AN ABSTRACT OF THE THESIS OF

Robert Steven Giles for the degree of Master of Forestry in Forest Engineering presented on May 1, 1986.

Title: LOGCOST a Harvest Cost Model for Southwestern Idaho.

Abstract approved: J Sessions
Dr. Julian Sessions

LOGCOST is an interactive computer program that predicts stump to mill logging costs, stumpage and net present value of a harvest based on stand data, pond value and logging parameters, entered by the user. The program is intended for use by foresters to evaluate the economics of different stand management strategies. It is also useful in deciding whether commercial thinning of existing stands is profitable. The current version is designed for use in southwestern Idaho, but minor changes could be made which would extend the applicability to other parts of the USDA, Forest Service, Intermountain Region.

Approximately two minutes is required to enter data, and program execution takes approximately 15 seconds, using an IBM Personal Computer. LOGCOST is compiled in BASIC and

will run on microcomputers that have at least 256K RAM and are IBM compatible. Documentation of the model and a Users' Guide are included in the Appendices.

Felling and bucking, as well as yarding production, computed by LOGCOST compared favorably with other studies. Stump to truck logging costs are significantly lower than the cost estimated by the Intermountain Region Timber Appraisal Handbook.

Preliminary testing of this harvest cost model, using stand data from the Boise National Forest in southwestern Idaho, suggests that the model is sensitive to such variables as tree size, species, volume per acre cut, logging system, terrain, and distance to the mill.

Differences in thinning intensity, and past stand history (precommercial thinning) also result in differences in harvest cost per mbf, when modeled by LOGCOST. The results of alternative stand management strategies tested suggest that precommercial thinning may be necessary to produce profitable stands on average sites, if rotations less than 100 years are desired.

LOGCOST A HARVEST COST MODEL
FOR SOUTHWESTERN IDAHO

by

Robert Steven Giles

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I also thank my wife Kathleen and children, Karen and Steven, for their moral support and patience throughout this project.

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Harvesting Factors Affecting Financial Feasibility of Thinning in Southwestern Idaho

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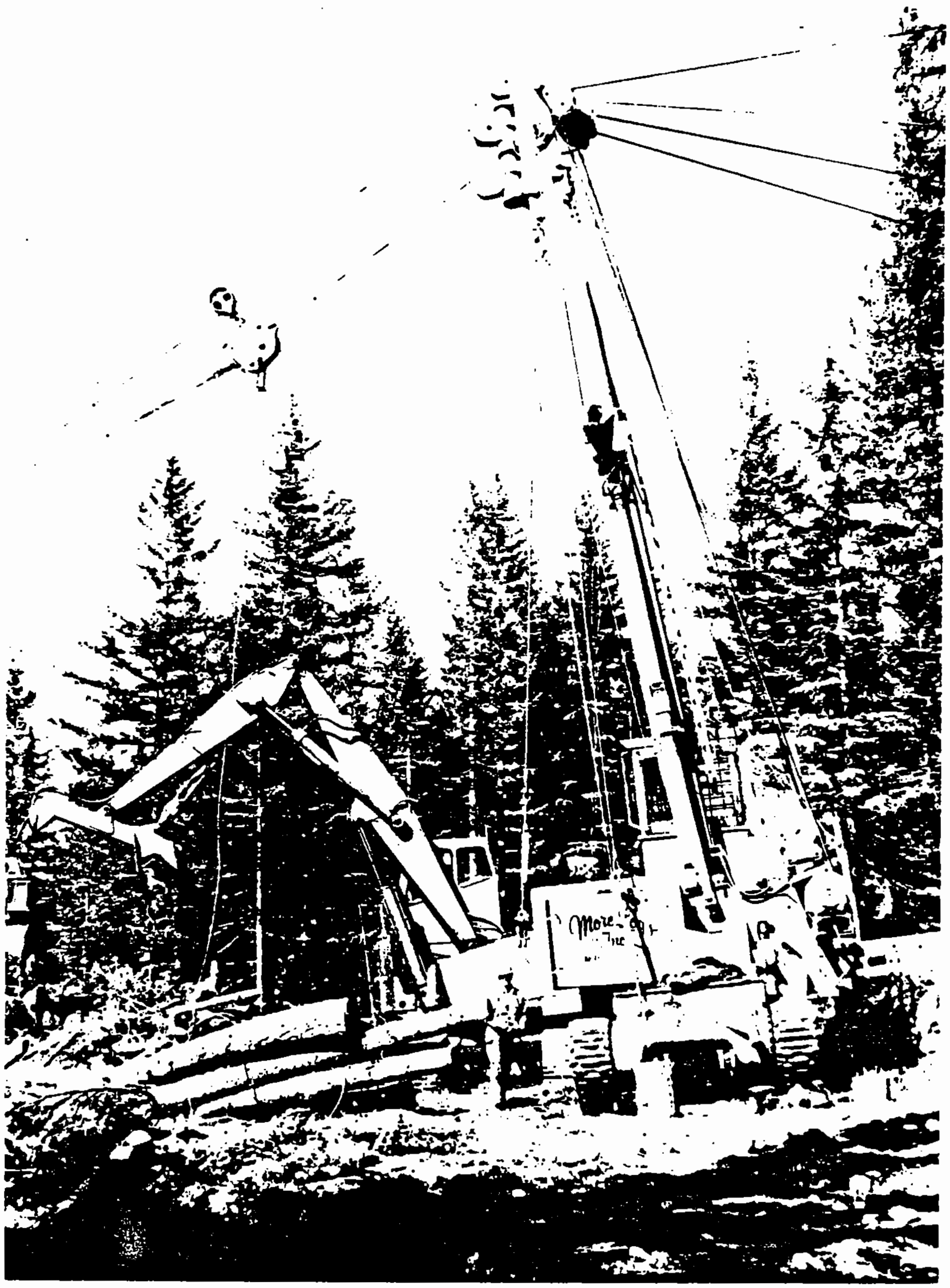
ABSTRACT

