Volume Equations for Young Growth Softwood Species at Mountain Home Demonstration State Forest

submitted to

Mountain Home Demonstration State Forest
California Department of Forestry & Fire Protection

by

Norman H. Pillsbury
John P. Joseph

Natural Resources Management Department
California Polytechnic State University
San Luis Obispo

November 1990

Acknowledgements

This project was conducted cooperatively between the Natural Resources Managemnent Department, California Polytechnic State University, San Luis Obispo, and the California Department of Forestry and Fire Protection, Mountain Home Demonstration State Forest (MHDSF). Dave Dulitz, the resident forester at MHDSF provided invaluable assistance in determining site selection, species distribution, bark thickness measurements (i.e., tree climbing) and lodgings during our tenure at MHDSF. Many thanks to Jenny Gonzales for her priceless assistance in the field and office work for the project. I also wish to thank Apple© Computers for developing a personal computer that even I can master. Data entry and analysis were performed at California Polytechnic State University, San Luis Obispo.

About the Authors:

Norman H. Pillsbury is professor of forestry and Department Head of the Natural Resources Management Department, California Polytechnic State University, San Luis Obispo. John P. Joseph is a forestry undergraduate and forestry research associate in the Natural Resources Management Department.

VOLUME EQUATIONS FOR YOUNG GROWTH
SOFTWOOD SPECIES AT
MOUNTAIN HOME DEMONSTRATION STATE FOREST

List of Tables

(continued)

List of Tables (continued)

List of Appendices

VOLUME EQUATIONS FOR YOUNG GROWTH SOFTWOOD SPECIES AT MOUNTAIN HOME DEMONSTRATION STATE FOREST

Abstract

Standard volume equations and tables, and local volume tables were developed for ponderosa pine (*Pinus ponderosa* Laws), sugar pine (*Pinus lambertiana* Dougl.), incense cedar (*Libocedrus decurrens* Torr.) and white fir (*Abies concolor* Gord. & Glend.) in Mountain Home Demonstration State Forest. For all species, local and standard equations were developed for total volume in cubic feet, and merchantable volume in Scribner board feet based on both total height and the number of 16 foot logs.

A total of 40 or more trees were measured for each species from stands representing a broad range of environmental, topographical and site quality conditions found on the forest. The sample trees were also chosen to represent a broad range of sizes from 10 inches to almost 50 inches at dbh and heights from 30 feet to over 170 feet.

VOLUME EQUATIONS FOR YOUNG GROWTH SOFTWOOD SPECIES AT MOUNTAIN HOME DEMONSTRATION STATE FOREST

I. Introduction and Background

A unique ecological niche exists in the southern Sierra Nevada where the most massive trees in the world grow. Although most of the attention in this area is on the gigantic sierra redwood (*Sequoiadendron gigantia*) other important timber species also grow there. Such species include ponderosa pine, sugar pine, white fir, red fir, Douglas-fir, and incense cedar. Generally called the "mixed conifer type" in California, it is described by the Society of American Foresters in Forest Cover Types of North America as Type 243, the ponderosa pine/sugar pine/fir type (SAF 1968). Incense cedar is included in the southern range and Douglas-fir is included in the northern part of the state with the dividing line at the Merced river. The incense cedar is considered a climax type and occurs as individuals or small stands and does not dominate the main canopy (SAF 1968).

Other forest types are also common. At lower elevations ponderosa pine (Type 245) dominates. If fire occurrence is high at lower elevations, California black oak (Type 246), canyon live oak (Type 249), and Jeffrey pine (Type 247) will also be present. At higher elevations, only fir and sugar pine remain, with eventual conversion to red fir (SAF 1968). The giant sequoia is not considered a forest type because it occurs only as "islands of a different type within this zone" and the groves cover a very limited area (SAF 1968). The commercial, economic, and social importance of the four conifer species studied at MHSDF should not be under estimated. Sugar pine, for example, is generally considered to be the most valuable species in the west, even though it can be infested with white pine blister rust (*Endocronatium ribicola*). And, ponderosa pine is the most widely distributed conifer species in the United States. Its commercial value is diverse, as are its uses. Though the majority of ponderosa pine occurs at the lower elevations, it mixes readily and even becomes dominant on dry, southern sites which occur towards the lower edge

of the forest. White fir, another conifer of commercial importance, is found on cooler sites and becomes dominant at higher elevations. Because white fir is a shade tolerant species it will grow as an understory on any site with adequate moisture. White fir is generally used for structural and other building uses including plywood. Incense cedar, generally considered less valuable than other conifers, is still used for fuelwood, craft items, and special products such as pencils. Effective management of the mixed conifer type becomes essential when the many uses and values of these species are considered.

Both logging and recreation have existed at Mt. Home for several decades. In the early 1880's, sequoia and pine were being cut to supply mills and markets in the San Joaquin Valley. Seven saw mills were constructed on-site to process logs into products (CDF 1986). Remnants of four of these mills are still on the forest today. In the late 1890's, valley residents would come to "mountain home" to escape the summer heat. In 1946, the State of California passed legislation to protect the sequoias of Mt. Home by allocating funds to purchase the tract from a logging company. This action established the first State Forest in California. Now the estimated 5200 ancient sequoia trees have been preserved. Since that time, thousands of young trees have been established following responsible timber harvesting practices (CDF 1986).

To properly manage the conifer stands at MHDSF and to assure continuous production, it is necessary to have an accurate method of estimating tree volumes. While several volume tables have been developed in the past, they do not represent the conditions found at MHDSF. For example, cubic-foot and Scribner board-foot volume tables have been developed for ponderosa pine, sugar pine, and other species found in the Sierras, (MacLean and Berger 1976). However, the application of these tables would require extensive field testing and modification.

The purpose of this study was to develop local and standard volume equations for the four conifer species found extensively at MHDSF. These equations can be used to assist in making estimates of stand volume and composition. They can also be used in designing stocking levels and thinning schedules.

II. Previous Studies

A volume equation is a mathematical relationship used to estimate tree volume. A common volume prediction model (Husch *et al.* 1982) is:

$$V = aD^bH^c \quad [1]$$

where: V = tree volume
D = tree diameter
H = tree height
a, b, c = regression coefficients

Volume equations are usually developed for one species in a particular region. They are based on established relationships between tree volume and easily measured dimensions of the tree, like diameter, height and form class (Husch *et al.* 1982). These dimensions are measured and recorded in the field by forestry personnel. The data is then entered into a computer, and through multiple regression analysis, volume equations are developed.

Developing Volume Equations

Volume equations are developed through the multiple regression of sample tree data. They are used to predict individual tree volume based on tree diameter and height measurements. The most accurate way of obtaining sample tree data is to fell a tree, cut it into segments, make measurements of each stem or branch segment, calculate the volume of each segment, and finally, sum the volumes. However, due to the large amount of time involved in felling and measuring each sample tree, plus the lost dollar and environmental value if the tree cannot be utilized, a more expedient and less expensive method was developed.

In 1978, methodology for estimating standing tree volume was developed by Pillsbury and Stephens and used extensively by Pillsbury and Kirkley (1984) and Pillsbury and Pryor (1988, 1989). In this method, an optical dendrometer, the Spiegel Relaskop, is used to calculate standing tree volume of sample trees. Each sample tree was systematically divided into segments and numbered. Each segment is measured with the relaskop for length and

upper and lower segment diameters. To obtain total tree volume, the volume of each segment is calculated and all segment volumes are added.

In order to assess the accuracy of their method for calculating standing tree volume Pillsbury and Stephens felled and remeasured 63 of the 170 samples (Pillsbury *et al.* 1989). They were remeasured based on the same criteria used to measure the sample trees when they were standing. The volumes from the 63 felled trees were considered to be more accurate (because they were based on direct measurements) than the corresponding volumes of the same trees measured with the dendrometer. The felled tree volumes were then regressed against the standing tree volumes to obtain a felled tree to standing tree volume regression equation. The equation indicated that volume calculated for standing trees correlated well to volume calculated for felled trees. This basic technique has been slightly refined in subsequent studies. These studies show that tree volumes are normally under-estimated by approximately 8 percent.

Other studies have also shown that measurements of standing trees using optical dendrometers may give a biased estimate of tree volume. Brickell (1976) showed that the Barr and Stroud dendrometer over-estimated tree volumes by 5.4%, and Pillsbury and DeLasaux (1988) found that measuring Sierra redwood with a tele-relaskop over-estimated volume by up to 9 percent (Pillsbury *et al.* 1989).

III Problem Statement

The current lack of accurate volume equations for these four species on private, federal and state owned lands precludes:

1) reliable estimates of harvest volume which can result in economic loss through under-estimation of large-sized, lump sum sales, and,

2) efficient forest management activities such as inventory, thinning, stocking, and growth and yield studies.

The development of accurate volume tables is considered essential for on-going management activities and future studies at Mountain Home Demonstration State Forest.

IV. Study Objectives

The objectives of this project are to develop local and standard volume equations and tables for young growth ponderosa pine, sugar pine, incense cedar and white fir that will:

1) represent the full range of diameters and corresponding heights, and,

2) will be applicable to the various stand and site conditions at Mountain Home Demonstration State Forest.

