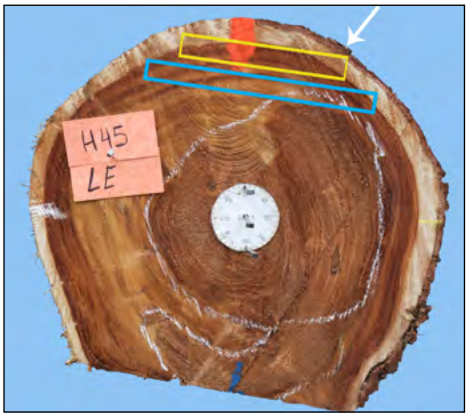
Adventitious branch and adventitious branch clusters are indicators of current or overgrown branch "sprouts" or epicormic branches. They occur on the face (side or surface) of logs. These defects, whether single or occurring in groups, look like a cluster of small buds that have been overgrown. Some of these adventitious defects will show a bud trace that goes all the way to the pith. Others are more localized and seem to originate from latent bud cells in the periphery of the stem. Lumber defects associated with adventitious branch clusters include sound and unsound knots and knot clusters, which are sometimes referred to as a "cats paw" figure, and bark pockets.

Log grading rule interpretation— Live adventitious or epicormic branches, if larger than 3/8 in, are considered to be a defect in the grading of hardwood logs. Smaller adventitious or epicormic branches are counted as a defect when they are on a log that is smaller than 14 in diameter on the small end, inside bark. On larger logs, every other smaller adventitious branch is treated as a defect (Rast et al. 1973).

Figure 5—Adventitious branch defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of adventitious branch defect:
3.5 in long by 2.7 in wide
Total log length = 101 in
SED = 15.5 in, LED = 18.4 in

Board 45B: 101 in by 7.6 in by 1 in
Sound knot: 1 in by 1 in
(1.3 percent of board)



The defect indicator is centered 88 in down the log from the large end. Sawn lumber position within log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the adventitious branch is located.

Board 45C: 101 in by 10.7 in by 1 in
Unsound knot: 0.5 in by 0.4 in
(0.02 percent of board)

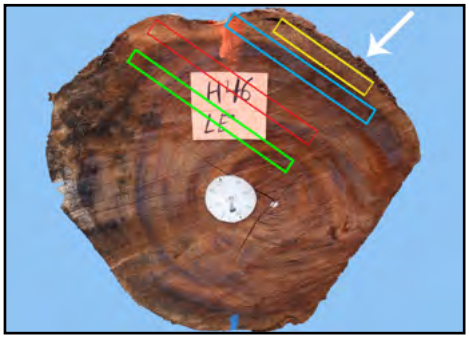
- Other lumber defects related to this adventitious branch but not pictured: unsound knot

- **Total lumber defect volume attributed to this adventitious branch = 11.7 in^3**

Figure 6—Adventitious branch cluster indicator on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown). SED = small-end diameter, LED = large-end diameter.

External dimensions of adventitious branch cluster defect: 1 in long by 1 in wide

Total log length = 117 in
SED = 19.4 in, LED = 19.4 in



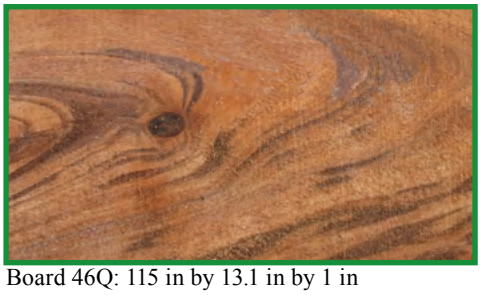
Sawn lumber position within log is designated by colored rectangles. The arrow indicates the external position around the log and the angle at which the adventitious branch cluster is located. The cluster is 7 in down the log from the large end.

- Other lumber defects related to this adventitious branch cluster but not pictured: sound knots
- **Total lumber defect volume attributed to this adventitious branch cluster = 12 in^3**

Board 46A: 114 in by 7 in by 1 in
Cat paw and figure: 2 in by 1 in
(0.25 percent of board)

Board 46H: 115 in by 11.5 in by 1 in
Sound knot: 2.2 in by 1.3 in
(0.22 percent of board)

Board 46O: 115 in by 13.1 in by 1 in
Sound knot: 1 in by 0.8 in
(0.1 percent of board)

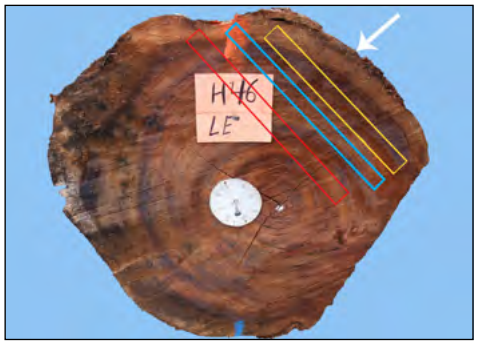


Board 46Q: 115 in by 13.1 in by 1 in
Unsound knot: 1 in by 0.8 in
(0.1 percent of board)

Figure 7—Adventitious branch cluster on the face of a log from standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of adventitious branch cluster defect:
1.3 in long by 1.7 in wide

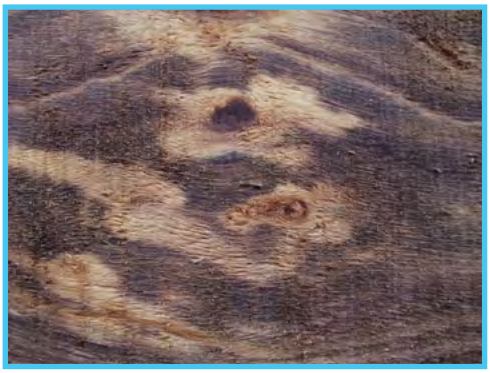
Total log length = 117 in
SED = 19.4 in, LED = 19.4 in



The defect indicator is centered 19 in down the log from the large end. The arrow indicates the orientation around the log and angle at which the adventitious branch cluster indicator is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this adventitious branch cluster but not pictured: unsound knot
- **Total lumber defect volume attributed to this adventitious branch cluster = 6.48 in^3**

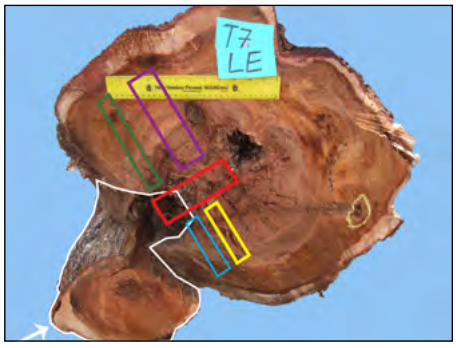
Board 46H: 115 in by 11.5 in by 1 in
Sound knot: 1.7 in by 1.2 in
(0.2 percent of board)



Board 46I: 115 in by 14.2 in by 1 in
Knots and bark pockets: 1.7 in by 1.2 in
(0.1 percent of board)

Board 46O: 115 in. by 13.2 in. by 1 in
Unsound knot : 1.2 in by 1 in
(0.1 percent of board)

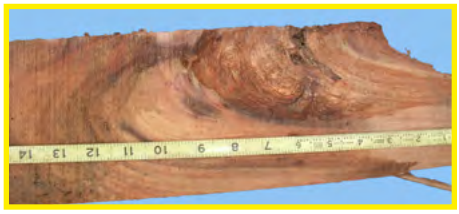
Figure 8—Major branch defect on the face of a log from a dying old-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.



External dimensions of branch defect:
12 in long by 6 in wide by 4.5 in deep
Total log length = 76 in
SED = 23.3 in, LED = 27 in

The arrow indicates the orientation around the log and the angle at which the branch is located. The junction of the branch with the main stem occurs 7 in down the length of the log from the large end. Sawn lumber position within the log is indicated by colored rectangles.

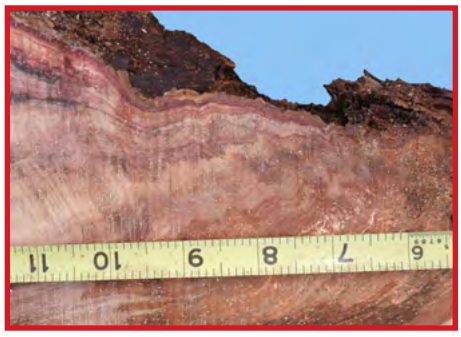
- Other lumber defects related to this branch but not pictured: bark pocket, decay, wane
- **Total lumber defect volume attributed to this branch = 642.7 in^3**



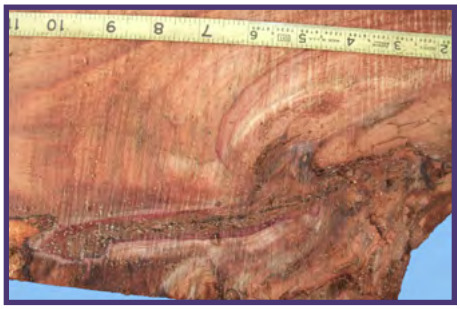
Board 7L: 68 in by 4.9 in by 1 in
Unsound knot: 9 in by 3.3 in
(8.9 percent of board)

Board 7M: 68 in by 4.9 in by 1 in
Bark pocket: 15.5 in by 2.9 in
(13.5 percent of board)

Board 7O: 68 in by 8.1 in by 1 in
Bark pocket: 10 in by 4.1 in
(7.4 percent of board)



Board 7J: 68 in by 6.5 in by 2 in
Bark pocket/decay: 13 in by 4 in
(11.8 percent of board)

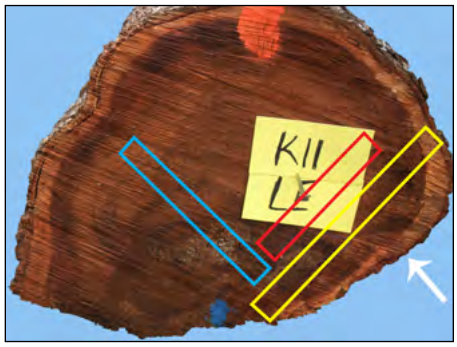


Board 7Q: 69 in by 8 in by 2 in
Bark pocket: 12 in by 4 in
(8.7 percent of board)

Figure 9—Major branch defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
3.2 in long by 1.7 in wide

Total log length = 92 in
SED = 8.6 in, LED = 13.9 in

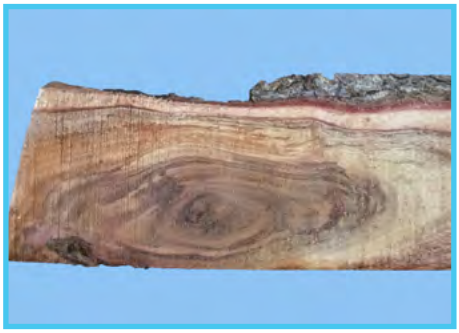


Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch is located. The branch is centered 6 in from the large end of the log.

- Other lumber defects related to this branch but not pictured: sound knot

- **Total lumber defect volume attributed to this branch = 241 in^3**

Board 11A: 30 in by 8 in by 1 in
Knot/bark pocket/decay: 12 in by 8 in
(40 percent of board)



Board 11C: 91 in by 6.8 in by 1 in
Decay: 4 in by 1.1 in
(0.7 percent of board)

Board 11F: 92 in by 5.6 in by 1 in
Bark pocket/decay: 20 in by 5.6 in
(21.7 percent of board)

Figure 10—Major branch defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown). SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
26 in long by 15 in wide
Total log length = 89 in
SED = 14.2 in, LED = 17.3 in

Sawn lumber position within the log is indicated by colored rectangles. The branch is centered 28 in from the large end of the log. The arrow indicates the orientation around the log and the angle at which the branch is located.

- Other lumber defects related to this branch but not pictured: decay, incipient decay
- **Total lumber defect volume attributed to this branch = 366 in^3**

Outer face of 1.2-in thick waste slab section.

Inner face of 1.2-in thick waste slab section.

Board 12K: 88 in by 4.1 in by 2 in
Decay and void: 15 in by 4.1 in
(17 percent of board)

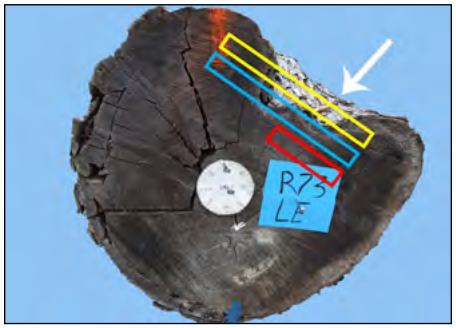
Board 12J: 89 in by 4.1 in by 1 in
Unsound knot: 14 in by 4.1 in
(15.7 percent of board)

Board 12Q: 89 in by 4 in by 2 in
Decay: 6 in by 0.6 in
(1 percent of board)

Figure 11—Branch defect on the face of a log from a dead "relic" *Acacia koa* tree
SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
16 in long by 13 in wide

Total log length = 133 in
SED = 14.4 in, LED = 16.2 in



The defect is centered 56 in down the log from the large end. Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch is located.

- Other lumber defects related to this branch but not pictured: unsound knot
- **Total lumber defect volume attributed to this branch = 97 in^3**

Board 23G: 86 in by 9 in by 1 in
Unsound knot: 10 in by 4.5 in
(5.8 percent of board)

Board 23H: 132 in by 9 in by 1 in
Unsound knot: 8 in by 1.7 in
(1.1 percent of board)

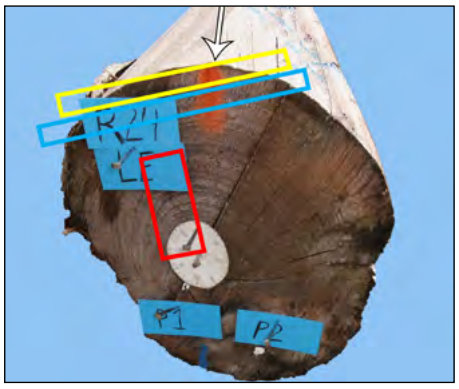
Board 23M: 133 in by 4.2 in by 1 in
Sound knot: 4 in by 0.7 in
(0.5 percent of board)

Figure 12—Branch defect on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
7 in long by 5.5 in wide by 1.5 in high

Total log length = 114 in
SED = 12.7 in, LED = 14.5 in

Board 24C: 97 in by 9.2 in by 1 in
Unsound knot: 6 in by 2.5 in
(1.7 percent of board)



The branch is centered 61 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the branch is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this branch: none
- **Total lumber defect volume attributed to this branch = 40.2 in^3**

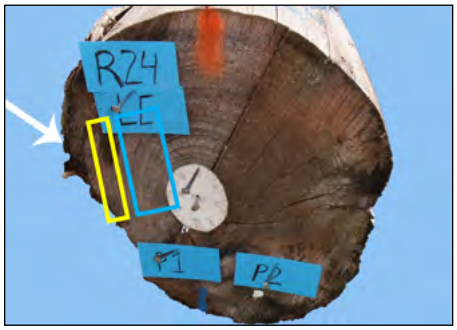
Board 24D: 106 in by 11.8 in by 1 in
Sound knot: 4 in by 3.8 in
(1.2 percent of board)

Board 24M: 114 in by 4 in by 2 in
Sound spike knot: 2 in by 2.5 in
(1.1 percent of board)

Figure 13—Branch defect on the face of a log from dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
9 in long by 8 in wide by 2.5 in deep

Total log length = 114 in
SED = 12.7 in, LED = 14.5 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch is located. The branch is centered 30 in down the log from the large end.