The financial feasibility of thinning in southwestern Idaho is not well established. A logging cost model, LOGCOST, was developed to estimate harvesting costs for seven major tree species. The financial feasibility of thinning depends heavily upon species, tree size, skidding or yarding method, topography, and haul distance. In order to provide financially feasible thinnings, biologically similar stands may have to be managed quite differently if haul distance or terrain vary significantly.

INTRODUCTION

The economics of forest management have become increasingly important in the Rocky Mountain area and there has been considerable debate concerning "deficit" timber sales. Much of this debate centers around the cash flow or financial feasibility of timber management. To be financially feasible, a thinning must be able to pay for itself. Large areas of southwestern Idaho are being considered for precommercial or commercial thinning over the next decade (Morelan, 1985; Jacobsen, 1985). The financial feasibility of these thinnings is not well established. In addition, attempts have been made to identify the



silvicultural prescriptions which would maximize value either through traditional timber appraisal or mathematical optimization (Johnson, 1985). Both approaches require that the user supply cost and revenue information.

Costs and revenues have typically been derived from the USDA, Forest Service, Region 4 Timber Appraisal System. This system is based on historical cost data. Appraisal variables are the number of logs per thousand board feet, average yarding distance, timber haul characteristics, scaling defect, and volume removed per acre, with limited reference to tree diameter and tree volume. No differentiation is made between tractor and rubber-tired skidding. From the silviculturist's point of view, the important variables are the species, number of trees per acre and tree sizes to be removed, and the number and sizes of trees to be left. The logging engineer shares these same concerns, with the addition of terrain, yarding distance, and haul distance.

To increase the manager's ability to distinguish between alternative silvicultural prescriptions and to decrease the effort required to estimate logging costs and revenues, LOGCOST, a harvesting cost model was developed. The LOGCOST model is specifically calibrated for southwestern Idaho. A similar approach could be used in other areas. This paper describes the structure of the LOGCOST model and the application of the model to a typical, well-stocked, immature stand. The financial implications of thinning are discussed in terms of the silvicultural and logging cost variables.