V. Methodology

Stand and Sample Tree Selection

Data collection was completed at Mountain Home Demonstration State Forest, Springville, California during the summer of 1989. To sample an accurate representation of the trees of MHDSF the forest was divided into five major areas (Figure 1). These areas represent sites where diverse conditions exist and representative tree species could be found. Stands were chosen from within each area that represented the various site qualities, stand densities, elevation, and topography. A clear line of sight for measurements was necessary, therefore most measurements were made on trees found in low to moderately dense stands.

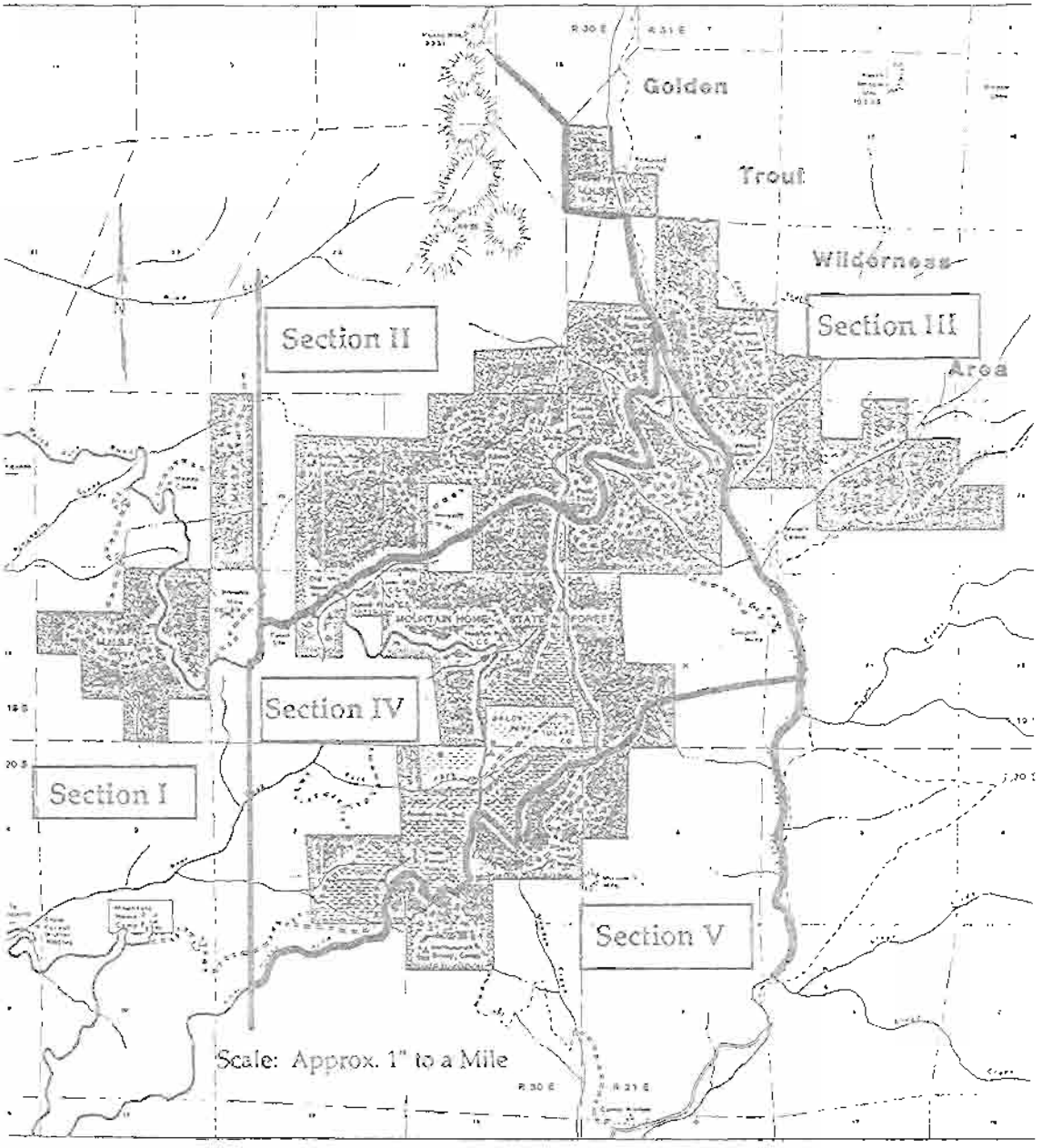
For each species, trees were selected to represent the existing range of diameters, heights, and growth forms. Experience has shown that a carefully selected sample of about 40-50 trees is normally satisfactory for estimating volume regression coefficients and testing for adequacy of equations (Pillsbury, *et al.* 1978, 1984, 1988). Sound trees of 10 inches dbh or larger were selected with the highest diameter class being slightly over 40 inches. Decadent trees and trees with major defects were avoided.

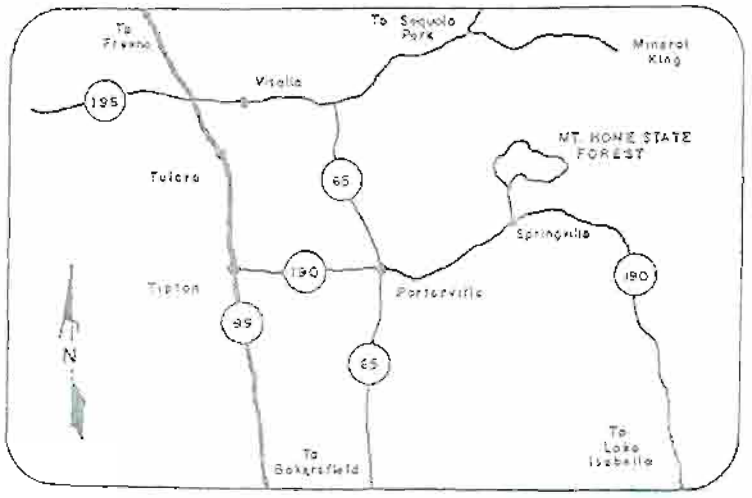
Sample Tree Measurement

A total of between 40-46 trees were measured for each species. The methodology used for measuring, standing trees is similar to that developed by Pillsbury and Stephens (1978), and used by Pillsbury *et al.* (1984, 1988).

Trees were systematically divided into segments approximately 16 feet in length. For each segment, the exact length, and the upper and lower diameters were measured using a relascope. If the bole was not visible at each 16 foot point then a nearby point was selected in order that the bole be clearly seen to make the diameter measurement. Only trees having a dbh of 10 inches or greater were included in the sample. All trees were measured to a 6 inch top.

Figure 1. Mountain Home Demonstration State Forest





Vicinity Map

Diameter at breast height (dbh) was measured with a D-tape. Stump diameter (height of 1 foot) was also measured with a D-tape and used in the volume calculation of the first segment for cubic-foot volumes. Total height was measured from ground level on the uphill side to the tip of the tree. Trees that were leaning were measured as if they were vertical by determining their total stem length. Bark thickness was measured at breast height with an inch ruler and used in the development of Scribner merchantable volume equations. A summary of the sample tree variables measured in the field is presented in Table 1.

Table 1. Tree variables measured, units, and method of measurement.

Tree Variables	Units and Precision	Method of Measurement
Dbhob	0.1 inch	diameter tape
Average bark thickness	0.1 inch	inch ruler
Diameter at top of first (16') log (17.5').	1/2 inch	relaskop
Intermediate diameters on stem	1/2 inch	relaskop
Intermediate heights	1 foot	relaskop
Diameter at merch-antable height (6" top)	1/2 inch	relaskop
Merchantable height	1 foot	relaskop
Total height	1 foot	relaskop

Utilization Standards

Sample tree volumes were calculated for three utilizations standards. The utilization standards are: total volume (in cubic feet) and two methods of determining merchantable volume in Scribner board feet. Scribner volumes are based on: a) dbh and total height, and, b) dbh and the number of 16 foot logs. All volumes are based on inside bark measurements.

To obtain inside bark volume, a linear regression model was used to estimate diameter inside bark (dib) from diameter outside bark (dob). The equation was developed from tree diameter and bark thickness data. It was assumed, based on field observations, that the dib versus dob relationship was constant for all tree heights except for incense cedar where the dib/dob ratio was observed to be different. Therefore, ten incense cedars were either felled or climbed, and measured for bark thickness and diameter at the top of each segment to develop a bark thickness relationship. It was found that above the first merchantable log, the bark thickness relationship was fairly constant. Separate equations expressing the dib/dob relationship for incense cedar were developed at stump height, breast height, the top of the first merchantable log, and for heights above the first log. The equations developed for all species are shown in Table 2.