- Other lumber defects related to this branch but not pictured: sound knot
- **Total lumber defect volume attributed to this branch = 36.3 in^3**

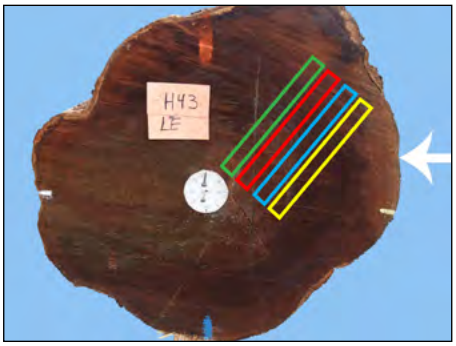
Board 24I: 113 in by 4.2 in by 1 in
Unsound knot: 7 in by 4.2 in
(6.2 percent of board)

Board 24N: 114 in by 4.1 in by 2 in
Sound knot: 3 in by 1.3 in
(0.8 percent of board)

Figure 14–Branch and decay defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown). SED = small-end diameter, LED = large-end diameter.

External dimensions of branch and decay defect:
8 in long by 8 in wide by 1.3 in deep

Total log length = 164 in
SED = 26.2 in, LED = 25.4 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch and decay are located. The branch is centered 76 in down the log from the large end.

- Other lumber defects related to this branch and decay but not pictured: hole, bark
- **Total lumber defect volume attributed to this branch and decay = 202.4 in^3**

Board 43O: 164 in by 10.6 in by 1 in
Unsound knot: 7 in by 4.7 in
(1.9 percent of board)

Board 43P: 164 in by 10.6 in by 1 in
Unsound knot: 7 in by 6.5 in
(2.6 percent of board)

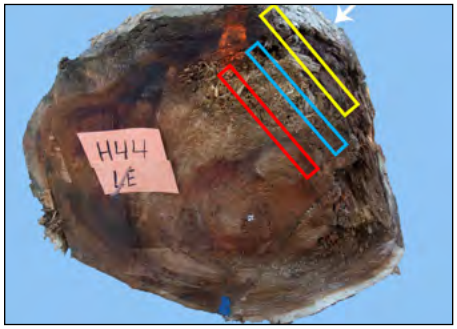
Board 43Q: 164 in by 10.6 in by 1 in
Unsound knot: 9 in by 5.8 in
(3 percent of board)

Board 43R: 164 in by 10.6 in by 1 in
Unsound knot: 8 in by 5.5 in
(2.5 percent of board)

Figure 15—Branch and decay defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of branch and decay defect:
9 in long by 8 in wide by 2.5 in deep

Total log length = 113 in
SED = 18.4 in, LED = 20.7 in

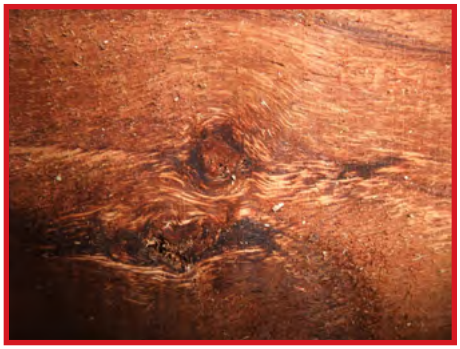


Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch and decay are located. The branch and decay are centered 108 in down the log from the large end.

- Other lumber defects related to this branch but not pictured: unsound knot, hole
- **Total lumber defect volume attributed to this branch and decay = 215.5 in^3**

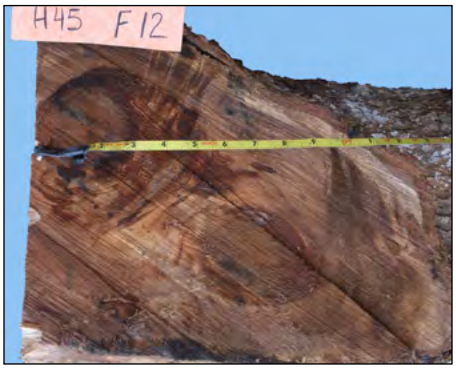
Board 44A: 72 in by 8.5 in by 1 in
Hole and decay: 8 in by 8.5 in
(11.1 percent of board)

Board 44K: 113 in by 9 in by 1 in
Hole and decay: 10 in by 5 in
(4.9 percent of board)



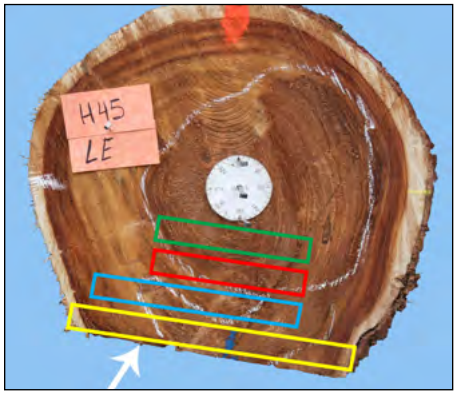
Board 44M: 113 in by 9 in by 1 in
Unsound knot: 2.2 in by 2.5 in
(0.5 percent of board)

Figure 16—Double branch on the face (and large end) of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of branch defect:
18 in wide by 14.5 in wide

Total log length = 101 in
SED = 15.5 in, LED = 18.4 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch is located.

- Other lumber defects related to this branch but not pictured: sound knot
- **Total lumber defect volume attributed to this branch = 126 in^3**

Board 45A: 101 in by 12 in by 1 in
Unsound knot: 8 in by 5 in
(3.3 percent of board)

Board 45K: 101 in by 8.8 in by 1 in
Sound knot: 3.5 in by 4 in
(1.6 percent of board)

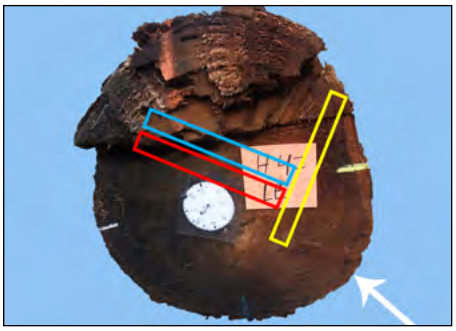
Board 45S: 101 in by 6.5 in by 1 in
Unsound knot: 6 in by 3.5 in
(3.2 percent of board)

Board 45R: 101 in by 6.4 in by 1 in
Bark pocket: 0.5 in by 0.5 in
(0.004 percent of board)

Figure 17—Branch defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
4 in long by 3 in wide

Total log length = 138
SED = 13 in, LED = 18 in

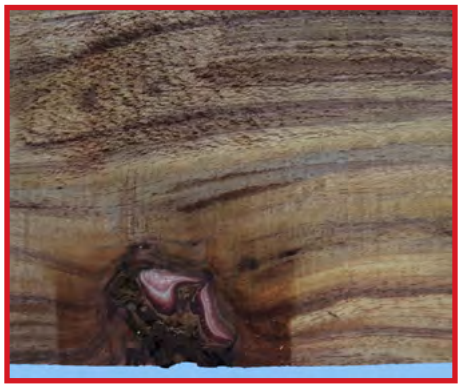


Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch is located. The branch is centered 58 in from the large end of the log.

- Other lumber defects related to this branch: none
- **Total lumber defect volume attributed to this branch = 25.5 in^3**

Board 47G: 137 in by 8.3 in by 1 in
Unsound knot and bark pocket:
5 in by 2.4 in
(1.1 percent of board)

Board 47O: 137 in by 7.5 in by 1 in
Unsound knot and bark pocket:
2.5 in by 3.3 in
(0.8 percent of board)

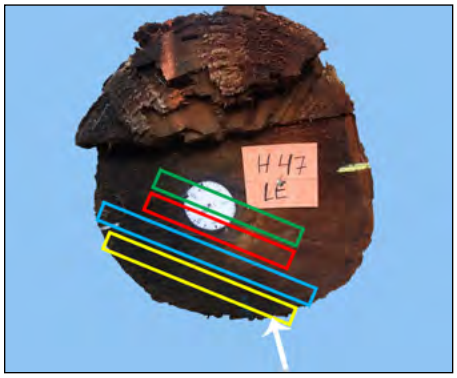


Board 47P: 137 in by 7.5 in by 1 in
Bark pocket: 2.5 in by 2.1 in
(0.5 percent of board)

Figure 18—Major branch and crotch defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of branch defect:
12 in long by 10 in wide

Total log length = 138 in
SED = 13 in, LED = 18 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log where the branch/crotch is located. The defect is centered 30 in from the large end of the log.

- Other lumber defects related to this branch/crotch but not pictured: bark pocket
- **Total lumber defect volume attributed to this branch/crotch = 269 in^3**

Board 47C: 122 in by 10.5 in by 1 in
Unsound knot: 19 in by 3.5 in
(5.2 percent of board)

Board 47D: 133 in by 11 in by 1 in
Unsound knot: 6 in by 3.6 in
(3.9 percent of board)

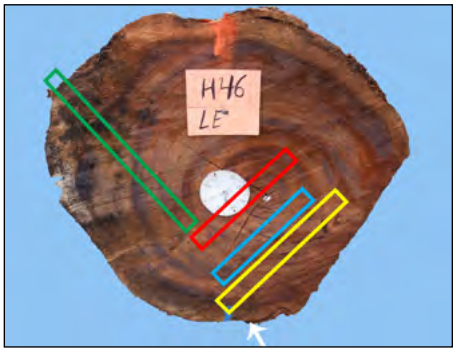
Board 47J: 136 in by 7.5 in by 1 in
Unsound knot: 12 in by 2.2 in
(2.6 percent of board)

Board 47K: 136 in by 7.5 in by 1 in
Unsound knot/bark pocket: 13 in by 2.9 in
(3.7 percent of board)

Figure 19—Major branch and decay defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of branch and decay defect:
18 in long by 9 in wide

Total log length = 118 in
SED = 19.4 in, LED = 19.4 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the branch and decay are located. The defect is centered 110 in from the large end of the log.

- Other lumber defects related to this branch and decay but not pictured: unsound knots
- **Total lumber defect volume attributed to this branch and decay = 199.2 in^3**

Board 46B: 50 in by 10.5 in by 1 in
Unsound knot: 10 in by 6 in
(11.4 percent of board)

Board 46C: 117 in by 8 in by 1 in
Unsound knot: 12 in by 7 in
(8.97 percent of board)

Board 46K: 118 in by 8.5 in by 1 in
Sound knot: 5 in by 3 in
(1.5 percent of board)

Board 46L: 116 in by 13.3 in by 1 in
Unsound knot: 6 in by 2 in
(0.8 percent of board)

Bump and Bulge

A bump is a raised area on the surface of the tree or log that is covered over with bark. A bump is an indicator of an overgrown defect such as a broken out limb or a wound. A bulge is a defect in which the bole appears generally swollen. Bumps, surface rises, and bulges are log face defects. Lumber defects associated with bumps and bulges include sound and unsound knots, bark pockets, and decay.

Log grading rule interpretation—
High bumps, having a height to length ratio of 1:3 or less, and medium bumps (between 1:6 and 1:3) are hardwood log grading defects. Low bumps, with a height to length ratio between 1:12 and 1:6, also are defects but in assessing usable clear area above and below the defect, the upper and lower one fourth of the bump's length can be treated as clear (nondefective). Bulges always should be treated as defects in their entirety (Rast et al. 1973).

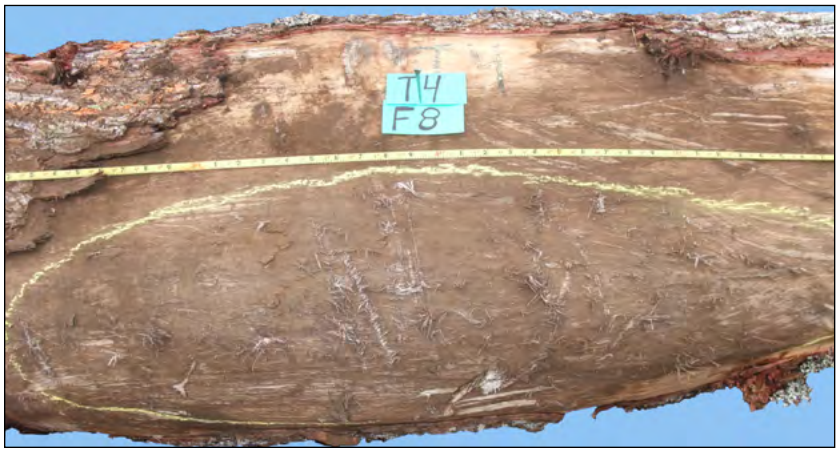
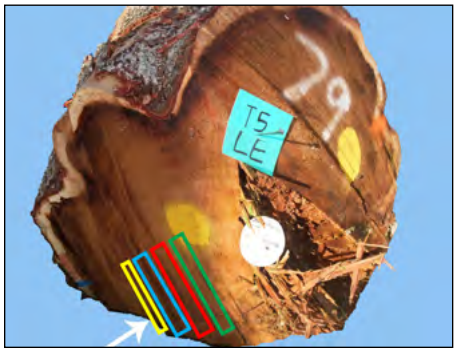


Figure 20—Bulge defect on the face of a log from a dying old-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

External dimensions of bulge defect:
19 in long by 13 in wide by 2.5 in rise above log surface

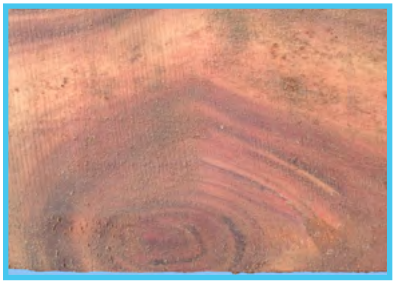
Total log length = 72 in
SEDs = 20 in and 21.4 in (small end is forked), LED = 33.8 in



The bulge is centered 28 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the bulge is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this bulge but not pictured: bark pocket, decay
- **Total lumber defect volume attributed to this bulge = 77.4 in^3**

Board 5F1: 50 in by 7.2 in by 1 in
Sound knot: 1.1 in by 0.8 in
(0.2 percent of board)



Board 5G1: 60 in by 7.5 in by 2 in
Sound knot: 3 in by 2 in
(1.3 percent of board)

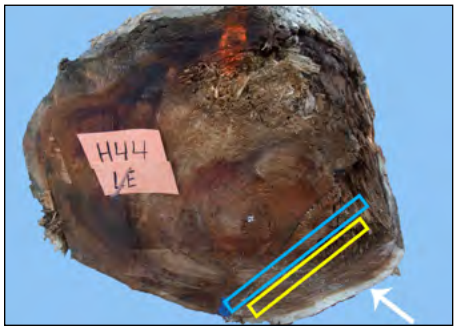
Board 5H1: 64 in by 10 in by 2 in
Sound knot: 9 in by 2.1 in
(3 percent of board)

Board 5I1: 66 in by 11.2 in by 2 in
Bark pocket: 1.1 in by 1 in
(0.1 percent of board)

Figure 21—Bump on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter. LED = large-end diameter.

External dimensions of bump defect:
8 in long by 6 in wide

Total log length = 113 in
SED = 18.4 in, LED = 20.7 in



The defect indicator is centered 77 in from the large end of the log. Sawn lumber position within log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the bump is located.