LOGCOST has been programmed on an IBM PC, 256K system in Microsoft BASIC. The program requires the use of one 5-1/4 inch disk drive for operation. A User's Guide and a diskette containing the program are available from the Department of Forest Engineering, Oregon State University. Examples of the inputs needed to run LOGCOST are shown in Figures 1-3. An example of the harvest summary output is shown in Figure 4.

MODEL STRUCTURE

Timber yield data is derived from sources that include a timber cruise, stand examination, or growth model such as the STAND PROGNOSIS MODEL (Wycoff, et. al., 1982). Harvest stand variables are tree species, number of trees per acre, gross volume per acre, quadratic mean diameter, and average total height. Terrain variables are average yarding distance, skidding or yarding equipment, average percent slope in direction of yarding, maximum payload, and haul route characteristics. Pond values are distinguished by species. Seven important southwestern Idaho tree species are considered: ponderosa pine (*Pinus ponderosa* Dougl. ex Laws. var. *ponderosa*), Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco), lodgepole pine (*Pinus contorta* Dougl. ex Loud.), grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), subalpine fir (*Abies lasiocarpa* (Hook.)

```
(1) STAND DATA AND CUT TREE CHARACTERISTICS
-------------------------------------------

ENTER THE ANALYSIS YEAR, HARVEST YEAR - (____,____)
FOR EXAMPLE, 1986,1995                                          -->1986,1995
ENTER THE STAND ACRES                                           -->40
ENTER THE STAND AVERAGE SCALING DEFECT (IN PERCENT)             -->5
ENTER SPECIES CODE (PP,DF,LP,GF,AF,ES,WL) - (TYPE END TO QUIT)  -->PP
ENTER THE FOLLOWING DATA FOR THE TREE SPECIES HARVESTED:
ENTER CUT TREES/AC, GROSS VOL/AC (BF) - (___,_____)             -->70,12600
ENTER QUAD MEAN DBH, AVE TOTAL HEIGHT - (__._,__)               -->16,75
ENTER THE POND VALUE (LOG PRICE FOB, MILL)                      -->125
ENTER SPECIES CODE (PP,DF,LP,GF,AF,ES,WL) - (TYPE END TO QUIT)  -->END
```

FIGURE 1. Stand Data Input

```
(2) LOGGING SYSTEM AND TERRAIN INPUTS
-------------------------------------

ENTER THE YARDING TYPE
GBS = GROUND BASED SYSTEM, SKY = SKYLINE SYSTEM                     -->GBS
ENTER A SKIDDING MACHINE
STRAC = SMALL CRAWLER TRACTOR,     LTRAC = LARGE TRACTOR
SRTS  = SMALL RUBBER TIRED SKIDDER, LRTS = LARGE SKIDDER            -->SRTS
ENTER THE AVE SLOPE IN THE DIRECTION OF LOADED SKIDDER
(CHOOSE -30,-25,-20,-15,-10,-5,0,+5,+10)                            -->-15
ENTER THE AVE SLOPE YARDING DISTANCE IN FEET                        -->500

ENTER THE ONE-WAY MILES OF PAVED HAUL ROAD                          -->20
ENTER THE ONE-WAY MILES OF UNPAVED HAUL ROAD                        -->10

ENTER THE MILES OF ROAD CONSTRUCTION OR RECONSTR CHARGED
TO THIS STAND (INCLUDE BOTH SPECIFIED AND TEMPORARY ROADS)          -->0
ENTER THE MILES OF ROAD TO BE MAINTAINED                            -->10
ENTER THE AVE VARIABLE COST FOR ROAD MAINTENANCE ($/MBF-MILE)       -->.50
```

FIGURE 2. Logging System Input

```
(3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA
----------------------------------------------

ENTER THE SALE AREA IMPROVEMENT COST/AC                          -->10
ENTER THE EROSION CONTROL COST/AC                                -->5
ENTER THE SLASH DISPOSAL COST/AC                                 -->10
ENTER THE SALE PREP AND ADMIN COST/AC                            -->100
```

FIGURE 3. Environmental and Administration Input

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----------------------------------------------------
TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY
----------------------------------------------------