Table 2. Relationship of diameter inside bark to diameter outside bark for four species at Mountain Home Demonstration State Forest

Species	Dib/Dob Equation	R-Squared	N
Incense Cedar	Stump dib (in) = -0.80168 + 0.8999 [Stump Dob (in)]	0.973	22
Incense Cedar	Dbhib (in) = 0.27221 + .8709 [Dbhob (in)]	0.983	22
Incense Cedar	Dib top of butt log (in) = 0.92916 + .8587 [Dob top of butt log (in)]	0.984	22
Incense Cedar	Dib's above first log (in) = 0.51092 + .8906 [Dob's above first log (in)]	0.998	41
Ponderosa Pine	Dib (in) = -0.38886 + 0.88494 [Dob (in)]	0.993	20
Sugar Pine	Dib (in) = 0.62453 + 00.85715 [Dob (in)]	0.995	19
White Fir	Dib (in) = -0.86063 + 0.92852 [Dob (in)]	0.996	25

For incense cedar it was found that all dob and dib data pairs for points above the first log were very closely correlated, therefore, the data were grouped for a total of 41 points. This step mathematically deducts the bark volume from total volume of each log.

The utilization standards are described below.

Total volume

Total tree volume includes the volume of all stem segments, terminal branches plus the volume of the stump. It does not include the volume of bark, roots and foliage. A sample computer spreadsheet is shown in Appendix B. Total volume was computed from relaskop height coordinates and diameter measurements using Smalian's volume formula (Equation 2; Husch *et al*. 1982).

$$\text{Smalian's Volume } (ft^3) = \frac{(B + b)}{2} \times L \qquad [2]$$

where: B is the basal area in square feet (cross-sectional area) at the large end of segment, b is the basal area at the small end of the segment, and L is length in feet.

The volume of the top segment of the tree, that is, the segment above 6", was calculated as a cone by the following equation.

$$\text{Volume of the tree tip} = \frac{B \times L}{3} \qquad [3]$$

Lastly, the volume of the stump was calculated as a cylinder, using the dib at the top of the stump to calculate the basal area.

Merchantable Volume

Merchantable volume is the volume inside bark of all 16 foot logs from stump height to a 6 inch top, calculated in board feet using the Scribner log

rule. Upper dib's were calculated by interpolating diameters to specified stem lengths, including trim allowance (e.g., 17.5, 34.0, 50.5, etc.). Log lengths were calculated to even 2-foot lengths with a minimum length of 6 feet. Trim was prorated at 6" per 16' length. Scale diameters are small end, inside bark to the nearest inch.

Volume was computed from relaskop height coordinates and diameter measurements using Scribner's log rule (Equation 4; Husch *et al.* 1982).

$$\text{Scribner (bd. ft.)} = (0.79D^2 - 2D - 4) \times \frac{L}{16} \qquad [4]$$

where: D is the log diameter inside bark in inches, small end, and L is the log length in feet.

Lastly, the log volumes were summed to equal the Scribner board-foot volume of the tree. A sample computer spreadsheet is shown in Appendix B. The spreadsheet also provides: Total volume in cubic meters, and International 1/4" board-foot volumes to a 6" top.

Correction of Sample Tree Volumes

As noted in Section II of this report, measuring tree volumes with dendrometers introduces a bias into the data. Several previous studies have carefully examined the relationship between the volumes calculated for standing trees and for the same trees after they have been felled. In all cases a correction equation was necessary and used to adjust standing tree volumes. For this study the results of previous studies by Pillsbury *et al.*, (1978, 1984, 1988) was used to adjust standing tree volumes.

Data from the three studies referenced above showed little difference in the correction equation developed. The "volume cut" versus the "volume standing" data for the three studies were compared using a statistical test for large populations. The data set included 93 trees (20 trees from the Pillsbury and Pryor study (1988); 10 trees from Pillsbury and Kirkley (1984); and 63 from Pillsbury and Stephens (1978)). A two tailed *t*-test at the 0.99 probability level with dummy variables assigned to the sample trees was used. The test results showed that the

t value fell within the acceptance region and therefore the three data sets could be considered from the same population (Pillsbury and Pryor 1988).

Therefore the three data sets were combined and the correction equation shown below was developed for adjusting standing tree cubic-foot volumes.

$$\text{Corrected volume } (ft^3) = 1.247236\ (\text{Standing volume } (ft^3))^{0.9750} \quad [5]$$

[N=93; R^2 = 0.983; Standard Error = 0.002 cubic feet]

A close examination of this equation shows that the standing tree measurement technique under-estimates the actual (felled) tree volume by about 8 percent. However, the high degree of correlation (R^2 = 0.98) between standing and felled tree volumes shows that volumes from standing trees could be adjusted by this equation to accurately represent felled volumes. This equation is species independent because the difference between standing and cut volumes is primarily a measure of the measurement technique and is not based on differences in species.

Equation [5] was modified to adjust board-foot volumes. The average ratio of board-foot to cubic-foot volume is about 5.5:1 for the sample trees measured in this study. Therefore, this ratio was also used to calculate the regression intercept for correcting board-foot volumes, equation [6].

$$\text{Corrected volume (bf)} = 1.301541\ (\text{Standing volume (bf)})^{0.9750} \quad [6]$$

Equations [5] and [6] were used in this study to adjust standing tree cubic-foot and board-foot volumes, respectively.

Error and Outlier Analysis

Several checks were made to determine if measurement and recording errors were present in the data set. We developed computer programs to "look" for possible errors in height and diameter measurements by checking to see if upper diameters were greater than lower diameters. Also, volume calculation errors, as well as other tree measurement errors, were detected by

statistical outlier analysis. This involved plotting and analyzing scatter plots of measured tree variables. For example, dbh was plotted against total volume and the standardized residuals were evaluated. This process detects large errors resulting from incorrect tree measurement, data recording, and data entry. Approximately 1 to 2 sample trees per species were removed from the data sets based on the error and outlier analysis. Trees dropped from the data set are noted on the listing shown in Appendix C.

VI. Volume Equation Development

Local and standard equations were developed in units of cubic feet and Scribner board feet for merchantable volume for each species. The following models were used to develop the equations.

$$\text{Local Volume:} \quad V = aD^b \qquad [7]$$

$$\text{Standard Volume:} \quad V = aD^bH^c \qquad [8]$$

where: V is the volume in cubic feet or board feet, D is dbhob (diameter breast height outside bark) in inches, H is total height in feet, or number of 16 ft. logs, and, a, b, and c are regression coefficients.

Multiple regression analysis was used to develop the volume equations. A logarithmic transformation of volume, dbh, and height was used to linearize the data and to equalize the variation about the regression line. The data were converted to the logarithmic form to compute the regression coefficients a, b, and c. This is the normal procedure when fitting nonlinear tree volume equations because the logarithmic form tends to reduce variance in homogeneous samples (Husch *et al.* 1982). From these equations local and standard volume tables were developed and are presented in the Appendix.

VII. Results of the Study

Local and standard volume equations (and tables) were developed for four species at Mountain Home Demonstration State Forest based on the utilization standards previously described. For all species, volume equations and tables were developed in English units for total and board-foot volume. All volume equations are listed in Tables 3 - 6; volume tables are in Appendix A. The values found in these tables were checked against tables of the same species from other areas in the Sierra-Nevada and were found to be reasonably close. Field testing should be conducted to ensure their accuracy.

VIII. Summary and Recommendations

Standard volume equations and tables, and local volume tables were developed for ponderosa pine, sugar pine, incense cedar, and white fir at Mountain Home Demonstration State Forest. It is recommended that volume equations and tables from this study be used for volume prediction for species at MHDSF based on the excellent correlation obtained from the statistical analysis discussed in this report.

These volume equations and tables will allow accurate assessment of tree and stand volumes for the four species at Mountain Home Demonstration State Forest. Moreover, they will provide the volume information necessary for periodic inventories, and implementation of specific management programs such as thinning prescriptions, timber harvesting, and growth and yield studies.

In addition to the benefits this information will have to MHDSF, publication of the data by the California Department of Forestry and Fire Protection will aid managers of federal and county lands having these species, as well as providing valuable baseline information to non-industrial private landowners involved in forest management.

Table 3. Local and Standard volume equations for young growth ponderosa pine at Mountain Home Demonstration State Forest.

Standard Volume Equations:

LOG RULE	EQUATION	R^2	N	SE
Smalian's (cu. ft.):	Volume = $0.0046019\ (DBH^{1.7648290})(HT^{0.951568})$	0.981	49	1.14
Scrib. 1 (bd. ft.):	Volume = $0.0011752\ (DBH^{2.1394300})(HT^{1.322741})$	0.973	47	1.21
Scrib. 2 (bd. ft.):	Volume = $0.1485371\ (DBH^{1.9722420})(NL^{1.187217})$	0.977	49	1.21

DBH in inches, HT is total height in feet, NL is number of 16' logs.

Local Volume Tables:

Local volume equations were developed using standardized height equations for Smalian's (cu. ft.) and Scrib. 1 (bf) volume equations shown above. The standard height equation for young growth ponderosa pine for both equations is: $HT = 4.8966 + 3.4022(dbh) + 0.023178(dbh)^2 - 0.00043708(dbh)^3$ for diameters in the range 10 - 50 inches.

Notes:

Ponderosa pine equations were developed from trees of diameter ranging from 10 to 50 inches.

Smalians (cu. ft.) = Total tree volume including all stem and branch wood plus stump and bark; excludes foliage and roots.

Scrib. 1 (bd. ft.) = Scribner board foot volume based dbh, and for standard volume equations, total tree height.