- Other lumber defects, related to this bump: none
- **Total lumber defect volume attributed to this bump = 19.3 in^3**

Board 44F: 113 in by 8.5 in by 1 in
Unsound knot: 2.8 in by 2.4 in
(0.7 percent of board)

Board 44G: 113 in by 13.3 in by 1 in
Unsound knot: 3.7 in by 3.4 in
(0.8 percent of board)

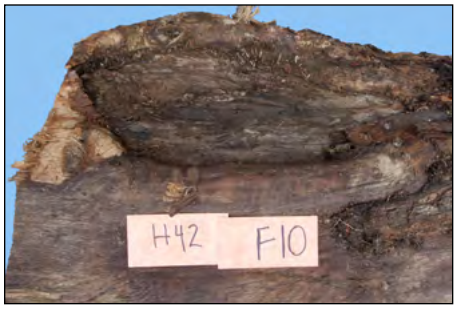
Cat Face (a type of wound)

Many overgrown spot wounds (as opposed to lightning strikes) that have been surrounded by callus wood growth are called "cat faces" as they assume an oval facelike form. Cat face defects occur on log faces. Lumber defects associated with cat faces include bark pockets, seams, and decay.

Log grading rule interpretation—

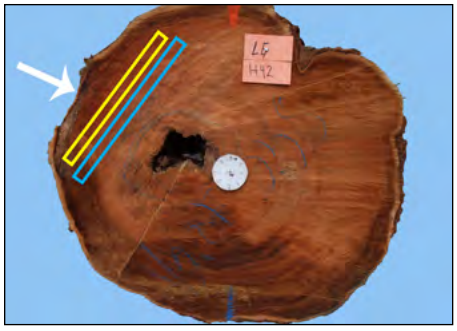
Cat faces are old wounds that have had time to build up callus tissue along their margins. The cat face/butt scar often will have rot associated with it. For this reason, a reduction in log scale often is required. The scale deduction is a percentage that is based on the length of the defective area (rounding up to the next whole foot) divided by the length of the log, times the percentage of the log's diameter affected. Cat face/butt scars are grading defects (Rast et al. 1973).

Figure 22—Cat face near the large end of the log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of cat face defect:
20 in long by 11 in wide

Total log length = 104 in
SED = 28.2 in, LED = 30.5 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the cat face is located. The defect is centered 11 in from the large end of the log.

- Other lumber defects related to this cat face: none
- **Total lumber defect volume attributed to this cat face = 75 in^3**

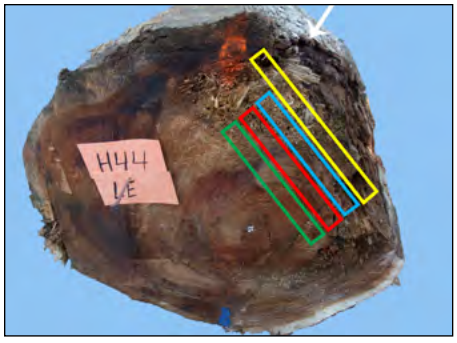
Board 42C: 58 in by 15.5 in by 1 in
Seam and bark: 12 in by 4.5 in
(6 percent of board)

Board 42H: 103 in by 13 in by 1 in
Unsound knot and bark: 24 in by 9 in
(16.1 percent of board)

Figure 23—Cat face on the log face and decay on the log large end of a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of defect:
Cat face: 33 in long by 18 in wide by 1.5 in deep
Decay: 31 in long by 7.5 in wide by 4.7 in deep
Decay: 27 in long by 9 in wide by 6 in deep

Total log length = 113 in
SED = 18.4 in, LED = 20.7 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the cat face is located. The cat face extends 33 in from the large end.

- Other lumber defects related to this cat face but not pictured: decay
- **Total lumber defect volume attributed to this cat face = 2,167.4 in^3**

Board 44H: 113 in by 11.5 in by 1 in
Decay: 38 in by 11.5 in
(33.6 percent of board)

Board 44K: 113 in by 9 in by 1 in
Decay: 32 in by 9 in
(28.3 percent of board)

Board 44L: 113 in by 9 in by 1 in
Decay: 60 in by 9 in
(53.1 percent of board)

Board 44M: 113 in by 9 in by 1 in
Decay: 30 in by 9 in
(26.6 percent of board)

Crack or Split

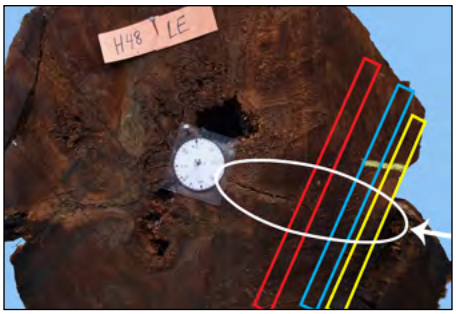
Cracks and splits are essentially the same defect type, but the term "crack" may be used when the radial separation of the wood fibers along the log is wider. Both cracks and splits will penetrate into the heartwood and even to the pith center of the log. They usually result from a traumatic stress such as occurs when a tree is felled (Carpenter et al. 1989). Cracks and splits are considered log face defects because they can affect a significant length of the log and are readily seen on the log face. Lumber defects associated with cracks include splits, shakes, checks, and voids.

Log grading rule interpretation—
A crack/split with a depth into the log that equals or exceeds 15 percent of the log's diameter (30 percent of its radius) is considered a grading defect (Rast et al. 1973).

Figure 24—Crack on the face, large end, and along the full length of an old-growth *Acacia koa* log from a standing dead or dying tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of crack defect:
116 in long by 3.5 in wide

Total log length = 116 in
SED = 26.2 in, LED = 31.3 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates the external position around the log and the angle at which the crack is located. The defect is at the large end and extends 116 in (the entire length) down the log. The white oval encircles the crack and measures 18 in across the end of the log.

- Other lumber defects related to this crack but not pictured: shake
- **Total lumber defect volume attributed to this crack = 394.9 in^3**

Board 48D: 112 in by 8.5 in by 1 in
Shake: 3 in by 1.3 in
(0.4 percent of board)

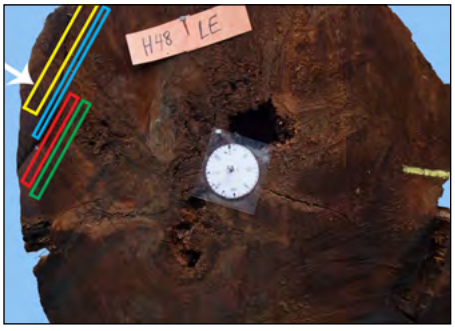
Board 48E: 116 in by 11 in by 1 in
Checks: 11 in by 9 in
(7.8 percent of board)

Board 48G: 116 in by 20.7 in by 1 in
Shake: 30 in by 7 in
(8.7 percent of board)

Figure 25—Crack and wound on the face and large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of the crack and wound defect:
Crack: 36 in long by 11 in wide by 1 in deep
Wound: 48 in long by 11 in wide by 2 in deep

Total log length = 116 in
SED = 26.2 in, LED = 31.3 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the crack and wound are located. The defects are at the large end and extend 36 in (crack) an 48 in (wound) down the log from the large end.

- Other lumber defects related to this crack and wound but not pictured: shake, bark pocket
- **Total lumber defect volume attributed to this crack and wound = 827.1 in^3**

Board 48I: 16 in by 14 in by 2 in
Shake: 12 in by 12.5 in
(67 percent of board)

Board 48J: 20 in by 19.5 in by 1 in
Shake: 19.5 in by 5 in
(25 percent of board)

Board 48K: 113 in by 13 in by 1 in
Shake: 16 in by 8.5 in
(9.3 percent of board)

Board 48L: 113 in by 14 in by 1 in
Shake: 25 in by 6.5 in
(10.3 percent of board)

Decay (sapwood)

Decay is the general term for wood degradation that is caused by the presence of fungi. In living trees and logs from recently felled trees, extensive areas of decay are most frequently associated with heartwood. The sapwood of downed trees becomes quickly susceptible to fungal propagation. Sapwood decay is typically a defect seen on the log faces. Lumber defects associated with sapwood decay include soft decayed wood that is discolored and often riddled with checks.

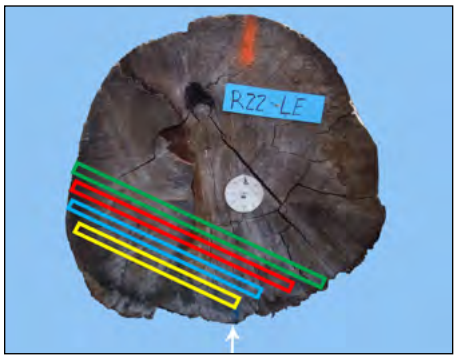
Log grading rule interpretation—

Sapwood decay is typically confined to the outermost portions of the log faces and as such, is expected to be contained in the slab sections, which are the exterior portions of the log removed when producing lumber. Therefore, sapwood decay on the surfaces of the log are not considered grading defects.

Figure 26—Decay indicator on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of decay defect:
44 in long by 22 in wide

Total log length = 88 in
SED = 21.4 in, LED = 25.2 in



The decay is centered 43 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the decay is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this decay but not pictured: decay
- **Total lumber defect volume attributed to this decay = 1,495 in^3**

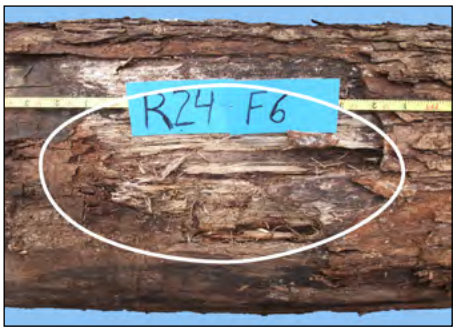
Board 22C: 22 in by 13 in by 1 in
Decay: 14 in by 8.5 in
(41.6 percent of board)

Board 22D: 26 in by 14 in by 1 in
Decay: 22 in by 5 in
(30.2 percent of board)

Board 22E: 30 in by 13.5 in by 1 in
Decay: 23 in by 13.5 in
(76.7 percent of board)

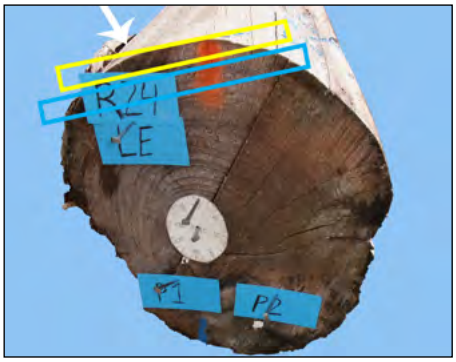
Board 22F: 38 in by 15 in by 1 in
Decay: 27 in by 13.5 in
(14.1 percent of board)

Figure 27—Decay on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.



External dimensions of decay defect:
40 in long by 16 in wide

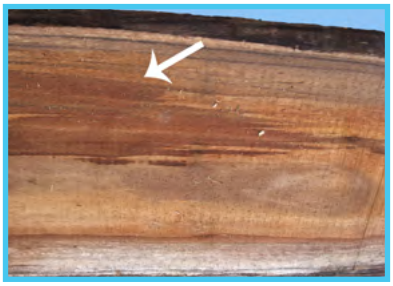
Total log length = 114 in
SED = 12.7 in, LED = 14.5 in



The decay is centered 90 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the branch is located. Sawn lumber position within the log is indicated by colored rectangles.

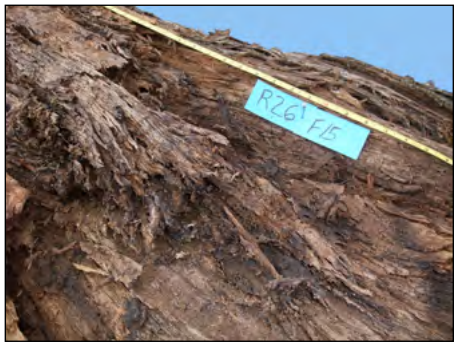
- Other lumber defects related to this decay: none
- **Total lumber defect volume attributed to this decay = 499 in^3**

Board 24C: 97 in by 9.2 in by 1 in
Decay: 28 in by 9.2 in
(28.9 percent of board)



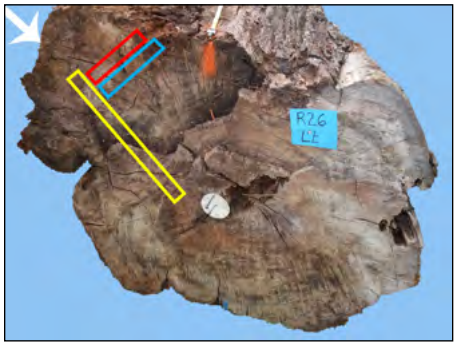
Board 24D: 106 in by 11.8 in by 1 in
Decay: 40 in by 3.6 in
(11.8 percent of board)

Figure 28—Decay on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.



External dimensions of decay and seam defect: 36 in long by 29 in wide

Total log length = 67 in
SED = 37.3 in, LED = 37.5 in

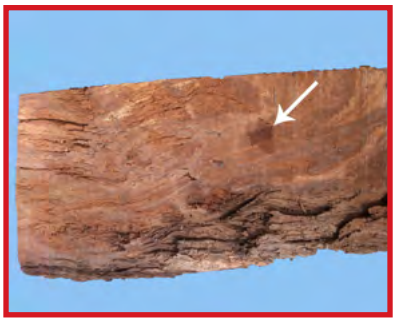


Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the decay is located. The decay is centered 18 in down the log from the large end.

- Other lumber defects related to this decay but not pictured: decay
- **Total lumber defect volume attributed to this decay = 1,274.6 in^3**

Board 26A1: 62 in by 19 in by 2 in
Decay: 63 in by 5.5 in
(29.4 percent of board)

Board 26L1: 62 in by 11 in by 1 in
Decay: 62 in by 9.5 in
(86.4 percent of board)



Board 26K1: 62 in by 10 in by 2 in
Decay: 52 in by 10 in
(83.9 percent of board)

Distortion

Heavy, medium, and light distortions are defect indicators in which the pattern of the bark is irregular, providing a clue as to the type of overgrown defect and number of years that clear wood has been deposited over the top of the defect. A concentric circular bark distortion pattern is indicative of an overgrown branch. Lumber defects associated with distortions include knots (both sound and unsound), bark pockets, stain, and decay.

Log grading rule interpretation—

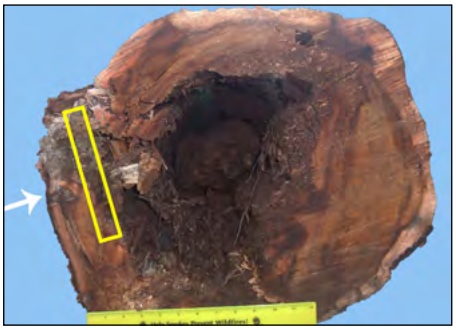
Heavy and medium bark distortions, in which the normal pattern of the bark is entirely or almost entirely interrupted by concentric bark patterns, are indicators of a recently overgrown defect that is considered a grading defect. Light bark distortions, in which the normal pattern of the bark is interrupted to a lesser extent and the underlying cause of the defect often is indeterminate, are not grading defects.