STAND AREA                         -->  40 ACRES
NET VOLUME                         --> 479 MBF
NET VOLUME PER ACRE                -->12.0 MBF
TREES PER ACRE                     -->  70 TPA
QUADRATIC MEAN DIAMETER            -->  16 INCHES
AVERAGE TOTAL HEIGHT               -->  75 FEET
AVERAGE GROSS LOG VOLUME           --> 180 BF
AVERAGE STEM LENGTH                -->  51 FEET

YARDING SYSTEM                     --> SRTS
AVERAGE SLOPE YARDING DISTANCE     --> 500 FEET
AVERAGE SLOPE                      --> -15 PERCENT
YARDING AND LOADING PRODUCTION     -->  19 MBF/DAY
DISTANCE TO THE MILL               -->  30 MILES


FELLING AND BUCKING COST           -->  13.62 $/MBF
YARDING AND LOADING COST           -->  26.54 $/MBF
HAULING COST                       -->  31.19 $/MBF
GENERAL LOGGING OVERHEAD COST      -->   8.42 $/MBF
STUMP TO MILL LOGGING COST         -->  79.77 $/MBF
SPEC AND TEMP ROAD COST            -->   5.00 $/MBF
SAI,EC AND BD COST                 -->   2.09 $/MBF
TOTAL HARVEST COST                 -->  86.86 $/MBF
PROFIT AND RISK (12 PERCENT)       -->  13.39 $/MBF
AVERAGE POND VALUE                 --> 125.00 $/MBF
ESTIMATED STUMPAGE                 -->  24.75 $/MBF