Scrib. 2 (bd. ft.) = Scribner board foot volume based on dbh and number of 16 foot logs to a 6" top.

R^2 = the multiple coefficient of determination.

N = the sample size.

SE = the standard error of the estimate in cubic feet or board feet.

Table 4. Local and Standard volume equations for young growth sugar pine at Mountain Home Demonstration State Forest.

Standard Volume Equations:

LOG RULE	EQUATION	R^2	N	SE
Smalian's (cu. ft.):	Volume = $0.0127581\ (DBH^{2.1151430})(HT^{0.485265})$	0.978	49	1.15
Scrib. 1 (bd. ft.):	Volume = $0.0042926\ (DBH^{2.4444710})(HT^{0.833562})$	0.961	49	1.26
Scrib. 2 (bd. ft.):	Volume = $0.1048716\ (DBH^{2.2772860})(NL^{0.790662})$	0.972	49	1.22

DBH in inches, HT is total height in feet, NL is number of 16' logs.

Local Volume Tables:

Local volume equations were developed using standardized height equations for Smalian's (cu. ft.) and Scrib. 1 (bf) volume equations shown above. The standard heights were determined by plotting dbh versus Total Height and graphically fitting the data by hand.

Notes:

Sugar pine equations were developed from trees of diameter ranging from 10 to 50 inches.

Smalians (cu. ft.) = Total tree volume including all stem and branch wood plus stump and bark; excludes foliage and roots.

Scrib. 1 (bd. ft.) = Scribner board foot volume based dbh, and for standard volume equations, total tree height.

Scrib. 2 (bd. ft.) = Scribner board foot volume based on dbh and number of 16 foot logs to a 6" top.

R^2 = the multiple coefficient of determination.

N = the sample size.

SE = the standard error of the estimate in cubic feet or board feet.

Table 5. Local and Standard volume equations for young growth incense cedar at Mountain Home Demonstration State Forest.

Standard Volume Equations:

LOG RULE	EQUATION	R^2	N	SE
Smalian's (cu. ft.):	Volume = 0.00758690 $(DBH^{1.750414})(HT^{0.838679})$	0.963	49	1.18
Scrib. 1 (bd. ft.):	Volume = 0.00104650 $(DBH^{1.935883})(HT^{1.480513})$	0.935	48	1.33
Scrib. 2 (bd. ft.):	Volume = 0.18773920 $(DBH^{1.986904})(NL^{0.938761})$	0.921	49	1.36

DBH in inches, HT is total height in feet, NL is number of 16' logs.

Local Volume Tables:

Local volume equations were developed using standardized height equations for Smalian's (cu. ft.) and Scrib. 1 (bf) volume equations shown above. The standard height equation for young growth incense cedar for both equations is: HT = 11.888 + 2.4996(dbh) for diameters in the range 10 - 50 inches.

Notes:

Incense cedar equations were developed from trees of diameter ranging from 10 to 50 inches.

Smalians (cu. ft.) = Total tree volume including all stem and branch wood plus stump and bark; excludes foliage and roots.

Scrib. 1 (bd. ft.) = Scribner board foot volume based dbh, and for standard volume equations, total tree height.

Scrib. 2 (bd. ft.) = Scribner board foot volume based on dbh and number of 16 foot logs to a 6" top.

R^2 = the multiple coefficient of determination.

N = the sample size.

SE = the standard error of the estimate in cubic feet or board feet.

Table 6. Local and Standard volume equations for young growth white fir at Mountain Home Demonstration State Forest.

Standard Volume Equations:

LOG RULE	EQUATION	R^2	N	SE
Smalian's (cu. ft.):	Volume = 0.01414750 $(DBH^{1.790957})(HT^{0.731500})$	0.952	52	1.20
Scrib. 1 (bd. ft.):	Volume = 0.02668300 $(DBH^{1.765320})(HT^{1.013663})$	0.973	50	1.16
Scrib. 2 (bd. ft.):	Volume = 0..39126230 $(DBH^{1.974737})(NL^{0.748537})$	0.968	52	1.19

DBH in inches, HT is total height in feet, NL is number of 16' logs.

Local Volume Tables:

Local volume equations were developed using standardized height equations for Smalian's (cu. ft.) and Scrib. 1 (bf) volume equations shown above. The standard height equation for young growth white fir for both equations is: $HT = 12.443 + 5.2795(dbh) - 0.04836(dbh)^2$ for diameters in the range 10 - 50 inches.

Notes:

White fir equations were developed from trees of diameter ranging from 10 to 50 inches.

Smalians (cu. ft.) = Total tree volume including all stem and branch wood plus stump and bark; excludes foliage and roots.

Scrib. 1 (bd. ft.) = Scribner board foot volume based dbh, and for standard volume equations, total tree height.

Scrib. 2 (bd. ft.) = Scribner board foot volume based on dbh and number of 16 foot logs to a 6" top.

R^2 = the multiple coefficient of determination.

N = the sample size.

SE = the standard error of the estimate in cubic feet or board feet.

IX. Literature Cited

Brickell, J. E. 1976. Bias and precision of the Barr and Stroud dendrometer under field conditions. USDA Forest Service, Resource Paper. INT-186. 46 p.

California Department of Forestry, 1986. *Mountain Home State Forest* , Forest Information Pamphlet.

Fowell H. A. 1965. Silvics of Forest Trees of the United States. Agriculture Handbook No. 271. USDA Forest Service. Washington, D. C. 762 p.

Griffin, James R. and William B. Critchfield. 1972. The distribution of forest trees in California. U. S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, PSW-82. 114 p.

Husch, B., C. I. Miller, and T. W. Beers. 1982. Forest Mensuration, 2nd edition. John Wiley and Sons, New York, NY. 402 p.

MacLean, C. and J. Berger. 1976. Conifer tree volume equations for major California species. Res. Note PNW-266. Portland, OR: U. S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 34 p.

Neter, John, William Wasserman and Michael H. Kunter. 1985. Applied Linear Statistical Models, 2nd Edition. Richard D. Irwin, Inc. 842 p.

Pillsbury, Norman H. and Michael L. Kirkley. 1984. Equations for total, wood, and saw-log volume for thirteen California hardwoods. Research Note. PNW-414, Berkeley, CA: U. S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 52 p.

Pillsbury, Norman H. and Robert D. Pryor. 1988. Biomass equations for *Quercus chrysolepis* in the San Bernardino Mountains of Southern California. U. S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Riverside, CA. 37 p.

Pillsbury, Norman H., and Michael J. DeLasaux. 1988. Young growth Sierra Redwood volume equations for Mountain Home Demonstration State Forest. California Department of Forestry and Fire Protection, Sacramento, CA. 86 p.

Pillsbury, Norman H. and Robert D. Pryor. 1989. Volume equations for young growth softwood and hardwood species at Boggs Mountain Demonstration State Forest. California Department of Forestry and Fire Protection, Sacramento, CA. 41 p.

Society of American Foresters, Committee on Forest Types. 1968. Forest Cover Types of Northern California (Exclusive of Mexico). 67 p.

Wensel, Lee C. 1977. Volume tables for young growth conifers in the Northern Regions of California. U. S. Department of Agriculture, Forest Service. Bulletin 1883. 43 p.

Appendix A

Local and Standard Volume Tables

LOCAL VOLUME TABLE

Mt. Home State Demonstration Forest

Table 7. Incense Cedar

Dbh (inches)	Standard Height	Total Volume (cubic feet)	Merch. Volume (Scrib. bf)
10	37	10.4	23
12	42	15.7	39
14	47	22.5	61
16	52	30.6	91
18	57	40.4	129
20	62	51.8	178
22	67	65.0	238
24	72	79.9	312
26	77	96.8	400
28	82	115.7	503
30	87	136.6	625
32	92	159.6	765
34	97	184.9	926
36	102	212.4	1109
38	107	242.2	1316
40	112	274.4	1549
42	117	309.1	1809
44	122	346.3	2098
46	127	386.1	2419
48	132	428.5	2771
50	137	473.6	3158

Note: Volumes calculated from equations in Table 5.

Table 8. Sugar Pine

Dbh (inches)	Standard Height	Total Volume (cubic feet)	Merch. Volume (Scrib. bf)
10	32	10.6	26
12	42	17.5	50
14	52	26.6	86
16	61	37.8	134
18	70	51.4	199
20	82	68.6	290
22	94	89.3	407
24	103	111.6	539
26	115	138.7	713
28	122	166.2	892
30	128	196.0	1093
32	131	226.4	1300
34	136	261.1	1549
36	139	296.8	1807
38	140	333.0	2069
40	143	373.9	2380
42	147	418.9	2734
44	149	464.0	3090
46	150	510.2	3455
48	152	560.8	3867
50	155	615.4	4331

Note: Volumes calculated from equations in Table 4.