Figure 29—Medium distortion defect on the face of a log from a dying old-growth *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of medium distortion defect: 11 in long by 11 in wide

Total log length = 96 in
SED = 16.6 in, LED = 20.2 in

Board 1A: 93 in by 6.8 in by 1 in
Decay/bark pocket: 6.5 in by 6.2 in
(6.4 percent of board)



The medium distortion defect is centered 62 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the distortion is located. Sawn lumber position within the log is indicated by the colored rectangle.

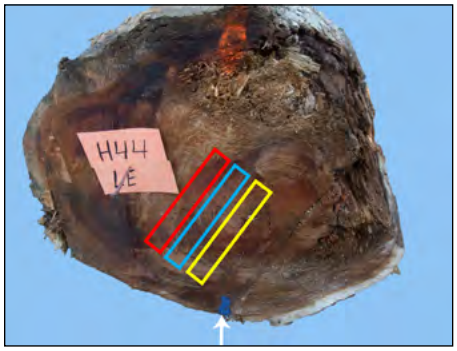
- Other lumber defects related to this distortion but not pictured: none

- **Total lumber defect volume attributed to this distortion = 40.3 in^3**

Figure 30—Medium distortion defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of medium distortion defect:
2.5 in long by 1.5 in wide

Total log length = 113 in
SED = 18.4 in, LED = 20.7 in



The defect indicator is centered 101 in down the log from the large end. Sawn lumber position within the log is designated by colored rec-tangles. The arrow indicates external position around the log and the angle at which the distortion is located.

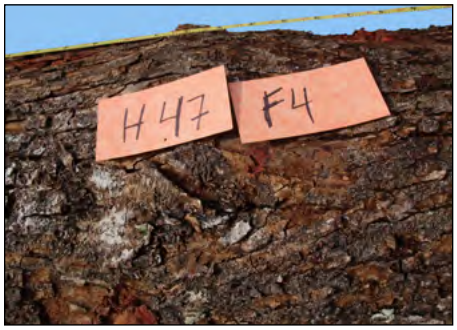
- Other lumber defects related to this distortion: none
- **Total lumber defect volume attributed to this distortion = 16.2 in^3**

Board 44P: 113 in by 7.1 in by 1 in
Bark pocket: 5.5 in by 1 in
(0.7 percent of board)

Board 44Q: 113 in by 7.2 in by 1 in
Bark pocket: 2.5 in by 2.5 in
(0.8 percent of board)

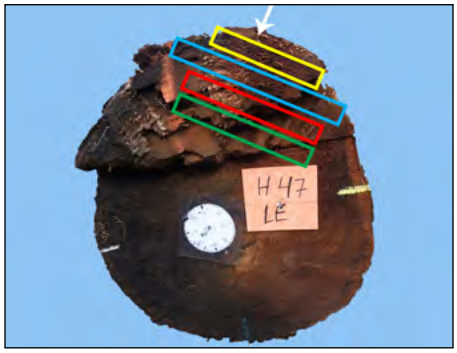
Board 44R: 113 in by 17.2 in by 1 in
Bark pocket: 2.5 in by 1.8 in
(0.2 percent of board)

Figure 31—Medium distortion/overgrown knot defect on the face of a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of medium distortion/overgrown knot defect: 4 in long by 1.5 in wide

Total log length = 138 in
SED = 13 in, LED = 18 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the distortion/overgrown knot is located. The defect is centered 100 in down the log from the large end.

- Other lumber defects related to this distortion but not pictured: unsound knot
- **Total lumber defect volume attributed to this distortion = 36.4 in^3**

Board 47E: 138 in by 6 in by 1 in
Bark pocket: 7 in by 1 in
(0.8 percent of board)

Board 47F: 137 in by 9.5 in by 1 in
Unsound knot: 2 in by 1 in
(0.2 percent of board)

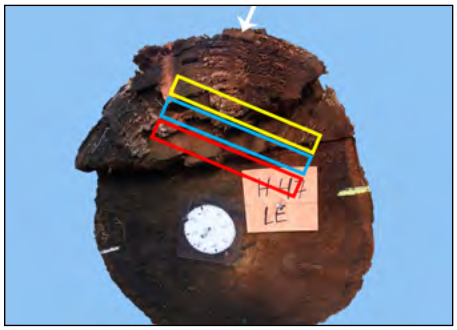
Board 47L: 137 in by 7.5 in by 1 in
Sound knot: 2.3 in by 2.1 in
(0.5 percent of board)

Board 47M: 137 in by 7.5 in by 1 in
Unsound knot: 4.2 in by 3 in
(1.2 percent of board)

Figure 32—Heavy distortion on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of heavy distortion defect: 4 in long by 3.5 in wide

Total log length = 138 in
SED = 13 in, LED = 18 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the distortion is located. The defect is centered 56 in down the log from the large end.

- Other lumber defects related to this distortion: none
- **Total lumber defect volume attributed to this distortion = 10.57 in^3**

Board 47L: 137 in by 7.5 in by 1 in
Sound knot: 2.3 in by 1.9 in
(0.4 percent of board)

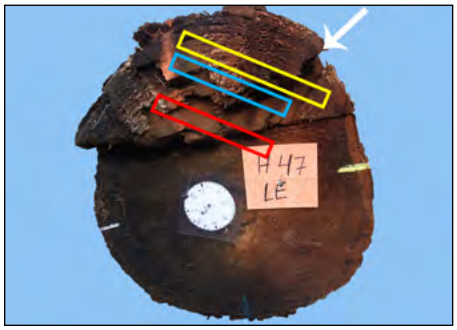
Board 47M: 137 in by 7.5 in by 1 in
Sound knot: 2.2 in by 2 in
(0.4 percent of board)

Board 47N: 137 in by 7.5 in by 1 in
Sound knot: 1.5 in by 1.2 in
(0.2 percent of board)

Figure 33—Heavy distortion/overgrown knot defect on the face of a log from a standing dead or dying *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.

External dimensions of heavy distortion/ overgrown knot defect:
3.8 in long by 2.6 in wide

Total log length = 138 in
SED = 13 in, LED = 18 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the distortion/overgrown knot and decay are located. The defect is centered 80 in down the log from the large end.

- Other lumber defects related to this distortion but not pictured: sound knots
- **Total lumber defect volume attributed to this distortion = 11.8 in^3**

Board 47F: 137 in by 9.5 in by 1 in
Bark pocket and rot: 4 in by 0.5 in
(0.2 percent of board)

Board 47L: 137 in by 7.5 in by 1 in
Unsound knot: 2.9 in by 2.7 in
(0.8 percent of board)

Board 47N: 137 in by 7.5 in by 1 in
Sound knot: 1 in by 1 in
(0.1 percent of board)

Hole

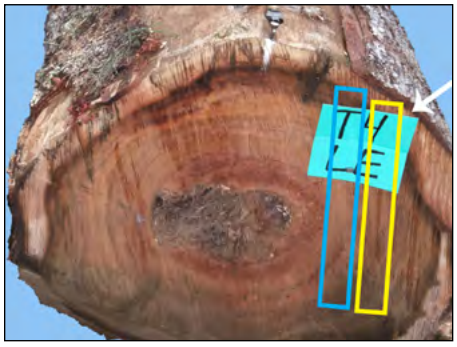
Holes in logs are distinguished, for log grading purposes, by their size. Knowing the origin of the hole (e.g., broken out limb, bird peck damage, beetle damage) can be very helpful in estimating the underlying wood quality. Holes can occur on the ends of logs if a beetle enters the log after it is bucked, but they typically are log face defects. Other lumber defects associated with holes include bark pockets, stain, and decay.

Log grading rule interpretation—
Large holes, those exceeding 1/2-in diameter, always are considered defects in grading hardwood logs (Rast et al. 1973). Increment borer holes and similar mechanical holes that penetrate into the central heartwood zone also are grading defects. Medium-sized holes that are between 3/16- and 1/2-inch in diameter usually are considered grade defects unless their character indicates the hole does not penetrate the wood significantly (Lockard et al. 1963).

Figure 34—Large hole on the face of a log from a dying old-growth *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of large hole defect:
2 in long by 1 in wide

Total log length = 114 in
SED = 17.7 in, LED = 20.5 in



The hole is centered 109 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the hole is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this hole: none
- **Total lumber defect volume attributed to this hole: 18 in^3**

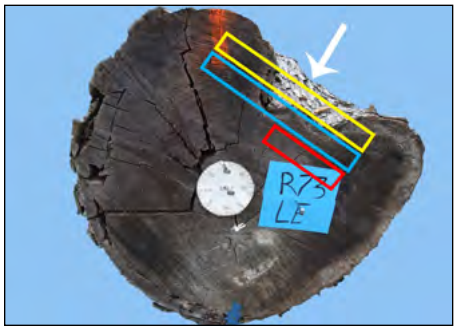
Board 4G: 114 in by 8.5 in by 1 in
Hole/decay: 3 in by 3 in
(1 percent of board)

Board 4H: 114 in by 10.5 in by 1 in
Hole/decay: 3 in by 3 in
(0.8 percent of board)

Figure 35—Large hole on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of hole defect:
4.5 in long by 1.5 in wide by 2 in deep

Total log length = 133 in
SED = 14.4 in, LED = 16.2 in



The hole is centered 38 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the hole is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this hole but not pictured: bark pocket
- **Total lumber defect volume attributed to this hole = 131 in^3**

Board 23G: 86 in by 9 in by 1 in
Bark pocket: 18 in by 4.4 in
(10.2 percent of board)

Board 23H: 132 in by 9 in by 1 in
Hole/bark pocket: 10 in by 3.5 in
(2.9 percent of board)

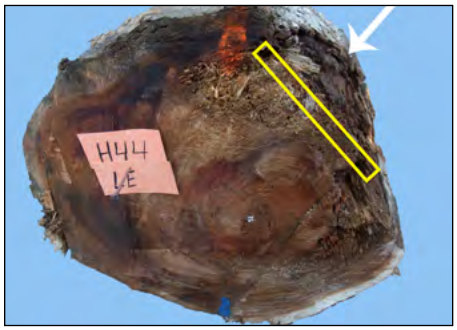
Board 23M: 133 in by 4.2 in by 1 in
Hole/bark pocket: 5.7 in by 2.3 in
(2.3 percent of board)

Figure 36—Large hole/bark pocket defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of large hole/bark pocket defect:
3 in long by 1.5 in wide

Total log length = 113 in
SED = 18.4 in, LED = 20.7 in

Board 44H: 113 in by 11.5 in by 1 in
Decay: 28 in by 7.5 in
(16.2 percent of board)



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the large hole/bark pocket is located. The hole is centered 77 in down the log from the large end.

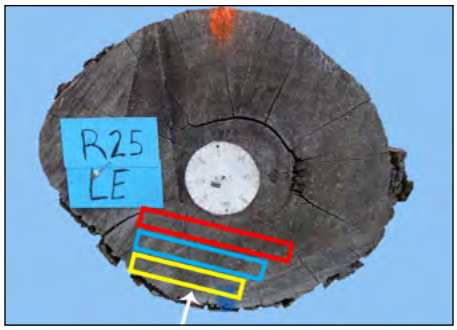
- Other lumber defects related to this hole: none

- **Total lumber defect volume attributed to this hole = 210 in^3**

Figure 37—Holes (small) caused by insects, on the face of a log from dead "relic" *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

External dimensions of grub holes/ damage defect:
36 in long by 16 in wide

Total log length = 86 in
SED = 13.8 in, LED = 13.4 in



The grub damage is centered 48 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the damage is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to these holes but not pictured: small, medium, and large insect holes
- **Total lumber defect volume attributed to these holes = 714.3 in^3**

Board 25J: 50 in by 6.5 in by 1 in
Large insect holes: 42 in by 2 in
(25.8 percent of board)

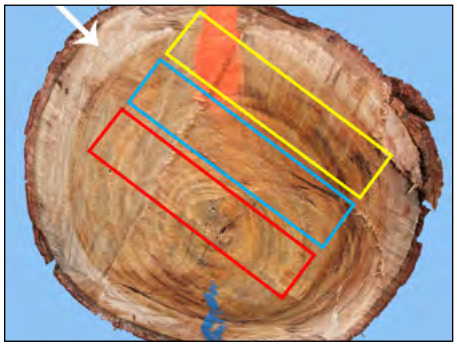
Board 25K: 60 in by 7 in by 1 in
Large insect holes: 42 in by 3.3 in
(33 percent of board)

Board 25N: 72 in by 8.3 in by 1 in
Large insect holes: 26.5 in by 5.8 in
(25.7 percent of board)

Figure 38—Holes (small) caused by insects on a butt log from a young-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

External dimensions of hole defects:
38 in long by 13 in wide

Total log length = 101 in
SED = 7.1 in, LED = 7.7 in



The region shown is centered 81 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the holes are centered. Sawn lumber position within the log is indicated by colored rectangles.

Small end of the log, which also shows insect holes included in defect volume.

- Other lumber defects related to these holes but not pictured: large insect holes
- **Total lumber defect volume attributed to these holes = 780 in^3**

Board 28E: 101 in by 4.6 in by 1 in
Large holes: 41.5 in by 3 in
(26.8 percent of board)

Board 28I: 101 in by 4.6 in by 1 in
Large holes: 32 in by 4.6 in
(31.7 percent of board)

Board 28H: 101 in by 4.6 in by 1 in
Large holes: 27 in by 4.6 in
(26.7 percent of board)

Mechanical Damage

Mechanical damage refers to a fresh wound that is equipment or human caused. Recent wounds typically expose just the sapwood component of the bole and appear sound (Carpenter et al. 1989). Lumber defects associated with older wounds and mechanical damage include torn grain, voids, shakes, splits, checks, stain, insect damage, and, in some cases, decay.

Log grading rule interpretation—
Mechanical damage/wounds that are of recent origin rarely have associated deterioration and therefore are not grading defects. Older wounds/mechanical damage typically have associated stain, etc. and therefore are grading defects (Lockard et al. 1963).

Figure 39—Mechanical damage on the face of a log from a young-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

External dimensions of mechanical damage defect:
6.5 in long by 4 in wide by 0.2 in deep

Total log length = 101 in
SED = 7.8 in, LED = 9.7 in

Board 27C: 101 in by 5 in by 1 in
Mechanical damage: 4.5 in by 0.7 in
(0.6 percent of board)

The mechanical damage is centered 14 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the mechanical damage is located. Sawn lumber position within the log is indicated by the colored rectangle.

- Other lumber defects related to this mechanical damage: none
- **Total lumber defect volume attributed to this mechanical damage = 3.15 in^3**

Seam

Seams, which generally run along the log's length (but can also spiral up the log face) may be caused by several different sources including lightning, wind, frost, and damage caused by falling trees (Carpenter et al. 1989). Seams may be open or overgrown with callus tissue. They may contain ingrown bark. Seams typically are seen on the face (side) of the log. Lumber defects associated with seams include bark pockets, wane, decay, cracks, and holes.

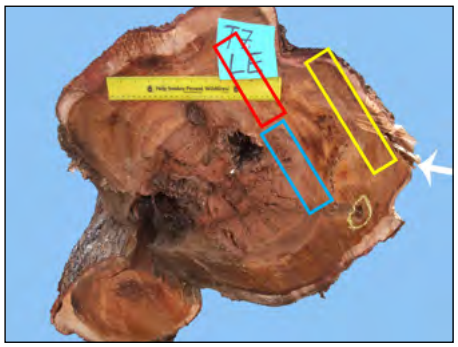
Log grading rule interpretation—

Seams are not grading defects unless their depth into the log exceeds 15 percent of the log's diameter. If the seam does penetrate into the log's "inner quality zone," it is a defect unless the seam is straight and located at the boundary of two log grading faces. If the seam is straight and does not run the full length of the log, a portion of the seam may be included in the clear grade cutting used to determine the log grade. This portion differs according to the location of the seam (Rast et al. 1973).