LOCAL VOLUME TABLE

Mt. Horne State Demonstration Forest

Table 9. White Fir

Dbh (inches)	Standard Height	Total Volume (cubic feet)	Merch. Volume (Scrib. bf)
10	69	29.4	77
12	69	30.8	125
14	77	43.6	188
16	85	58.9	268
18	92	76.7	366
20	99	97.1	482
22	105	120.0	619
24	111	145.4	775
26	117	173.3	952
28	122	203.6	1150
30	127	236.3	1368
32	132	271.2	1606
34	136	308.2	1864
36	140	347.3	2141
38	143	388.3	2438
40	146	431.0	2748
42	149	475.4	3075
44	151	521.1	3417
46	153	568.1	3772
48	154	616.1	4139
50	156	664.9	4510

Note: Volumes calculated from equations in Table 6.

Table 10. Ponderosa Pine

Dbh (inches)	Standard Height	Total Volume (cubic feet)	Merch. Volume (Scrib. bf)
10	41	10.8	44
12	48	17.3	76
14	56	25.8	121
16	63	36.5	180
18	71	49.7	256
20	79	65.5	350
22	86	84.1	463
24	94	105.6	597
26	101	130.3	753
28	108	158.0	931
30	116	188.9	1131
32	123	223.2	1354
34	130	260.8	1600
36	137	301.7	1867
38	144	345.9	2155
40	150	393.3	2464
42	156	444.0	2791
44	162	497.6	3135
46	168	554.2	3493
48	173	613.6	3864
50	178	675.4	4248

Note: Volumes calculated from equations in Table 3.

Table 11. Standard volume table* for Incense Cedar in cubic feet.

Diameter breast-height outside bark (inches)	Total height (feet)													
	20	30	40	50	60	70	80	90	100	110	120	130	140	150
10	6	9	11	13	15	18								
12	9	12	15	18	21	24								
14	11	16	20	24	27	31	35	38						
16	14	20	25	30	35	39	44	48						
18	17	24	30	36	42	46	53	59	64	69				
20	21	29	36	44	51	57	64	70	77	83				
22	24	34	43	51	58	67	75	83	90	98				
24	28	39	49	59	69	78	87	95	103	113				
26	32	45	57	68	79	90	100	110	120	130	139	149		
28	37	51	64	77	90	102	113	125	136	147	158	169		
30	41	57	72	87	101	114	128	141	153	166	178	190		
32	46	64	81	97	113	128	143	157	171	185	199	212	225	
34	51	71	90	108	125	142	158	174	190	205	220	235	250	
36	56	78	99	119	138	156	174	192	208	226	243	259	275	291
38		86	108	130	151	171	191	210	229	248	266	284	302	320
40		94	118	142	165	187	209	230	250	271	291	310	330	349
42			129	154	179	203	227	250	272	294	316	337	358	379
44				167	194	220	245	270	295	318	342	365	388	410
46				180	209	237	265	292	318	343	369	394	418	443
48					225	255	283	314	342	369	397	424	450	476
50					241	274	305	336	366	395	425	454	482	510

* Volume (cubic feet) = 0.011 * [DBH^ 1.70] * Total Height ^ 0.810

Table 12. Standard volume table* for Ponderosa Pine in cubic feet.

Diameter breast-height outside bark (inches)	Total height (feet)														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
10	5	8	11	13	16	19									
12	7	11	14	18	22	25	29								
14	9	14	18	23	28	32	37	42							
16	11	17	23	29	34	40	46	52	58						
18	14	21	28	35	42	49	56	63	71	78					
20	16	24	33	43	50	58	67	75	84	92	101				
22	19	28	38	48	58	68	78	88	98	108	118	128			
24	22	33	44	55	67	78	90	101	113	124	136	148			
26	25	37	50	63	76	89	102	115	128	142	155	168	181		
28	28	42	57	71	86	101	115	130	145	160	175	190	205	220	
30		47	63	80	96	113	129	146	162	179	196	212	229	246	
32		52	70	89	107	125	143	162	180	199	217	236	255	273	292
34			78	98	118	138	158	179	199	219	240	260	281	302	322
36				107	129	151	174	196	218	241	263	286	308	331	354
38				117	141	165	190	214	239	263	288	312	337	362	386
40				127	154	180	206	233	259	286	313	339	366	393	420
42					166	195	223	252	281	310	339	368	397	426	455
44					179	210	241	272	303	334	365	397	428	459	491
46						226	259	292	326	359	393	426	460	494	528
48						242	278	313	349	385	421	457	493	529	565
50						259	297	335	373	412	450	488	527	566	604

* Volume (cubic feet) = 0.006 * DBH^ 1.831 * Total Height ^ 1.026

Table 13. Standard volume table* for Sugar Pine in cubic feet.

Diameter breast-height outside bark (inches)	Total height (feet)															
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
10	8	10	12	13	14	15										
12	12	15	17	19	21	22										
14	17	20	23	26	28	31	33	34	36							
16	22	27	31	34	37	40	43	45	48	50						
18	28	34	39	44	48	51	55	58	61	64	66					
20	35	43	49	54	59	64	68	72	76	79	82					
22	43	52	60	66	72	78	83	88	92	96	100	104	108			
24	51	62	71	79	86	93	99	105	110	115	120	125	129			
26	61	73	84	94	102	110	117	124	130	136	142	147	152	157	162	
28	71	86	98	109	119	128	136	144	151	158	165	171	177	183	189	
30	81	99	113	126	137	147	157	166	174	182	190	197	205	211	218	
32	93	113	129	144	156	168	179	190	199	208	217	226	234	241	241	256
34		128	146	163	177	191	203	215	226	236	246	256	265	274	282	290
36		144	165	183	199	215	229	242	254	266	277	288	298	308	317	327
38			184	205	223	240	256	270	284	297	310	322	333	344	355	365
40				227	248	267	284	300	316	330	344	357	370	382	394	406
42					274	295	314	332	349	365	381	395	409	423	436	449
44							346	366	385	402	419	435	451	465	480	494
46								403	421	441	459	477	494	510	526	541
48								437	460	481	501	521	539	557	574	591
50								474	500	523	545	566	586	606	625	643

* Volume (cubic feet) $0.010 * DBH^{2.062} * Total\ Height^{0.473}$

Table 14. Standard volume table* for White Fir in cubic feet.

Diameter breast-height outside bark (inches)	Total height (feet)														
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
10	19	18	20	23	25	27	29								
12	21	24	28	31	34	37	40	43							
14	27	33	37	41	45	49	53	56	60						
16	35	40	46	51	57	62	66	71	76	80					
18	42	50	57	63	70	76	82	87	93	98					
20	51	60	68	76	84	91	98	105	112	118	125				
22	60	71	80	90	99	107	116	124	132	140	147				
24	70	82	94	104	115	125	135	144	153	162	171				
26	81	94	108	120	132	144	156	166	176	187	197	207	217		
28	92	108	122	137	150	164	176	189	201	213	224	235	247		
30	103	121	138	154	170	184	198	213	227	240	253	266	278	290	
32		136	155	173	190	206	223	238	254	268	283	297	311	325	
34			172	192	211	230	247	266	282	298	315	330	346	362	376
36				212	233	254	273	293	311	330	348	365	382	399	416
38				233	256	279	301	322	342	362	382	401	420	439	457
40				255	280	305	329	353	374	396	418	439	460	480	500
42					305	332	358	383	408	432	455	478	500	523	544
44						360	388	416	442	469	493	518	543	567	590
46						389	420	449	478	506	533	560	587	613	638
48							452	484	515	545	574	603	632	660	687
50							485	519	553	585	617	648	679	709	738

* Volume (cubic feet) = 0.020 * DBH^ 1.746 * Total Height ^ 0.713

Table 15. Standard volume table* for Incense Cedar in Scribner board feet.

Diameter breast-height outside bark (inches)	Total height (feet)													
	20	30	40	50	60	70	80	90	100	110	120	130	140	150
10	9	17	26	35	46	57								
12	13	24	36	50	65	81								
14	18	32	48	67	87	108	131	156						
16	23	41	62	86	112	139	169	200						
18	29	51	78	107	140	176	211	250	291	334				
20	35	63	95	131	170	213	258	305	356	408				
22	42	75	114	157	204	255	309	366	424	488				
24	49	88	134	185	240	300	364	431	502	576				
26	57	103	156	215	280	349	423	502	584	670	759	852		
28	66	118	179	247	322	402	487	577	672	770	873	980		
30	75	135	204	282	366	458	555	657	765	878	995	1117		
32	85	152	231	318	414	517	627	743	864	992	1124	1262	1404	
34	95	171	259	357	464	580	703	833	969	1112	1261	1415	1574	
36	106	190	288	398	517	646	783	928	1080	1239	1404	1576	1754	1937
38		211	319	440	573	715	867	1027	1196	1372	1556	1746	1943	2146
40		232	352	485	631	788	955	1132	1318	1512	1714	1923	2140	2364
42			386	532	692	864	1048	1241	1445	1658	1879	2109	2347	2591
44				581	756	944	1144	1355	1578	1810	2052	2303	2563	2831
46				632	822	1026	1244	1474	1716	1969	2232	2505	2787	3079
48					891	1112	1348	1598	1860	2134	2419	2715	3021	3337
50					962	1201	1456	1726	2009	2305	2613	2933	3263	3604

* Volume (board feet) = 0.002 * DBH^1.890 * Total Height ^ 1.442

Table 16. Standard volume table* for Ponderosa Pine in Scribner board feet.

Diameter breast-height outside bark (inches)	Total height (feet)														
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
10	11	18	26	34	43	53									
12	15	25	38	50	64	78	92								
14	21	36	52	69	88	107	127	148							
16	28	47	69	91	116	141	168	195	224						
18	36	60	88	117	148	180	214	249	286	323					
20	45	75	109	144	184	225	267	311	356	403	450				
22	54	92	133	178	225	274	326	379	434	491	549	609			
24	65	110	160	213	269	328	390	454	520	589	658	730			
26	77	130	189	251	318	388	461	537	615	695	778	863	949		
28	90	152	220	293	371	452	538	626	718	811	906	1007	1108	1211	
30		175	254	339	429	523	621	723	828	937	1048	1162	1279	1398	
32		200	291	388	490	598	711	827	948	1072	1199	1329	1463	1599	1738
34			330	440	556	678	806	939	1075	1216	1360	1508	1660	1814	1972
36				495	627	765	908	1057	1211	1370	1533	1699	1870	2044	2221
38				554	701	856	1017	1183	1356	1533	1715	1902	2093	2288	2486
40				617	781	952	1131	1317	1509	1706	1909	2116	2329	2546	2767
42					864	1054	1252	1458	1670	1889	2113	2343	2578	2818	3063
44					952	1161	1380	1606	1840	2081	2328	2581	2840	3105	3374
46						1274	1514	1762	2019	2283	2554	2832	3116	3406	3702
48						1392	1654	1925	2208	2494	2791	3098	3405	3722	4045
50						1516	1801	2096	2402	2716	3039	3369	3707	4052	4404

* Volume (board feet) = 0.002 * DBH^ 2.084 * Total Height ^ 1.290

Table 17. Standard volume table* for Sugar Pine in Scribner board feet.

Diameter breast height outside bark (inches)	Total height (feet)															
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
10	18	25	31	37	43	49										
12	28	38	48	58	67	75										
14	40	56	70	83	96	109	121	133	145							
16	55	76	96	115	133	150	167	183	199	215						
18	73	101	127	152	176	199	221	243	264	285	305					
20	94	130	164	196	226	256	285	313	340	367	393					
22	119	164	206	246	285	322	358	393	427	461	494	526	558			
24	146	202	254	303	351	396	441	484	526	568	609	649	688			
26	177	245	308	367	425	480	534	586	638	688	737	786	833	880	927	
28	212	293	367	439	507	573	638	700	762	822	880	938	995	1052	1107	
30	250	345	433	518	598	677	752	826	898	969	1039	1107	1174	1241	1306	
32	291	402	506	604	699	790	878	964	1049	1131	1212	1292	1371	1448	1524	1600
34		465	585	699	808	913	1015	1115	1213	1308	1402	1494	1585	1674	1762	1850
36		534	671	801	926	1047	1165	1279	1391	1500	1608	1714	1818	1920	2021	2121
38			764	912	1054	1192	1326	1456	1583	1708	1830	1951	2069	2186	2301	2415
40				1033	1192	1348	1499	1646	1790	1931	2070	2206	2340	2472	2602	2731
42					1340	1515	1685	1850	2013	2171	2326	2479	2630	2778	2925	3068
44							1884	2069	2250	2427	2601	2772	2940	3106	3270	3431
46								2301	2502	2700	2893	3083	3271	3455	3637	3817
48								2548	2771	2989	3204	3414	3622	3826	4028	4227
50								2810	3056	3297	3533	3765	3994	4219	4442	4661

* Volume (board feet) 0.007 * DBH^2.396 * Total Height ^ 0.796

Table 18. Standard volume table* for White Fir in Scribner board feet.

Diameter breast-height outside bark (inches)	Total height (feet)														
	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
10	51	64	76	89	102	114	127								
12	73	91	109	127	145	163	181	199							
14	98	123	147	171	196	220	244	268	292						
16	128	159	191	222	254	285	317	348	379	410					
18	161	200	240	280	319	359	398	438	477	516					
20	197	246	295	343	392	440	489	537	586	634	682				
22	238	296	355	413	472	530	589	647	705	763	821				
24	281	351	420	490	559	628	697	765	835	904	973				
26	328	410	491	572	653	734	815	896	976	1057	1137	1218	1298		
28	380	474	568	661	755	848	941	1035	1128	1221	1314	1407	1499		
30	435	542	649	756	863	970	1077	1183	1290	1396	1503	1609	1715	1821	
32		615	736	858	979	1100	1221	1342	1463	1583	1704	1824	1945	2065	
34			825	965	1102	1238	1374	1510	1646	1782	1917	2053	2188	2324	2459
36				1079	1231	1384	1536	1688	1840	1992	2143	2295	2446	2598	2749
38				1199	1368	1537	1706	1875	2044	2213	2381	2550	2718	2886	3054
40				1325	1512	1699	1886	2072	2259	2445	2631	2817	3003	3189	3375
42					1663	1868	2074	2279	2484	2689	2894	3098	3303	3507	3711
44						2045	2270	2495	2720	2944	3168	3392	3616	3840	4063
46						2230	2476	2721	2966	3210	3455	3699	3943	4187	4431
48							2690	2956	3222	3488	3753	4019	4284	4549	4814
50							2912	3201	3489	3776	4064	4351	4638	4925	5212

* Volume (board feet) = 0.015 * DBH^ 1.988 * Total Height ^ 0.990

Table 19. Standard volume table* for Incense Cedar in Scribner board feet.

Diameter breast-height outside bark (inches)	Number of 16 foot logs													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
10	22	42	60	78	96	113								
12	31	59	86	111	137	161								
14	42	80	115	150	184	217	250	283						
16	55	103	150	195	239	282	324	367						
18	69	130	188	245	300	354	408	461	513	565				
20	85	159	231	300	368	434	500	565	629	693				
22	102	192	278	361	443	523	602	680	757	834				
24	120	227	329	427	524	619	712	805	896	987				
26	141	265	384	498	612	723	832	940	1047	1153	1258	1362		
28	162	306	443	576	707	835	961	1085	1209	1331	1452	1572		
30	186	350	507	659	808	954	1098	1241	1382	1522	1660	1797		
32	210	396	574	747	916	1081	1245	1407	1566	1725	1881	2037	2192	
34	237	446	646	840	1030	1216	1400	1582	1762	1940	2116	2291	2465	
36	265	498	722	938	1151	1359	1565	1768	1968	2167	2363	2560	2754	2947
38		553	801	1042	1278	1509	1738	1963	2186	2407	2626	2843	3059	3273
40		611	885	1151	1412	1667	1920	2169	2415	2659	2901	3141	3379	3616
42			973	1266	1552	1833	2110	2384	2655	2923	3189	3452	3714	3974
44				1385	1698	2006	2309	2609	2905	3199	3490	3779	4065	4350
46				1510	1851	2187	2517	2844	3167	3487	3804	4119	4431	4742
48					2011	2375	2734	3089	3440	3787	4132	4473	4813	5150
50					2176	2571	2960	3343	3723	4099	4472	4842	5209	5574

* Volume (Board feet) = 0.253 * DBH² * 1.540 * No. 16' logs ^ 0.913

Table 20. Standard volume table* for Ponderosa Pine in Scribner board feet.

Diameter breast-height outside bark (inches)	Number of 16 foot logs														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	18	30	48	78	95	151									
12	26	58	83	113	144	174	205								
14	35	74	114	155	196	238	280	323							
16	46	97	149	202	256	311	367	422	479						
18	59	123	189	257	325	395	465	536	607	679					
20	73	152	234	317	402	488	575	663	753	840	930				
22	88	184	284	385	488	592	697	803	910	1018	1127	1236			
24	105	220	338	459	581	706	831	958	1085	1214	1343	1473			
26	124	258	397	539	683	829	977	1125	1275*	1426	1578	1731	1885		
28	144	300	461	626	793	963	1134	1307	1481	1657	1833	2010	2189	2368	
30		345	530	720	912	1107	1304	1502	1702	1904	2107	2311	2516	2722	
32		393	604	820	1039	1261	1485	1711	1939	2169	2400	2632	2866	3100	3336
34			683	926	1174	1425	1678	1934	2192	2451	2712	2975	3239	3504	3770
36				1040	1318	1599	1884	2170	2460	2751	3044	3338	3635	3932	4233
38				1160	1470	1783	2101	2421	2743	3068	3395	3723	4054	4386	4719
40				1286	1630	1978	2330	2685	3042	3403	3765	4129	4496	4864	5234
42					1798	2183	2571	2963	3357	3755	4155	4557	4961	5367	5775
44					1976	2398	2824	3254	3688	4124	4563	5005	5449	5895	6344
46						2623	3089	3560	4034	4511	4992	5475	5961	6449	6939
48						2858	3366	3879	4396	4916	5439	5966	6495	7027	7561
50						3103	3655	4212	4773	5338	5907	6478	7053	7630	8210

* Volume (board feet) = 0.173 * DBH^ 2.018 * No. 16' logs ^ 1.062

Table 21. Standard volume table* for Sugar Pine in Scribner board feet.