Figure 40—Seam on the face of a log from a dying old-growth *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

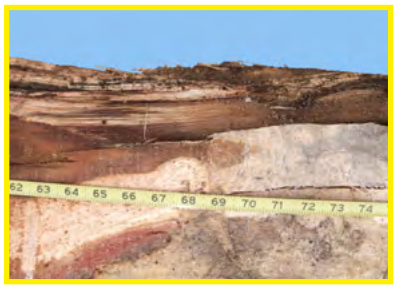
External dimensions of seam defect:
10 in long by 5.2 in wide (width of gap) by 6.5 in deep

Total log length = 74 in
SED = 23.3 in, LED = 27 in

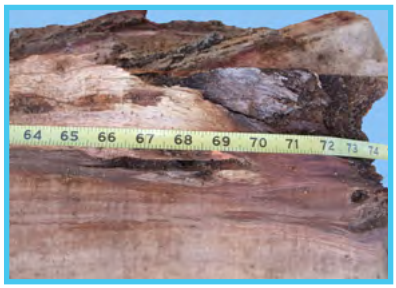


The seam is centered 72 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the seam is located. Sawn lumber position within the log is indicated by colored rectangles.

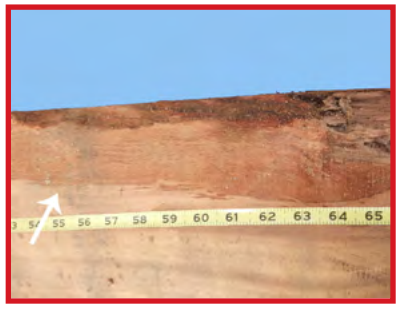
- Other lumber defects related to this seam but not pictured: wane, shake
- **Total lumber defect volume attributed to this seam = 271.2 in^3**



Board 7BB: 62 in by 10 in by 1 in
Wane: 12 in by 2.7 in
(5.2 percent of board)



Board 7H: 74 in by 7.2 in by 2 in
Wane/decay: 12 in by 3.7 in
(8.3 percent of board)

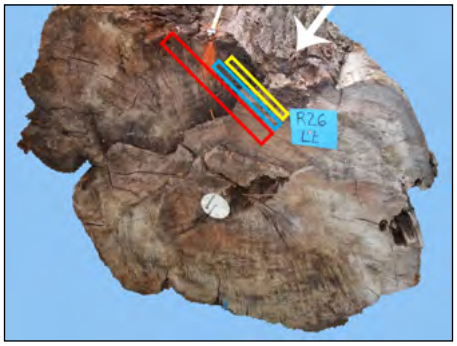


Board 7U: 74 in by 8 in by 2 in
Decay: 65 in by 4.5 in
(49.4 percent of board)

Figure 41—Seam on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of seam defect:
64 in long by 8 in wide by 2.8 in deep

Total log length = 67 in
SED = 37.3 in, LED = 37.5 in



The middle of the seam is centered 31 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the seam is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this seam but not pictured: decay
- **Total lumber defect volume attributed to this seam = 676 in^3**

Board 26B1: 67 in by 9 in by 1 in
Bark/seam: 35 in by 6 in
(34.8 percent of board)

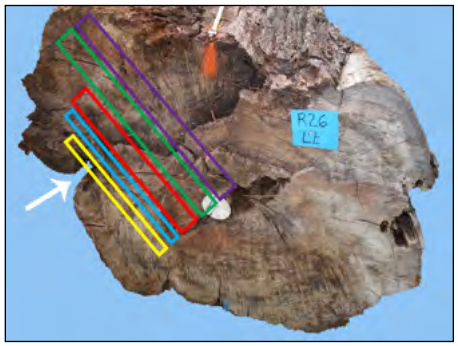
Board 26C1: 67 in by 10 in by 1 in
Decay: 22 in by 5 in
(16.4 percent of board)

Board 26D1: 61 in by 16 in by 2 in
Decay: 26 in by 3 in
(8 percent of board)

Figure 42—Seam on the face of a log from a dead "relic" *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.

External dimensions of seam defect: 62 in long by 4.5 in wide by 5 in deep

Total log length = 67 in
SED = 37.3 in
LED = 37.5 in



The middle of the seam is centered 31 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the seam is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this seam: none
- **Total lumber defect volume attributed to this seam = 836 in^3**

Board 26Z: 62 in by 18 in by 2 in
Bark pocket: 14 in by 5 in
(3.1 percent of board)

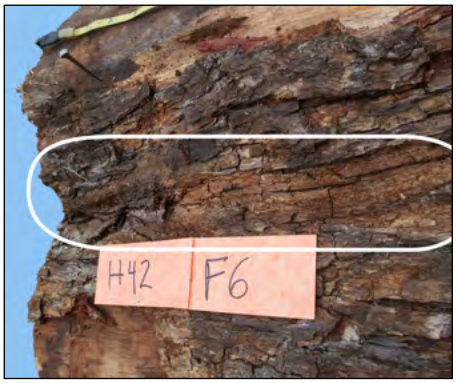
Board 26V: 62 in by 11.5 in by 1 in
Void: 31 in by 11.5 in
(50 percent of board)

Board 26W: 62 in by 13 in by 1 in
Void/bark pocket: 19 in by 3.5 in
(8.2 percent of board)

Board 26X: 62 in by 13.5 in by 2 in
Bark pocket: 19 in by 3.5 in
(4 percent of board)

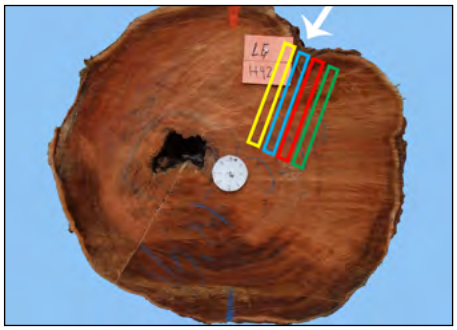
Board 26Y: 62 in by 18 in by 2 in
Void/bark pocket: 14 in by 5 in
(3.1 percent of board)

Figure 43—Seam with bark defect on the log end and the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of seam defect:
18 in long by 2 in wide

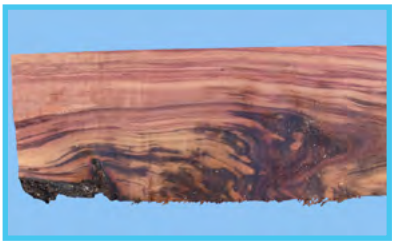
Total log length = 104 in
SED = 28.2 in, LED = 30.5 in



The seam runs from the large end for 18 in down the log. Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the seam, with included bark, is located.

- Other lumber defects related to this seam but not pictured: bark pockets, incipient decay
- **Total lumber defect volume attributed to this seam = 247.5 in^3**

Board 42G1: 104 in by 10.3 in by 1 in
Bark pocket and void: 7 in by 4 in
(2.6 percent of board)



Board 42H1: 104 in by 10.3 in by 1 in
Bark pocket: 7 in by 3 in
(2 percent of board)

Board 42I1: 40 in by 10.2 in by 1 in
Bark pocket: 6 in by 1.5 in
(2.2 percent of board)

Board 42J1: 36 in by 10.2 in by 1 in
Bark pocket: 6 in by 3.5 in
(5.7 percent of board)

Wound

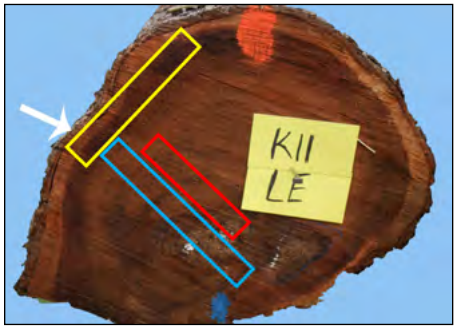
Wounds may be caused by a multitude of agents including impact from another tree, lightning (in which case the wound may appear as a seam), fire, impact from heavy equipment, and animal contact or herbivory. Many overgrown spot wounds (as opposed to lightning strikes) that have been surrounded by callus wood growth are called "cat faces" as they assume an oval facelike form. Lumber defects associated with wounds include bark pockets, wane, stain, decay, shakes, splits, and void areas.

Log grading rule interpretation—
Wounds that are of recent origin rarely have associated deterioration and therefore are not grading defects. Older wounds typically have associated stain, etc. and therefore are grading defects (Lockard et al. 1963).

Figure 44—Wound/cat face defect on the face of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.

External dimensions of wound/cat face defect:
6 in long by 3.5 in wide by 1 in deep

Total log length = 92 in
SED = 8.6 in, LED = 13.9 in



The wound/cat face is centered 35 in down the log from the large end. The arrow indicates the orientation around the log and the angle at which the defect is located. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this wound/cat face but not pictured: bark pocket
- **Total lumber defect volume attributed to this wound/cat face = 71.5 in^3**

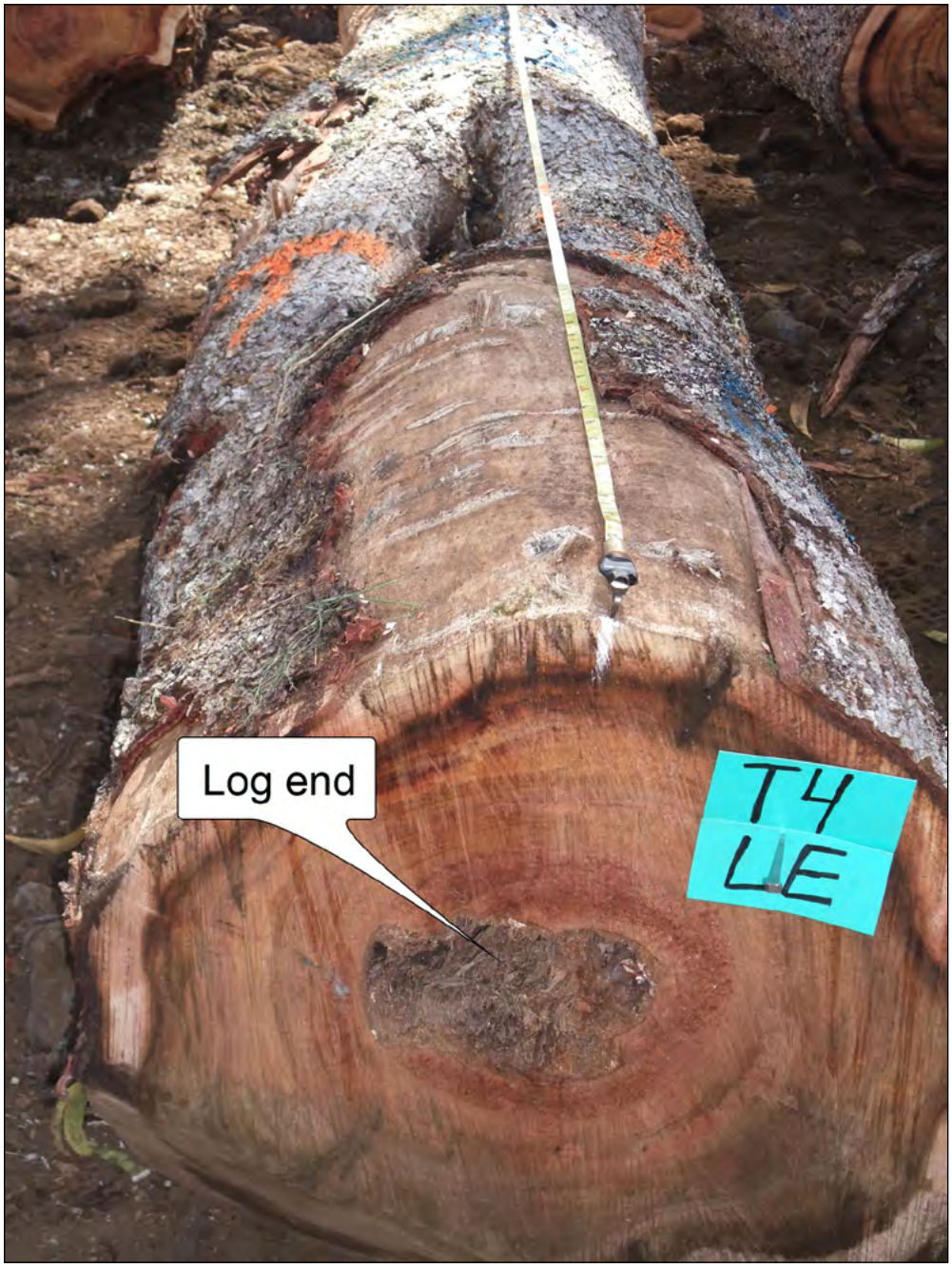
Board 11B: 50 in by 5.5 in by 1 in
Bark pocket: 3 in by 1.5 in
(1.6 percent of board)

Board 11C: 91 in by 6.8 in by 1 in
Wane/decay: 11 in by 6.5 in
(11.6 percent of board)

Board 11J: 92 in by 4.3 in by 1 in
Bark pocket/decay: 3 in by 2 in by 1 in
(1.5 percent of board)

Log-End Defects

Log-end defects are defects that occur most obviously and most commonly on the small or large end of a log that has been bucked.



Crotch (also known as “fork”)

When a major branch occurs at the end of the log, it is considered a crotch. The pocket formed between the main stem and the major branch (“the crotch”) is a location where moisture collects and decay and ingrown bark develop. The crotch defect is a very important defect in koa owing to the size of the branches in old-growth trees. Lumber defects associated with crotch include unsound knots, bark pockets, seams, wane, decay, and void areas.

Log grading rule interpretation—
Crotch defects are log grading defects. In addition, they often contain decay, bark, and seams that require that a board footage scale reduction be assessed (Lockard et al. 1963, Rast et al 1973).