Diameter breast-height outside bark (inches)	Number of 16 foot logs																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
10	24	41	56	69	82	94											
12	36	61	84	104	123	141											
14	51	87	118	147	174	200	224	248	271								
16	69	117	159	198	234	269	302	335	366	396							
18	90	152	207	257	305	350	393	435	476	516	554						
20	114	193	262	326	386	443	498	551	603	653	702						
22	141	238	324	403	478	548	616	682	746	808	868	928	986				
24	171	290	394	490	580	666	749	829	906	981	1055	1127	1197				
26	205	346	471	586	694	797	896	991	1084	1174	1262	1348	1432	1515	1596		
28	242	409	556	692	819	941	1057	1170	1279	1386	1489	1591	1690	1788	1884		
30	282	477	649	807	956	1098	1234	1365	1493	1617	1738	1856	1973	2087	2199		
32	326	551	750	932	1104	1268	1425	1577	1724	1868	2008	2145	2279	2411	2540	2667	
34		631	859	1068	1265	1452	1632	1806	1975	2139	2299	2456	2610	2761	2909	3055	
36		717	976	1214	1437	1650	1855	2053	2244	2431	2613	2791	2966	3137	3306	3472	
38			1101	1370	1622	1862	2093	2316	2533	2743	2919	3150	3347	3541	3731	3918	
40				1536	1819	2089	2348	2598	2841	3077	3306	3533	3754	3971	4184	4394	
42					2029	2330	2619	2898	3168	3432	3689	3941	4187	4429	4667	4901	
44							2906	3216	3516	3808	4094	4373	4646	4915	5179	5439	
46								3552	3883	4206	4522	4830	5132	5429	5720	6007	
48								3906	4271	4627	4973	5312	5645	5971	6292	6607	
50								4280	4680	5069	5449	5820	6185	6542	6893	7239	

* Volume (board feet) = 0.140 * DBH² 2.237 * No. 16' logs ^ 0.758

Table 22. Standard volume table* for White Fir in Scribner board feet.

Diameter breast-height outside bark (inches)	Number of 16 foot logs														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
10	44	73	98	121	142	162	181								
12	63	104	139	172	202	230	258	284							
14	84	139	187	231	272	310	347	382	417						
16	109	180	242	299	351	401	449	494	539	582					
18	136	226	304	375	441	503	563	620	676	730					
20	167	277	372	459	540	616	690	760	828	894	958				
22	201	333	447	551	648	741	829	913	995	1074	1151				
24	238	393	529	652	767	876	980	1080	1176	1270	1362				
26	277	459	617	760	895	1022	1143	1260	1373	1482	1589	1692	1794		
28	320	530	711	877	1032	1178	1318	1453	1583	1709	1832	1952	2069		
30	365	605	812	1002	1179	1346	1506	1660	1808	1952	2093	2230	2363	2494	
32		685	920	1134	1335	1524	1705	1879	2048	2211	2370	2525	2676	2825	
34			1034	1275	1500	1713	1916	2112	2301	2485	2663	2837	3008	3174	3338
36				1423	1674	1912	2139	2358	2569	2774	2973	3168	3358	3544	3726
38				1580	1858	2122	2374	2617	2851	3078	3299	3515	3726	3933	4135
40				1744	2051	2342	2621	2888	3147	3398	3642	3880	4113	4341	4565
42					2253	2573	2879	3173	3457	3733	4001	4263	4518	4769	5015
44						2814	3149	3470	3781	4083	4376	4662	4942	5216	5485
46						3066	3430	3781	4119	4448	4767	5079	5384	5682	5975
48							3723	4104	4471	4828	5174	5513	5844	6168	6486
50							4028	4439	4837	5222	5598	5964	6322	6672	7016

* Volume (board feet) = 0.521 * DBH^ 1.926 * No. of 16' logs 0.728

Appendix B

Sample Volume Calculation Worksheet

TABLE 23. COMPUTE TREE CUBIC AND BOARD-FOOT VOLUME

Species: SP

Tree Number: 1

Basal area = D^2 (in inches) x 0.005454

Regression coefficients for Dib vs. Dob:
a = 0.62453
b = 0.85715

Dbhob (in) = 36.0
Total Ht (ft) = 121.95
Horiz Dist (ft) = 99
Dob at 1' (in) = 43.8
Slit Dir = 0

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Tree Height	Relascope Height Reading	Dob (in)	Cumul. Height (feet)	Angle (deg.)	Segment Number	Segment Length (ft)	Dib (in)	Average Seg. BAib (sq. ft.)	Unadj. Gross Vol (ib) (cu. ft.)	Segment Length (ft)	Rate of Segment Taper (in/ft)	Log #	Upper Dib (in)	Scale Length (even feet)	Scale Dib (in)	Unadj. Board foot Volume (Scribner)	Unadj. Board foot Volume (Int'l 1/4")
Base	3.8	x	0.0		x	x	38.2	x	x	x	x	x	x	x	x	x	x
4.5'	x	38.6	4.5		x	x	35.7	x	x	x	x	x	x	x	x	x	x
17.3	5.4	36.0	13.8		1	13.8	31.5	6.675	92.12	13.8	0.24	1.0	30.1	16.0	30	647	674
MP1	22.4	28.0	39.3		2	25.5	24.6	4.558	111.66	25.5	0.27	2.0	26.0	16.0	26	478	501
MP2	38.0	22.0	62.7		3	23.4	18.5	2.588	62.91	23.4	0.22	3.0	22.2	16.0	22	334	350
MP3	53.5	16.0	86.0		4	23.2	14.3	1.596	37.10	23.2	0.22	4.0	18.5	16.0	18	243	260
MP4	64.0	12.0	101.7		5	15.8	10.5	0.855	13.94	15.8	0.27	5.0	14.9	16.0	15	143	157
MP5	68.0	8.0	107.7		6	6.0	5.8	0.416	2.49	6.0	0.66	6.0	11.3	16.0	11	69	80
MP6			--		0	--	--	--	--	--	0.66	7.0	6.1	6.0	6	4	3
MP7			--		0	--	--	--	--	--	--	0.0	0.0	0.0	0	--	--
MP8			--		0	--	--	--	--	--	--	0.0	0.0	0.0	0	--	--
MP9			--		0	--	--	--	--	--	--	0.0	0.0	0.0	0	--	--
Tip	77.5	0.0	122.0		7	14.3	0.9	0.050	0.86	107.7				102.0		1918	2026

Tot. Ht (ft) = 122.0

Cubic feet = 320.52

Cubic meters = 9.08

Notes:

Col. 5: Used for leaning trees; angle from vertical.

Col. 8: a) Base Dib is computed one of two ways:
1) the Dob at 1-foot and regression relationship, or,
2) by calculating the rate of taper between 4.5' & 17.3' and extrapolating to ground level.
b) DBHib = DBHob - 2(SBT). E.g., 33.5-2(2.5) = 28.5"
c) Other Dib values are calculated from the species Dib vs. Dob regression coefficients.

Col. 10: a) Volume is computed by Smalian's formula, V=((b+B)/2)xL, where b & B are basal areas at the small & large ends, and L is the segment length.
b) Volume of the tip is computed as a cone, V = (B x L)/3. c) Volume is cubic feet to a 0-inch top, excluding bark.

Col. 14: Upper Dib is calculated by interpolating diameters to specified stem lengths (17.5, 34, 50.5, 67, 83.5, 100, 116.5, 133, etc.).

Col. 15: Logs are calculated to even 2-foot lengths; minimum length of 6'. Trim is prorated at 6" per 16' length.

Col. 16: Scale diameters are small end, inside bark to nearest inch.

Col. 17: Scribner board foot volume to a 6" top calculated by: V = (0.710^2.2D-4) x L/16, or by using Scribner log rule (table form).

Col. 18: International 1/4" board foot volume to a 6" top. Log length calculated by Col. 15. Volume = 0.905(0.220^2-.71D) for 4 foot sections.

Appendix C

Tree Data

Table 24. Incense Cedar Data

Tree No.	Dbh(ob) (inches)	Tot. Ht. (feet)	Tot. Vol. Smalian (cu. feet)	Merch. Vol. Scribner (bd. feet)	No. 16' Logs
1	17.2	49.8	48	186.8	2
2	17.1	60.9	38	114.9	2
3	32.8	71.2	184	921.8	3
4	18.2	47.1	27	59.0	2
5	26.9	67.0	81	284.5	3
6	12.8	51.5	25	94.5	2
7	25.9	70.0	76	269.1	3
8	37.3	109.8	245	1320.9	5
9	23.2	44.8	45	140.8	1
10	20.0	45.5	42	121.7	2
11	20.7	52.9	61	230.2	2
12	24.5	44.0	63	161.0	2
13	39.2	133.7	303	1594.4	7
14	22.1	61.5	63	252.4	2
15	24.5	57.2	80	322.1	2
16	32.2	75.0	121	415.4	3
17	11.7	49.3	19	54.4	2
18	24.0	81.0	83	377.0	4
19	11.4	42.8	15	24.2	1
20	14.1	59.5	25	79.6	2
21	18.6	63.2	38	128.4	3
22	31.5	108.8	156	730.3	5
23	43.6	129.0	375	1846.6	6
24	33.9	131.0	273	1462.0	6
25	35.7	117.3	251	1405.8	6
26	28.8	79.3	103	435.1	3
27	35.5	77.5	183	912.1	3
28	28.5	78.7	118	598.4	3
29	27.2	63.6	65	225.8	3
30	28.0	75.3	95	428.5	3
31	26.1	95.3	90	425.2	4
32	25.5	83.3	93	423.0	4
33	21.6	61.1	61	281.2	2
34	35.1	95.3	236	1266.7	4
35	21.3	98.8	93	440.5	4
36	15.9	42.1	24	48.6	1
37	31.7	121.7	201	1179.4	6
38	13.3	57.6	30	139.7	2
39	18.5	77.5	58	243.6	3
40	25.5	76.7	96	411.0	3
41	26.3	87.9	78	269.1	3
42	22.8	61.2	55	185.7	2
43	18.2	54.5	33	87.6	2
44	46.8	115.5	414	2699.8	6
45	19.3	61.8	45	145.3	2
46	32.3	103.3	195	993.6	5
47	28.2	86.0	108	454.7	3
48	23.3	67.4	78	333.1	3
49	29.8	85.5	140	673.1	4
50	26.1	71.2	93	444.9	3

NOTE: Shaded numbers were determined to be outliers and were dropped from the sample.

Table 25. Ponderosa Pine Data

Tree No.	Dbh(ob) (inches)	Tot. Ht. (feet)	Tot. Vol. Smalian (cu. feet)	Merch. Vol. Scribner (bd. feet)	No. 16' Logs
1	10.9	47.1	14.1	29	2
2	24.4	70.7	85.7	353	3
3	26.5	129.3	137.7	668	7
4	16.9	72.8	44.1	154	3
5	22.2	80.5	79.7	318	3
6	22.2	67.3	67.1	248	3
7	25.9	87.5	107.2	510	4
8	15.9	58.8	35.4	110	2
9	14.3	58.9	24.8	64	2
10	23.5	112.4	119.2	584	5
11	37.6	132.3	369.7	2279	7
12	35.3	137.0	288.7	1639	7
13	44.9	159.8	563.8	3637	8
14	28.8	123.9	207.6	1166	6
15	29.9	109.1	167.7	847	5
16	15.1	71.0	48.8	199	3
17	36.4	139.8	325.6	2040	7
18	20.7	87.3	90.8	427	4
19	19.4	81.8	52.2	172	3
20	11.9	60.2	22.9	72	2
21	20.2	90.1	69.1	269	4
22	32.0	127.1	199.7	1131	6
23	17.6	80.0	56.1	210	3
24	30.5	113.6	202.0	1138	6
25	37.1	149.9	377.6	2315	7
26	39.9	152.7	414.9	2820	7
27	15.0	46.9	32.5	104	2
28	21.0	79.1	61.6	238	3
29	17.7	67.4	44.2	159	3
30	16.5	70.5	43.0	195	3
31	20.3	73.8	71.2	281	3
32	26.1	97.1	121.1	566	4
33	19.1	69.6	49.8	181	3
34	21.7	101.0	89.2	384	4
35	22.7	89.6	109.2	553	5
36	29.5	123.2	264.1	1438	6
37	29.8	103.2	173.7	890	5
38	25.5	93.9	113.0	594	4
39	23.5	185.9	167.9	932	8
40	24.4	70.1	72.8	334	3
41	21.6	68.5	58.6	200	3
42	34.1	133.5	275.2	1570	6
43	29.9	103.5	151.6	784	5
44	33.7	147.0	288.9	1745	7
45	15.7	76.6	41.0	150	3
46	19.7	86.7	65.9	280	4
47	45.5	163.2	454.9	2823	8
48	34.2	142.7	251.6	1396	7
49	16.0	43.1	20.7	36	1
50	28.0	107.3	163.9	995	6

NOTE: Shaded numbers were determined to be outliers and were dropped from the sample.

Table 26. Sugar Pine Data

Tree No.	Dbh(ob) (inches).	Tot. Ht. (feet)	Tot. Volume Smalian (cu. feet)	Merch. Vol. Scribner (bd. feet)	No. 16' Logs
1	38.6	122.0	346	2066.5	6
2	46.1	169.6	556	3861.6	9
3	40.0	136.2	343	1985.6	6
4	20.0	69.7	51	146.4	3
5	28.9	139.2	170	848.8	7
6	27.4	104.3	120	568.0	4
7	21.5	91.0	96	499.5	4
8	17.6	64.4	43	167.8	3
9	24.5	114.5	132	715.2	5
10	46.6	131.0	421	2512.8	7
11	15.0	81.6	45	208.0	4
12	33.2	136.1	255	1433.4	7
13	35.4	137.7	311	1861.4	7
14	38.3	143.9	316	1785.5	7
15	26.1	120.5	151	792.8	5
16	23.7	119.9	135	707.7	6
17	18.8	70.5	53	211.3	3
18	14.0	70.1	29	95.6	2
19	12.2	33.6	19	49.8	2
20	13.2	52.1	23	62.5	2
21	17.4	50.2	35	99.0	1
22	11.3	45.6	18	48.6	2
23	30.9	113.9	203	1138.9	5
24	36.7	143.6	347	2157.8	7
25	22.8	83.9	89	407.7	4
26	35.8	137.6	305	1791.8	7
27	29.6	144.5	247	1502.3	7
28	18.1	69.5	52	185.7	2
29	28.9	138.3	167	942.1	6
30	25.9	119.1	111	541.9	4
31	17.1	82.3	43	128.4	3
32	13.2	67.3	28	121.7	2
33	33.4	136.4	254	1537.2	7
34	29.9	129.8	190	1044.9	6
35	19.7	88.4	69	294.5	4
36	27.6	121.9	149	853.1	6
37	31.6	135.0	252	1596.5	6
38	23.1	121.7	121	630.9	5
39	15.9	56.9	29	112.6	2
40	16.0	71.0	45	183.4	3
41	21.0	89.0	68	284.5	4
42	24.2	103.5	131	681.7	5
43	21.0	60.5	100	541.9	5
44	37.3	80.1	288	1701.1	5
45	28.9	104.2	138	729.2	4
46	30.6	131.3	228	1344.3	6
47	19.3	76.9	55	223.6	3
48	32.3	121.5	241	1451.4	6
49	23.8	102.8	92	428.5	4
50	27.5	129.2	142	770.2	7

NOTE: Shaded numbers were determined to be outliers and were dropped from the sample.

Table 27. White Fir Data

Tree No.	Dbh(ob) (inches)	Tot. Ht. (feet)	Tot. Vol. Smalian (cu. feet)	Merch. Vol. Scribner (bd. feet)	No. 16' Logs
1	15.3	99.9	54.2	212	4
2	16.2	71.0	59.1	297	3
3	27.5	109.4	195.2	1081	5
4	15.7	66.7	46.8	166	2
5	29.4	143.9	251.8	1421	7
6	12.3	88.7	37.5	144	4
7	38.6	116.0	346.1	2066	6
8	28.4	155.0	267.7	1586	7
9	24.2	117.6	118.6	566	5
10	11.2	57.7	27.5	104	2
11	34.2	159.3	351.6	2063	8
12	25.3	105.9	144.9	735	5
13	45.6	188.3	780.4	5106	10
14	22.1	133.8	165.7	912	6
15	19.2	120.8	89.0	441	5
16	21.4	126.3	140.9	784	6
17	13.8	93.5	48.2	208	4
18	30.4	129.9	296.4	1750	6
19	38.2	140.0	400.8	2393	7
20	31.7	120.9	257.0	1376	6
21	32.8	102.4	268.8	1275	5
22	40.1	149.0	509.6	3247	8
23	39.4	115.3	364.7	2045	6
24	26.2	118.1	155.9	819	6
25	31.4	154.8	342.8	2110	8
26	16.9	77.1	59.9	289	4
27	16.9	87.9	68.8	298	4
28	35.0	136.8	338.5	1981	7
29	45.6	155.6	507.6	3009	8
30	22.8	104.4	153.8	852	5
31	13.0	64.6	41.3	188	2
32	17.9	92.1	67.5	297	4
33	24.0	92.7	125.3	660	4
34	22.4	116.4	134.7	754	5
35	31.5	113.6	227.8	1352	5
36	16.8	86.4	71.9	365	4
37	25.9	82.4	129.5	689	4
38	37.1	138.8	342.6	2120	6
39	20.6	120.0	140.2	797	6
40	29.2	131.0	88.8	1464	6
41	32.7	142.4	327.7	1995	7
42	24.5	99.9	115.9	534	5
43	22.9	104.2	121.1	622	5
44	15.0	71.1	47.6	219	3
45	20.3	99.0	87.9	436	4
46	26.9	103.1	147.1	753	4
47	29.5	126.8	281.0	1716	6
48	32.2	111.8	225.6	1185	5
49	26.6	120.8	204.5	1185	6
50	32.6	120.0	263.4	1485	6
51	28.9	129.3	210.1	1177	6
52	35.7	158.1	415.8	2611	8
53	16.0	88.3	57.3	261	3