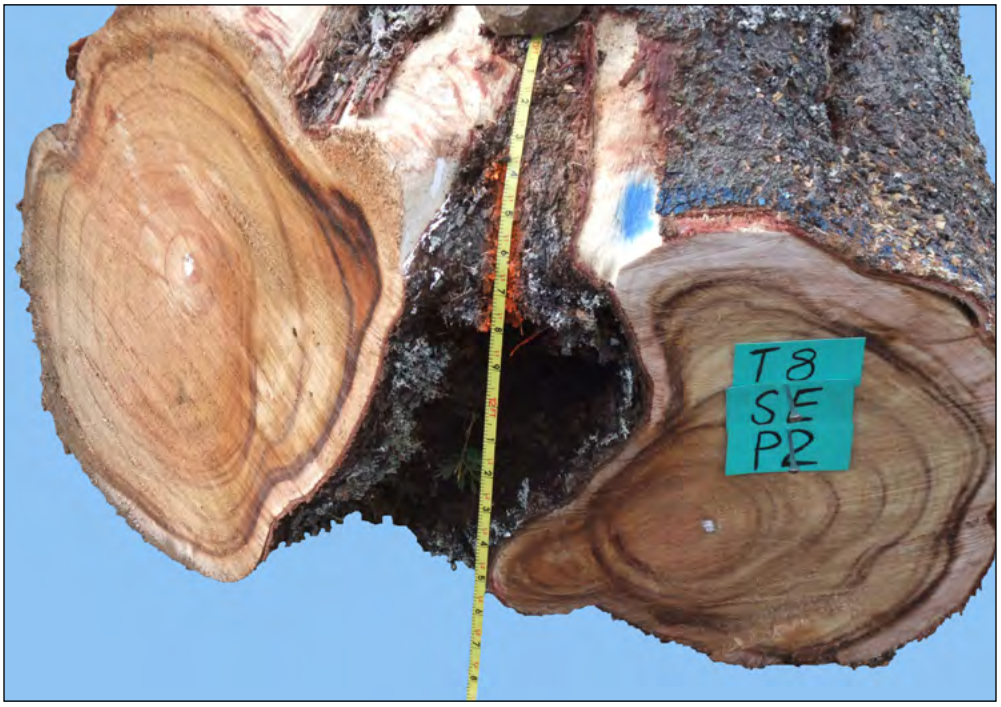
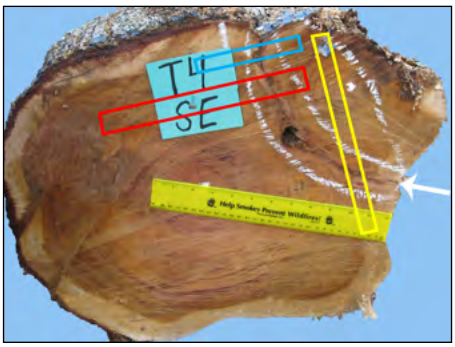


Figure 45—Crotch on the small end of a dying old-growth *Acacia koa* tree. SED = small-end diameter, LED = large-end diameter.



Dimensions of crotch defect:
9 in by 3 in on end of log with estimated length of 6 in

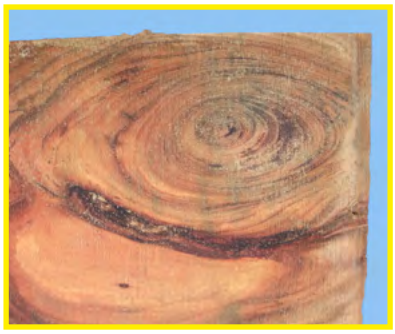
Total log length = 114 in
SED = 17.7 in, LED = 20.5 in

Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the crotch is located.

Log face view of crotch defect.

- Other lumber defects related to this crotch defect but not pictured:
  bark pocket

- **Total lumber defect volume attributed to this crotch defect = 238.5 in^3**

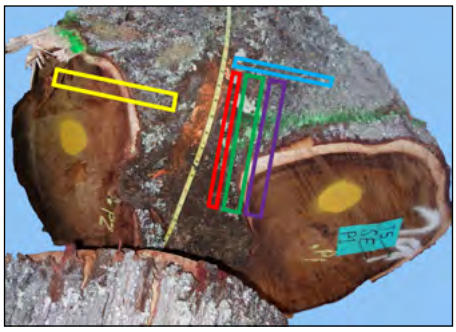


Board 4D: 114 in by 10.5 in by 1 in
Unsound knot/bark pocket: 5 in by 5.5 in (2.3 percent of board)

Board 4I: 30 in by 6.5 in by 1 in
Unsound knot/bark pocket: 12 in by 4 in (24.6 percent of board)

Board 4K: 63 in by 11.25 in by 1 in
Unsound knot/bark pocket: 12 in by 7 in (11.9 percent of board)

Figure 46—Crotch defect on the small end of a log from a dying old-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.



External dimensions of crotch defect:
14.2 in long by 10.5 in wide by 10 in deep

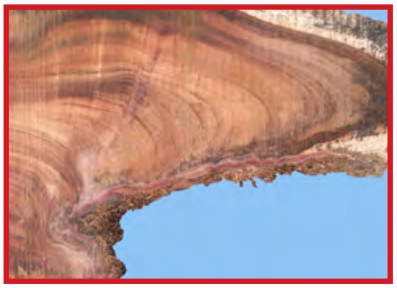
Total log length = 70 in
Left side: SED = 20 in, LED = 33.8 in
Right side: SED = 21.4 in, LED = 33.8 in

Crotch extended 10 in along small end of log length. Log was split in half at location of tape measure before sawing. Sawn lumber position within the log is indicated by colored rectangles.

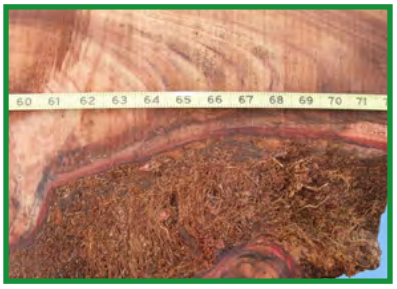
- Other lumber defects related to this crotch but not pictured: decay, wane, bark pocket
- **Total lumber defect volume attributed to this crotch = 975.8 in^3**

Board 5B1: 64 in by 9.8 in by 2 in
Bark pocket: 20 in by 6.5 in
(20.7 percent of board)

Board 5A: 41 in by 8.3 in by 1 in
Bark pocket: 4 in by 1 in
(1.2 percent of board)



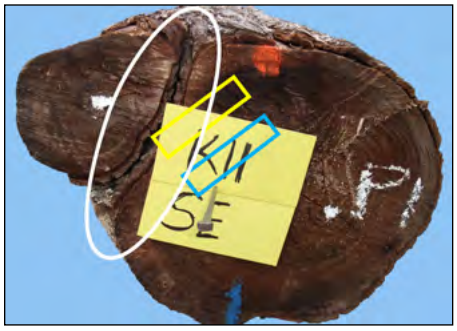
Board 5CC: 60 in by 11.4 in by 1 in
Void/decay: 15 in by 5 in
(11 percent of board)



Board 5B: 70 in by 11.5 in by 2 in
Wane/decay: 15 in by 5.1 in
(9.5 percent of board)

Board 5C: 68 in by 11.5 in by 2 in
Decay/wane: 12 in by 1.5 in
(2.3 percent of board)

Figure 47—Crotch defect on the small end of an upper log cut from a standing dead or dying old-growth *Acacia koa* tree (exact condition unkown). SED = small-end diameter, LED = large-end diameter.



External dimensions of crotch defect:
5 in long by 4 in wide by 52 in deep

Total log length = 92 in
SED = 8.6 in, LED = 13.9 in

The circle designates the location of the crotch. The crotch appeared to extend 52 in along the log length. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this crotch: none
- **Total lumber defect volume attributed to this crotch = 42 in^3**

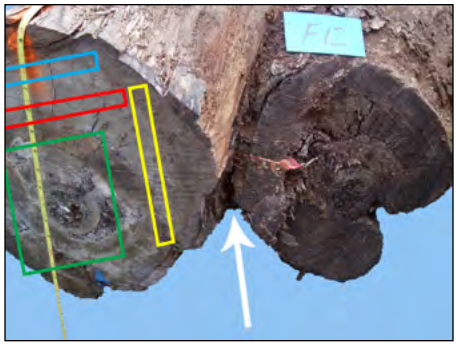
Board 11G: 92 in by 4.4 in by 1 in
Bark pocket/decay: 8 in by 2.5 in
(4.9 percent of board)

Board 11H: 92 in by 4.3 in by 1 in
Wane/decay: 6 in by 3.5 in
(5.3 percent of board)

Figure 48—Crotch on the face and small end of a "relic" *Acacia koa* log. SED = small-end diameter, LED = large-end diameter.

External dimensions of crotch defect:
9 in long by 12 in wide by 14 in deep

Total log length = 88 in
SED = 17.7 in, LED = 22.7 in



Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position, around the log, and the angle at which the crotch enters the log.

- Other lumber defects related to this crotch but not pictured: decay, hole
- **Total lumber defect volume attributed to this crotch = 2,266 in^3**

Board 21C: 77 in by 10 in by 1 in
Decay: 17 by 4.5 in
(9.9 percent of board)

Board 21I: 14 in by 9 in by 1 in
Decay: 6 in by 3.1 in
(14.8 percent of board)

Board 21K: 75 in by 15 in by 1 in
Decay: 18 in by 7 in
(11.2 percent of board)

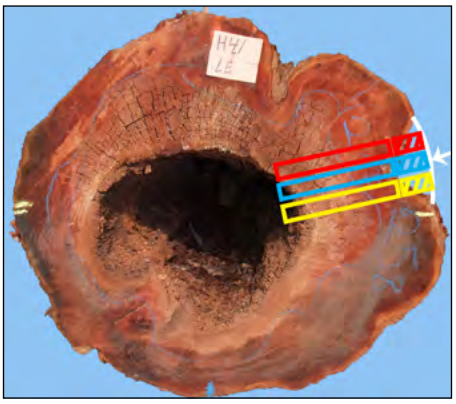
Cant: 82 in by 13 in by 5.6 in
Decay: 82 in by 13 in by 5.6 in
(100 percent of cant)

Flute

Flutes are tree/log form "defects" in which the tree bole, at its base, exhibits protrusions out from the normal cylindrical form. These protrusions start at the base and extend up the butt log, in rare cases, extending into the second log. Flutes are rounded undulations of the tree bole at its base (Carpenter et al. 1989). Flutes can be seen on both log faces and log ends. When the undulations extend more than just an inch or two out from the normal cylinder of the log, ingrown bark and wane may be found in the lumber sawn from this log section.

Log grading rule interpretation—
Flutes are usually restricted to the base of the butt log and therefore are not considered to be either a grade or scale defect. If a flute extends into the log at the small end such that the quality zone is impacted, a scale deduction may be required.

Figure 49—Flute on the large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.



External dimensions of flute defect:
2 in by 4 in wide by 18 in long

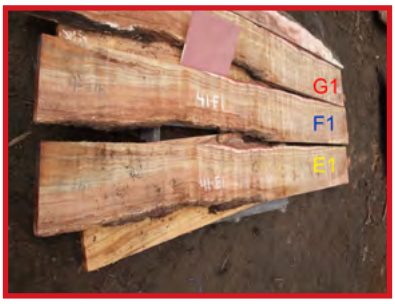
Total log length = 98 in
SED = 29.5 in, LED = 34.6 in

Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position and the angle of the flute on the log. Cross hatched section illustrates void where loss in board width occurred.

- Other lumber defects related to this flute but not pictured: wane, loss in width of about 5 to 6 in (not accounted for in total defect area below)
- **Total lumber defect volume attributed to this flute = 61.8 in^3**

Board 41E1: 94 in by 11.2 in by 1 in
Wane: 28 in by 0.6 in
(1.6 percent of board)

Board 41F1: 94 in by 11.2 in by 1 in
Wane: 20 in by 0.5 in
(0.9 percent of board)



Board 41G1: 94 in by 11.2 in by 1 in
Wane: 50 in by 0.7 in
(3.3 percent of board)

Heart Check

Checks are a radial separation of wood fibers and are often caused by drying stresses. Checks that occur in the heart-center region of the log are called heart checks. Unlike surface checks, heart checks are log-end defects. Significant radial checks originating from the pith and spreading in multiple directions are called spider checks (bottom left picture). A significant radial split that crosses the pith and extends out in both directions is called a wind shake (top picture below). Lumber defects associated with heart checks include shakes, splits, stain, and decay.

Log grading rule interpretation— If heart checks are confined to the heart center region (the innermost 40 percent of the wood cross-section surrounding the pith), they are not grading defects. If the heart check/spider heart/wind shakes are long enough to enter the quality zones, a scale reduction should be applied (Lockard et al. 1963). In addition, spider heart is a grading defect if it extends beyond the heart center (Rast et al. 1973).

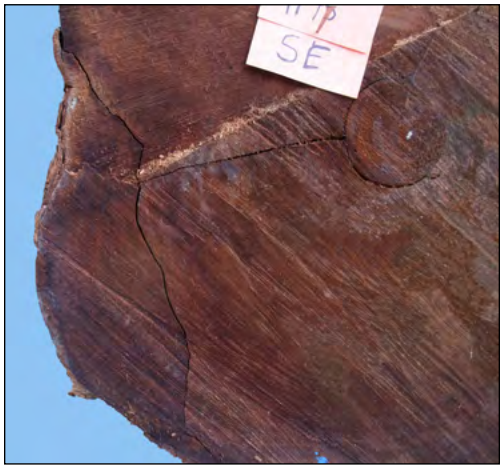
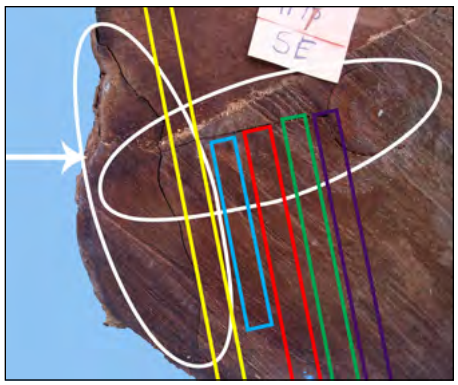


Figure 50—Heart check and split on the small end of the log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown).
SED = small-end diameter, LED = large-end diameter.



External dimensions of heart check and split defects:
Heart check: 8 in long by 0.2 in wide
Split: 16 in long by 2.5 in wide

Total log length = 116 in
SED = 26.2 in, LED = 31.3 in

Sawn lumber position within the log is designated by colored rectangles. The arrow indicates external position around the log and the angle at which the check is located. The ovals encircle the heart check and split.

- Other lumber defects related to this check and split but not pictured: shake
- **Total lumber defect volume attributed to this check and split = 346.1 in^3**

Board 48R: 115 in by 12.9 in by 1 in
Shake: 12 in by 2 in
(1.6 percent of board)

Board 48G: 116 in by 20.7 in by 1 in
Shake: 24 in by 4 in
(4 percent of board)

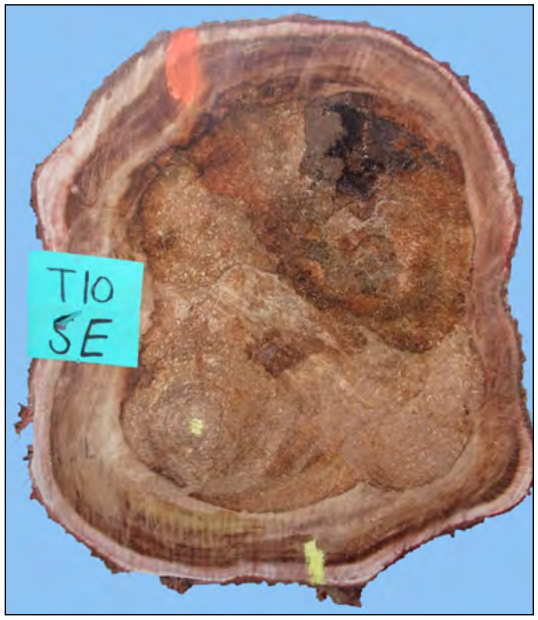
Board 48O: 116 in by 10.7 in by 1 in
Shake: 17 in by 10.7 in
(14.7 percent of board)

Board 48P: 116 in by 13 in by 1 in
Shake: 15 in by 1 in
(1 percent of board)

Board 48Q: 116 in by 12.6 in by 1 in
Shake: 13 in by 0.3 in
(0.3 percent of board)

Heart Rot

Heart rot is a type of decay that is found in the heartwood and is often, but not always, pith centered. It is usually associated with a broken out branch, tree top, or wound. Heart rot is a log-end defect that can be very significant, especially in logs from older trees. Lumber defects associated with heart rot include checks, stain, decay, and void areas.



Log grading rule interpretation— Rot that is confined to the heart center is not a grading defect. If the rot is confined to a small region and generally does not cross more than a few growth rings, a scaling deduction is made but it is not a grading defect. If the rot crosses a wider region and several growth rings, both a scale deduction and a grading defect are warranted.

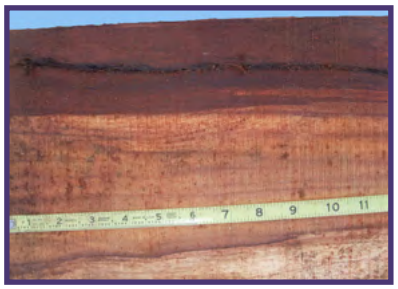
Figure 51—Heart rot on the large end of a log from a dying old-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

External dimensions of heart rot defect:
14.5 in long by 9 in wide by 42 in deep

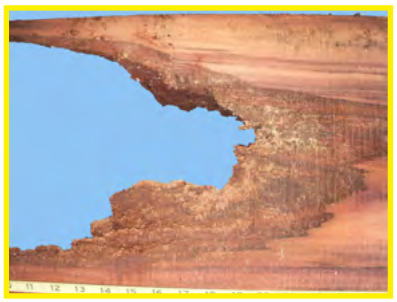
Total log length = 96 in
SED = 16.6 in, LED = 20.2 in

Heart rot defect at the large end of log is indicated by white outline. Sawn lumber position within the log is indicated by colored rectangles.

- Other lumber defects related to this heart rot but not pictured: decay, tear
- **Total lumber defect volume attributed to heart rot = 1,884.4 in^3**



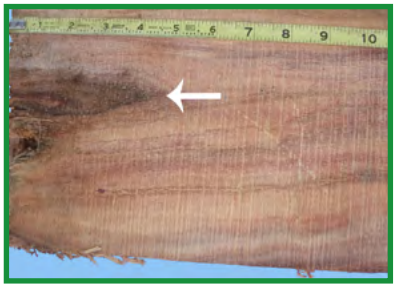
Board 1E: 96 in by 7.1 in by 2 in
Decay/shake: 24 in by 3.5 in
(12.3 percent of board)



Board 1C: 96 in by 13 in by 2 in
Void/decay: 22 in by 10.5 in
(18.5 percent of board)

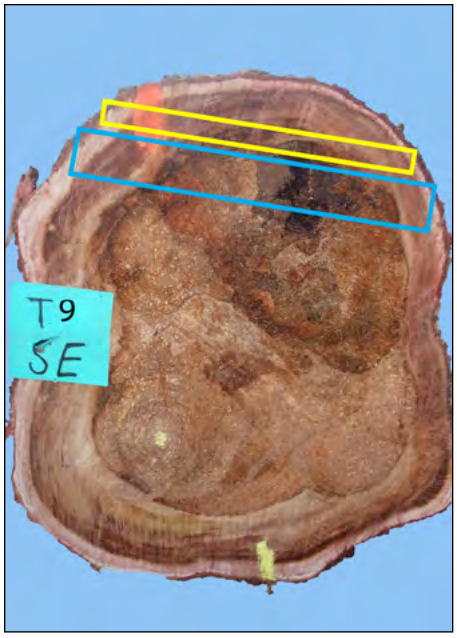
Board 1I: 70 in by 9.4 in by 2 in
Decay/void: 15 in by 8.4 in
(19.1 percent of board)

Board 1H: 94 in by 9.4 in by 2 in
Decay: 28 in by 9.4 in
(29.8 percent of board)



Board 1G: 94 in by 9.4 in by 2 in
Decay/checks: 16 in by 6.5 in
(11.8 percent of board)

Figure 52—Heart rot on the small end of a log from a dying old-growth *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.



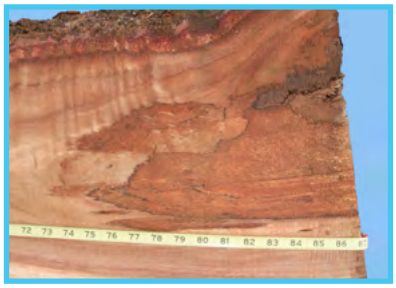
External dimensions of heart rot defect:
15.5 in long by 12 in wide

Total log length = 86 in
SED = 20.7 in, LED = 21.8 in

The defect indicator is on the small end of the log. Sawn lumber position within the log is indicated by colored rectangles.

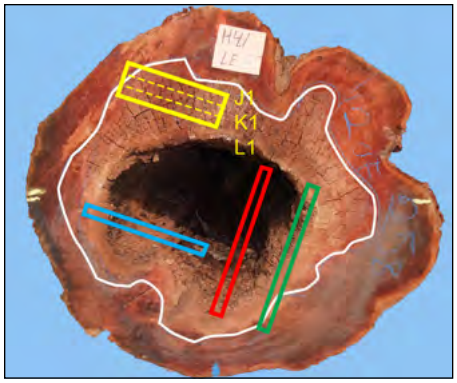
- Other lumber defects related to this heart rot but not pictured: incipient decay
- **Total lumber defect volume attributed to this heart rot = 1,966.8 in^3**

Board 9B: 86 in by 8.5 in by 1 in
Decay: 4 in by 7 in
(3.8 percent of board)



Board 9C: 86 in by 10 in by 2 in
Decay: 10 in by 8 in
(9.3 percent of board)

Figure 53—Heart rot on the large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of heart rot defect:
24.2 in long by 25.2 in wide by 53 in deep

Total log length = 98 in
SED = 29.5 in, LED = 34.6 in

Sawn lumber position within the log is designated by colored rectangles. Heart rot is outlined in white.

- Other lumber defects related to this heart rot but not pictured: void, decay, incipient decay
- **Total lumber defect volume attributed to this heart rot = 13,790.9 in^3**

Board 41Q: 96 in by 14.7 in by 1 in
Void and decay: 48 in by 11.7 in
(38 percent of board)

Board 41L1: 97 in by 10 in by 1 in
Decay: 70.0 in by 8.5 in
(61.3 percent of board)

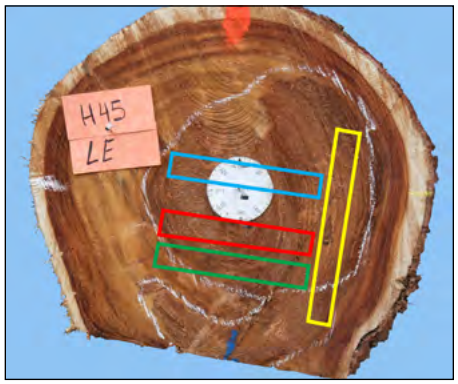
Board 41K1: 96 by 10 in by 1 in
Decay: 62 in by 7.5 in
(48.4 percent of board)

Board 41J1: 97 in by 10.0 in by 1 in
Decay: 20 in by 4 in (8.2 percent of board)
Incipient decay: 42 in by 4 in
(17.3 percent of board)

Board 41S1: 98 in by 12 in by 1 in
Decay and wane: 50 in by 8.5 in
(36.1 percent of board)

Board 41T: 95 in by 14.5 in by 1 in
Void and decay: 60 in by 11.5 in
(50.1 percent of board)

Figure 54—Heart rot on the large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of heart rot defect:
10.5 in long by 10.2 in wide

Total log length = 101 in
SED = 15.5 in, LED = 18.4 in

The defect indicator is on the large end of the log. Sawn lumber position within the log is indicated by colored rectangles. The white chalk mark on the log encircles the visible heart rot zone.

- Other lumber defects related to this heart rot but not pictured: decay, incipient decay
- **Total lumber defect volume attributed to this heart rot = 1,150.8 in^3**

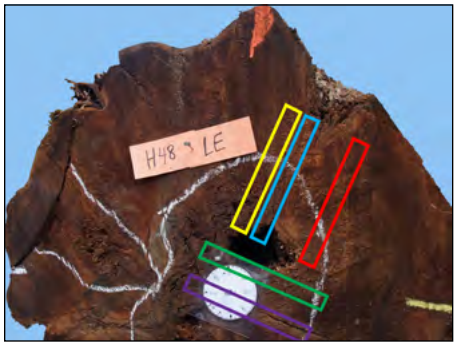
Board 45J: 101 in by 8.3 in by 1 in
Decay: 11 in by 8.3 in
(10.9 percent of board)

Board 45P: 101 in by 6.4 in by 1 in
Decay: 24 in by 6.4 in
(23.8 percent of board)

Board 45R: 101 in by 6.4 in by 1 in
Decay: 17 in by 6.4 in
(16.8 percent of board)

Board 45S: 101 in by 6.5 in by 1 in
Decay: 27 in by 4 in
(16.5 percent of board)

Figure 55—Heart rot defect on the large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of heart rot defect:
16.5 in long by 9 in wide by 18 in deep

Total log length = 116 in
SED = 26.2 in, LED = 31.3 in

Sawn lumber position within the log is designated by colored rectangles. White chalk line/circle delineates heart rot defect.

- Other lumber defects related to this heart rot but not pictured: decay
- **Total lumber defect volume attributed to this heart rot = 1,019 in^3**

Board 48T: 65 in by 9 in by 1 in
Decay: 26 in by 5 in
(22.2 percent of board)

Board 48N1: 114 in by 8.9 in by 1 in
Decay: 7 in by 6.4 in
(4.4 percent of board)

Board 48O1: 101 in by 8.9 in by 1 in
Decay: 12 in by 2.9 in
(3.9 percent of board)

Board 48R1: 114 in by 9 in by 1 in
Decay: 18 in by 2.4 in
(4.2 percent of board)

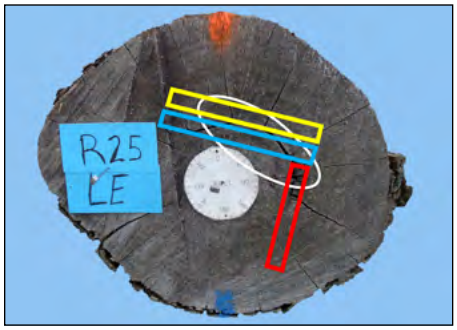
Board 48K1: 76 in by 9 in by 1 in
Decay and void: 17 in by 5.6 in
(13.9 percent of board)

Ring Shake

Shakes are separation of the wood tangentially with the fracture occurring within a given annual growth ring. Owing to the architecture of wood, fractures in a growth ring readily spread up or down the wood section longitudinally, therefore, ring shake can be a very serious defect. Shakes that are seen on the ends of the log and go substantially around the growth ring are termed "ring shakes." Shakes in logs produce lumber that also contain shakes.

Log grading rule interpretation— Shake that is confined to the heart center is not a grading defect. If the shake(s) is/are confined to a small region and generally do not include more than a few growth rings, a scaling deduction is made, but it is not a grading defect. If the shake crosses a wider region and several growth rings, both a scale deduction and a grading defect are warranted.

Figure 56—Ring shake defect on the large end of a log from a dead "relic" *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.



External dimensions of ring shake defect:
5 in long by 1 in wide

Total log length = 86 in
SED = 13.8 in, LED = 13.4 in

Ring shake defect at the large end of the log is designated by the white oval. The length into the log of the shake was not measurable. Sawn lumber position within the log is indicated by colored rectangles.

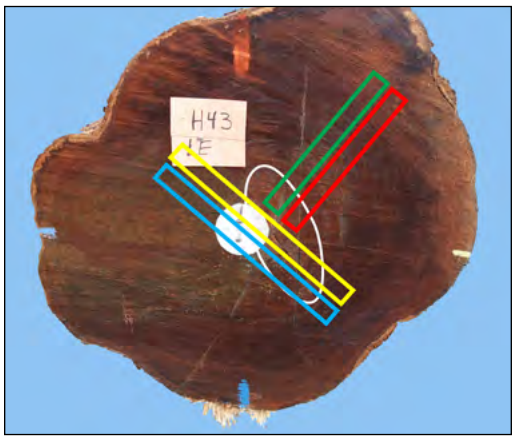
- Other lumber defects related to this ring shake but not pictured: shake, checks
- **Total lumber defect volume attributed to this ring shake = 191.6 in^3**

Board 25L: 28 in by 8.4 in by 1 in
Shake/unsound knot: 3.4 in by 6.2 in
(9 percent of board)

Board 25M: 84 in by 8.5 in by 1 in
Shake/unsound knot: 3.5 in by 5 in
(2.5 percent of board)

Board 25Q: 86 in by 6 in by 2 in
Shake: 4 in by 1.5 in
(1.2 percent of board)

Figure 57—Ring shake on the large end of a log from a standing dead or dying old-growth *Acacia koa* tree (exact condition unknown). SED = small-end diameter, LED = large-end diameter.



External dimensions of ring shake defect:
4 in long by 2.5 in wide

Total log length = 164 in
SED = 26.2 in, LED = 25.4 in

Sawn lumber position within the log is indicated by colored rectangles. The white oval encircles the ring shake on the log-end picture.

- Other lumber defects related to this ring shake but not pictured: shake
- **Total lumber defect volume attributed to this ring shake = 708 in^3**

Board 43X: 164 in by 14 in by 1 in
Shake (and knots): 56 in by 6.5 in
(15.9 percent of board)

Board 43Y: 164 in by 13.9 in by 1 in
Shake: 6 in by 4 in
(1.1 percent of board)

Board 43Q: 164 in by 10.6 in by 1 in
Shake: 20 in by 0.8 in
(0.9 percent of board)

Board 43R: 164 in by 10.6 in by 1 in
Shake: 24 in by 1.5 in
(2.1 percent of board)

Lumber Attributes

Lumber attributes, other than those identified as defects, include wood color and wood grain characteristics. For koa, which is used in products for which appearance is of paramount importance, a rich brown color and the presence of curl are highly valued.

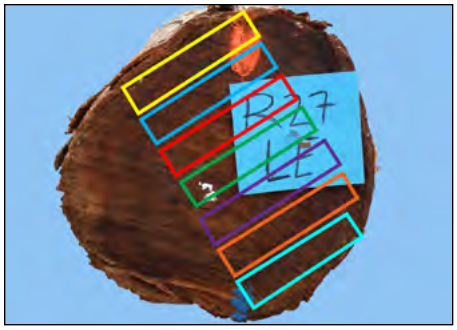
Color Attributes

Color variations are are not a defect but rather a characteristic of the wood that can be very important in some markets and more or less variable in different species and zones within the tree. A rich, brown heartwood color that dominates the cross section is the sought-after color in koa. In younger koa trees, the size of the heartwood zone, its color, and the degree of color variability are of interest as koa processors consider the utilization potential of the next koa forest.

Curl

Like color attributes, curl is not a defect but rather a characteristic of the wood that can be very important in different markets. Unlike color attributes, bark patterns on the face of the log often provide evidence of curl figure in the underlying wood. Curly koa wood is highly sought after.

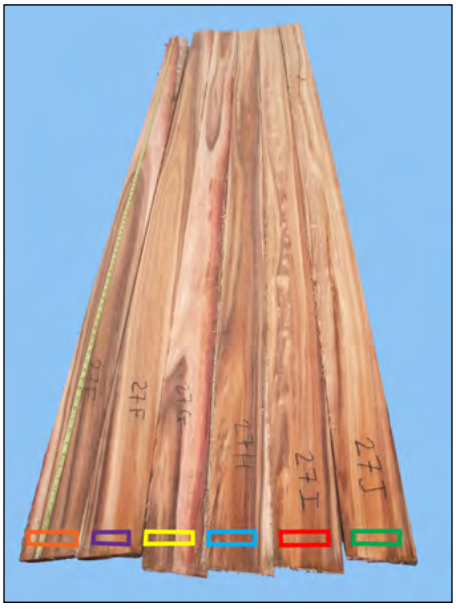
Figure 58—Color attributes of boards sawn from the butt log of a young-growth *Acacia koa* tree. This demonstrates the color variability of this young tree's wood (about 12 years old).
SED = small-end diameter, LED = large-end diameter.



The large end of a butt log from a young-growth koa tree. Sawn lumber position within the log is indicated by colored rectangles.

The small end of a butt log from young-growth koa tree.

Total log length = 101 in
SED = 7.8 in, LED = 9.7 in



Board 27E: 90 in by 4.6 in by 1 in
All other boards: 102 in by 4.6 in by 1 in

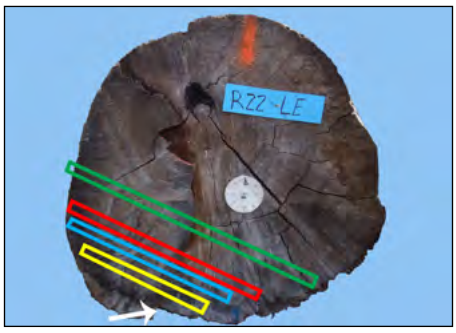
Board 27D: 39 in by 4.0 in by 1 in

Seven of the 10 boards sawn from the butt log of a young koa tree are displayed. Seventy percent of the board area recovered from this log was heartwood while 30 percent was sapwood. Four of the boards were 100 percent heartwood.

Figure 59—Curl (high-value grain) indicator on a log from dead "relic" *Acacia koa* tree.
SED = small-end diameter, LED = large-end diameter.

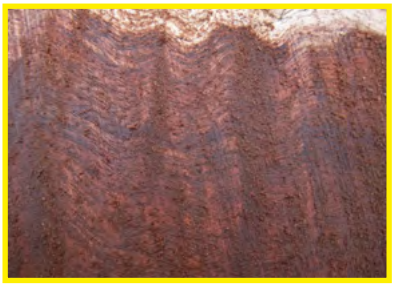
External dimensions of curl indicator:
18 in long by 15 in wide

Total log length = 88 in
SED = 21.5 in, LED = 25.2 in



The curl is centered 8 in down the log from the large end. The arrow indicates the angle at which the curl is located. Sawn lumber position within the log is indicated by colored rectangles.

- Additional curl (not pictured): present on four more boards
- **Total curl volume=192 in^3**



Board 22B: 19 in by 9 in by 1 in
Curl: 12 in by 2 in
(14 percent of board)

Board 22C: 22 in by 13 in by 1 in
Curl: 12 in by 2 in
(8.4 percent of board)

Board 22D: 26 in by 14 in by 1 in
Curl: 12 in by 2 in
(6.6 percent of board)

Board 22F: 38 in by 15 in by 1 in
Curl: 12 in by 2 in
(4.2 percent of board)

Acknowledgments

The authors gratefully acknowledge the contributions made by Karen Bennett (formerly of Region 5 State and Private Forestry); Steve Bergfeld, forester, State Department of Land and Natural Resources Division of Forestry and Wildlife; and Mike Robinson, Land Management Division, Forestry and Natural Resources, Department of Hawaiian Home Lands, for funding, facilitating, and coordinating the logistics of this study. We also thank the land managers and wood processors who graciously allowed us access to their sites/facilities; without their cooperation this study would not have been possible. In-kind contributions from the Pacific Southwest Research Station Institute of Pacific Islands Forestry and the University of Hawaii were greatly appreciated as were the data collection assistance provided by Judy Mikowski and Suzie Lee.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Feet (ft)	.305	Meters
Cubic feet (ft^3)	.0283	Cubic meters

Literature Cited

Baker, P.J.; Scowcroft, P.G.; Ewel, J.J. 2009. Koa (*Acacia koa*) ecology and silviculture. Gen. Tech. Rep. PSW-GTR-211. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 129 p.

Boddy, L. 2001. Fungal community ecology and wood decomposition processes in angiosperms: from standing tree to complete decay of course woody debris. Ecological Bulletins No. 49. Ecology of Woody Debris in Boreal Forests: 43–56.

Burgan, R.E.; Wong, W.H.C., Jr.; Skolmen, R.G.; Wick, H.L. 1971. Guide to log defect indicators in koa, ohia: preliminary rules for volume deductions. Berkeley, CA; U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 5 p.

Carpenter, R.D.; Sonderman, D.L.; Rast, E.D. 1989. Defects in hardwood timber. Agriculture Handb. 678. Washington, DC: U.S. Department of Agriculture, Forest Service. 88 p.

Gerry, E. 1955. Koa or Koa-Ka [Information leaflet]. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 8 p.

Lockard, C.R.; Putnam, J.A.; Carpenter, R.D. 1963. Grade defects in hardwood timber and logs. Agric. Handb. 244. Washington, DC: U.S. Department of Agriculture, Forest Service. 39 p.

Rast, E.D.; Beaton, J.A.; Sonderman, D.L. 1991. Photographic guide of selected external defect indicators and associated internal defects in sugar maple. Res. Pap. NE-647. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 35 p.

Skolmen, R.G. 1974. Some woods of Hawaii ... properties and uses of 16 commercial species. Gen. Tech. Rep. PSW-8. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 30 p.

Whitesell, C.D. 1990. *Acacia koa* A. Gray. In: Burns, R.M.; Honkala, B.H., tech. coords. Silvics of North America. Volume 2. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 17–28.

Wiedenbeck, J.; Wiemann, M.; Alderman, D.; Baumgras, J.; Luppold, W. 2003. Defining hardwood veneer log quality attributes. Gen. Tech. Rep. NE-313. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 36 p.

Wiedenbeck, J.; Lowell, E. 2011. An examination of the feasibility of using time-of-flight based non-destructive evaluation to assess the soundness of standing *Acacia koa*. In: Proceedings of the 3rd international scientific conference on hardwood processing. Blacksburg, VA: Virginia Polytechnic Institute and State University: 273–280.

Woodshop News [2009]. http://www.woodshopnews.com/news/wood-markets/498038-koa-is-highly-sought-and-high-priced. (May 31, 2012).

Appendix

This section consists of a copy of the 4-page guide to log defect indicators published by the Pacific Southwest Forest and Range Experiment Station in 1971.

PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U.S.DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

Guide to LOG DEFECT INDICATORS in KOA, OHIA... preliminary rules for VOLUME DEDUCTIONS

Robert E. Burgan Wesley H.C. Wong, Jr. Roger G. Skolmen Herbert L. Wick

This report offers the first guidelines for estimating the volume of unsound wood associated with log surface defects common in koa *(Acacia koa)* and ohia *(Metrosideros collina)* on the island of Hawaii. Until now, timber cruisers have had to rely chiefly on personal judgment in estimating volume losses from such defects. Their judgment is based on limited local observations and on guidelines for other species from other areas. As a result, there are frequent inconsistencies among individual cruisers.

These preliminary rules for volume deductions are summarized in a guide *(table 1)* for field use. Before timber cruisers apply these rules, they should read the full report on which the summary is based. The report includes 136 photographs illustrating surface defects to which the deduction rules apply, and the extent of unsound wood associated with the defects. Copies of the report may be read at...

> Institute of Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, 530 South Hotel Street, Honolulu, Hawaii 96813
>
> Division of Forestry, Hawaii Department of Land and Natural Resources, 25 Aupuni Street, P. O. Box 1761, Hilo, Hawaii 96720.

The guidelines will be revised as necessary to reflect new data or more current practices.

Figure 1--*The sound dead branch in this koa log measures five inches in diameter.*

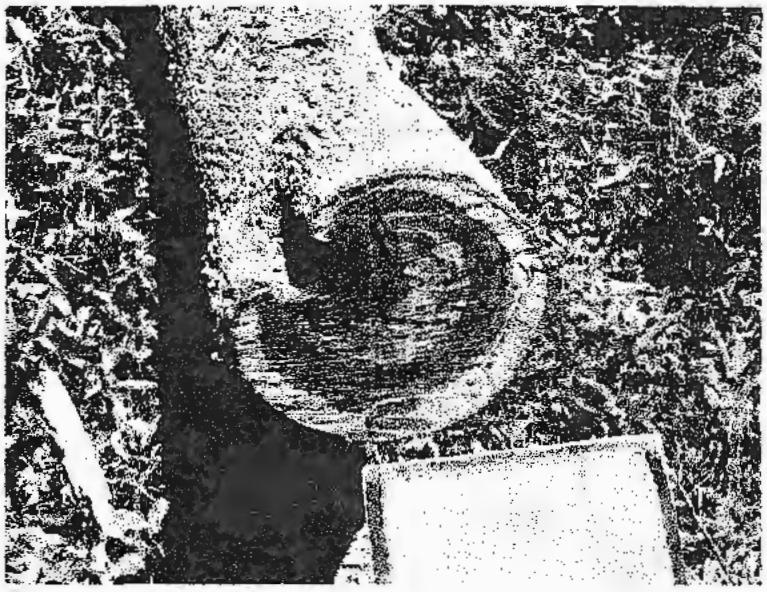


Figure 2–*The small hole is confined to the immediate vicinity of branch entry into the bole. At this stage, defect is minimal but decay–particularly down the bole--is probable in time.*

SELECTION OF SAMPLES

In developing these guidelines, we selected koa and ohia trees having different kinds and severity of log defects *(table 2).* Trees were selected from wet and dry areas, from young and old stands, and from high and low elevations. Common defects and defect indicators were forks, holes, stilted roots, broken limbs, conks, and knots. The sample trees were photographed standing, and then were felled. Sample defect indicators were numbered, measured and photographed. The extent of volume loss from each defect was then determined by bucking the log through the defect indicator and cutting off successive sections to measure the defect up and down the log. The measurements were analyzed and general rules for determining wood volume losses were developed.

DEFECT DEDUCTION RULES

Volume deduction rules are based on a 16-foot log length and are given for independent occurrences of defects in a tree. When combined defects occur, the best that can be done is to estimate the combined volume loss from all defects.

Although some volume losses from insect damages, i.e., termites, were noted, these did not appear to be extensive and are not included in this report.

Even though volume deduction rules probably should vary with the age and environment of the trees, such variations were not considered within the scope of this study. Consequently, deduction rules are broken down by species and type of defect only.

Table 2–*Number of koa and ohia samples on which volume deduction rules are based*[1]

Defect	Koa	Ohia
Butt scar	2	1
Fork	7	7
Seams	5	--
Sound dead branch stubs or knots	8	3
Rotten branch stubs or knots	6	7
Holes	15	3
Wounds	4	2
Conk	1	1
Butt swell	2	–
Stilt roots	–	3
Bump	--	2
Flutes	–	1
Snags	–	3

[1]Only samples of defect indicators which were not complicated by other sources of defect were included in the data, although additional samples were taken of combined defects.

TYPICAL INFORMATION

The photographs and defect deduction guidelines in this paper are typical of the information available in the full report.

Sound Dead Branch Stubs or Knots:

Sound knots *(figs. 1,2)* may result from green limbs, sound dead limbs, or sound branch stubs. Sound knots in either koa or ohia require no defect

Figure 3–*Holes in ohia as they appeared in the standing tree, are surface indicators of defect and call for volume deductions.*

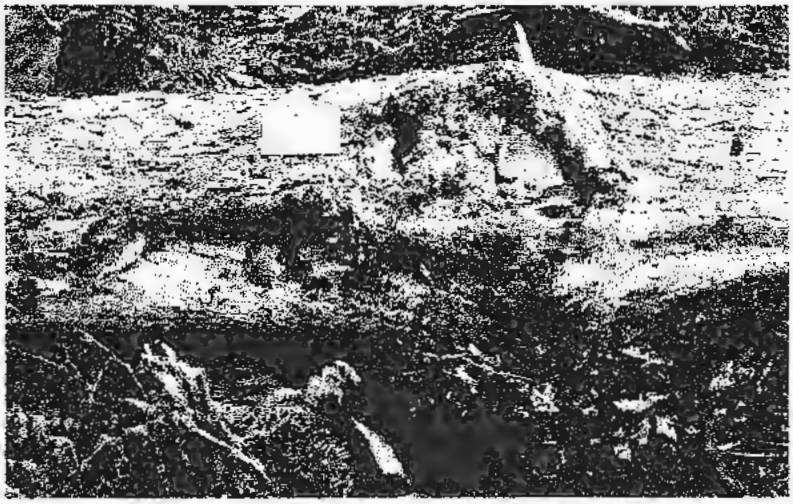


Figure 4–*The hole at the left measures 8 inches by 8 inches. There was no rot 4 inches to the left of it. The cut was made through the 4- by 7-inch hole directly below the card.*

Figure 5–*The rot measures 2 inches by 4 inches and extends down the tree 1 foot.*

deductions as they are lumber grading defects, not culling defects. A nearly overgrown knot may produce a "dimple" in the log.

Holes:

Holes *(figs. 3,4,5)* often indicate rot, the quantity depending on the size and age of the hole. Older holes are distinguished by a well-formed bark fold around the perimeter. Rot associated with holes is normally confined below the wound, but does extend upward in the larger holes.

Koa guideline: Cull 2 percent of the log volume per inch of hole diameter.

Ohia guideline: Cull 1 percent of the log volume per inch of hole diameter.

Acknowledgments: We are grateful to George Deconte and Sam Kamelamela, of the Hawaii District and to foresters Ernest Pung and Edwin Petteys of the Hawaii Division of Forestry for their field assistance.

The Authors

ROBERT E. BURGAN joined the staff of the Station's Institute of Pacific Islands Forestry, Honolulu, Hawaii, in 1969. He received bachelor's (1963) and master's (1966) degrees in forestry at the University of Montana. **WESLEY H. C. WONG,JR.,** has been with the Hawaii Division of Forestry since 1964, when he was graduated from Oregon State University with a bachelor's degree in forestry. **ROGER G. SKOLMEN,** also with the Institute staff, holds bachelor's (1958) and master's (1959) degrees in forestry from the University of California, Berkeley. **HERBERT L. WICK,** formerly on the Institute staff and now supervisory forester, Burns Ranger District, Malheur National Forest, Oregon, is a 1965 forestry graduate of the University of Washington.

ABSTRACT: An exploratory study provides the first volume deduction rules for various surface defect indicators common on koa *(Acacia koa)* and ohia *(Metrosideros collina)* trees in Hawaii. This report presents the deduction rules, illustrations of some typical defects, and an abbreviated set of deduction rules suitable for field use.

OXFORD: 174.7 *Acacia koa*–525.5–015 + 174.7 *Metrosideros collina*–525.5–015.
RETRIEVAL TERMS: *Acacia koa; Metrosideros collina;* cull deduction.

U.S. Forest Service research in Hawaii
is conducted in cooperation with
Division of Forestry
Hawaii Department of Land and Natural Resources

GPO 980-775

Pacific Northwest Research Station

Web site	http://www.fs.fed.us/pnw/
Telephone	(503) 808–2592
Publication requests	(503) 808–2138
FAX	(503) 808–2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208–3890

Federal Recycling Program
Printed on Recycled Paper

U.S. Department of Agriculture
Pacific Northwest Research Station
333 SW First Avenue
P.O. Box 3890
Portland, OR 97208–3890