SALE PREP AND ADMIN COST           -->  100  $/ACRE
NET REVENUE (NOT DISCOUNTED)       -->  196  $/ACRE
NET PRESENT VALUE (I = 4%)         -->  138  $/ACRE
```

FIGURE 4. Output Summary

Nutt.), Engelmann spruce (Picea engelmannii Parry ex Engelm.), and western larch (Larix occidentalis Nutt.).

Estimates of average piece size and weight to board foot ratio are computed using the harvest stand variables and regression equations derived from southwestern Idaho studies. Felling and bucking costs are based upon USDA, Forest Service production studies from southwestern Idaho. Skidding and yarding costs combine both stochastic and deterministic elements. The stochastic procedure used here distributes the felled trees or bucked logs throughout the stand to simulate the spatial distribution. Cycle time elements are calculated using the results from studies by Siefert (1982), the mobility model developed by Olsen and Gibbons (1983) for ground based systems, and Hochrein's study (1986) for skyline systems. Turn volume is estimated stochasticly using an approach similar to Sessions (1979) to provide estimates of logs per turn for all systems, total winch distance, intermediate move distance and number of intermediate moves per turn for ground-based systems, as well as to estimate production. Six machines, two cable and four ground based systems, are considered. Their characteristics are listed in Table 1. For the cable systems, hot loading is assumed; for ground skidding, loading is from cold decks.

Table 1. Characteristics of Four Ground-Based Systems and Two Skyline Systems Modeled by Logcost.

Machine Type	Max. Payload (pounds)	Net Flywheel Horsepower (hp)	Max. Span (feet)	Tower Height (feet)
Small crawler tractor	13,000	78	--	--
Large crawler tractor	20,000	140	--	--
Small rubber-tied skidder	7,000	70	--	--
Large rubber-tired skidder	10,000	120	--	--
Small skyline	2,000	65	1,000	23
Medium skyline	Entered by User	284	2,000	48

Using appraisal data, a simplified approach to estimating log hauling cost was derived by computing roundtrip travel times in minutes per mile for paved and unpaved roads in each of 48 timber sales. From this sample, mean roundtrip travel times were estimated for paved and unpaved roads. The results are displayed in Table 2.

Table 2. Mean Roundtrip Minutes per Mile for Paved and Unpaved Surfaces In Southwestern Idaho.

Surface Type	Mean Roundtrip Minutes per Mile	Standard Deviation	Standard Error of the Mean
Paved	3.92	.36	.052
Unpaved	5.38	.59	.086

MODEL VALIDATION - COMPARISON

Some logging costs, such as loading associated with ground-based systems and timber haul, modeled by LOGCOST are nearly the same as the Region 4 Appraisal Handbook, and are assumed to be representative of typical costs experienced by industry in southwestern Idaho. Because the felling and bucking and yarding cost centers use a different approach, they were compared with other studies and with the USDA, Forest Service Region 4 Appraisal estimates.

Felling and bucking daily production, predicted by LOGCOST, was compared with production for trees ranging in size from 14 inches to 24 inches dbh experienced by private industry in southwestern Idaho. To compare with LOGCOST, industry's measure of production, trees per hour, was multiplied by eight hours per day, and by the average volume per tree in mbf. Figure 5 shows that daily production predicted by LOGCOST matches industry's estimates throughout the range of tree sizes most commonly harvested. For trees 14-24 inches in diameter, the difference between industry's felling and bucking cost and LOGCOST is less than 10 percent (see Figure 6). LOGCOST uses felling and bucking costs of $18.33 per hour, derived from local labor and machine rates. Skidding and cable logging production computed using stochastically-derived estimates of turn volumes by LOGCOST compared favorably with production reported by the Siefert (1983) and Hochrein (1986) studies. Siefert estimated daily production, based on the average study conditions and cycle time equations. Using similar stand conditions, LOGCOST matched Siefert's estimates of production for each of the three machines Siefert studied within 10 percent (Figure 7).

Skyline yarding production was compared with Hochrein's time study results for two different stand conditions (see

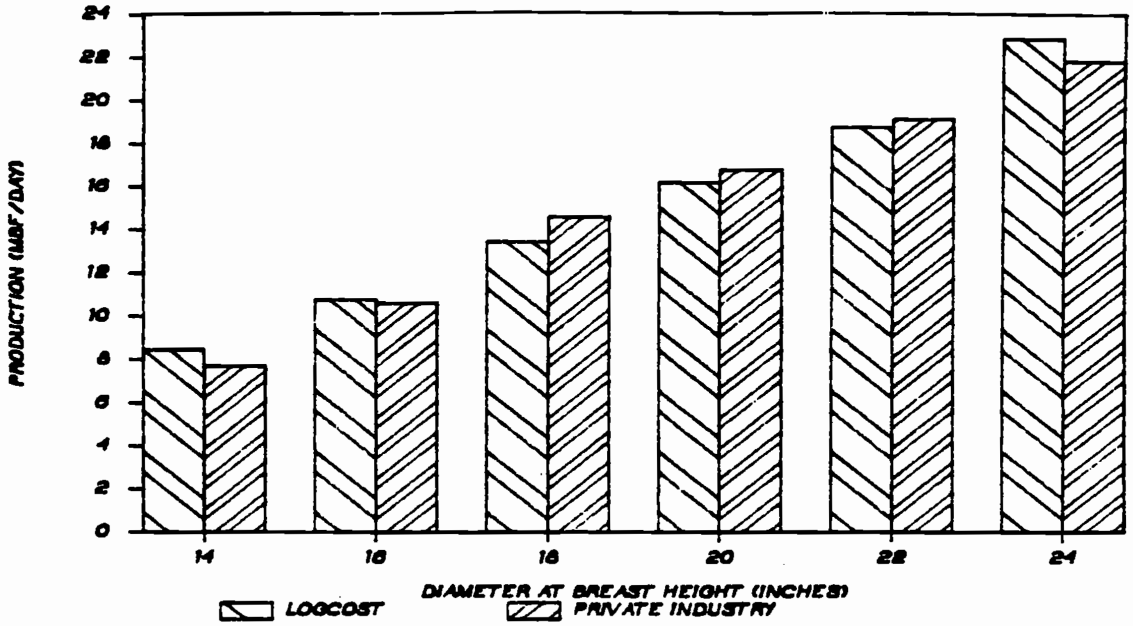

FIGURE 5. Comparison of LOGCOST Versus Felling and Bucking Production From Industry.

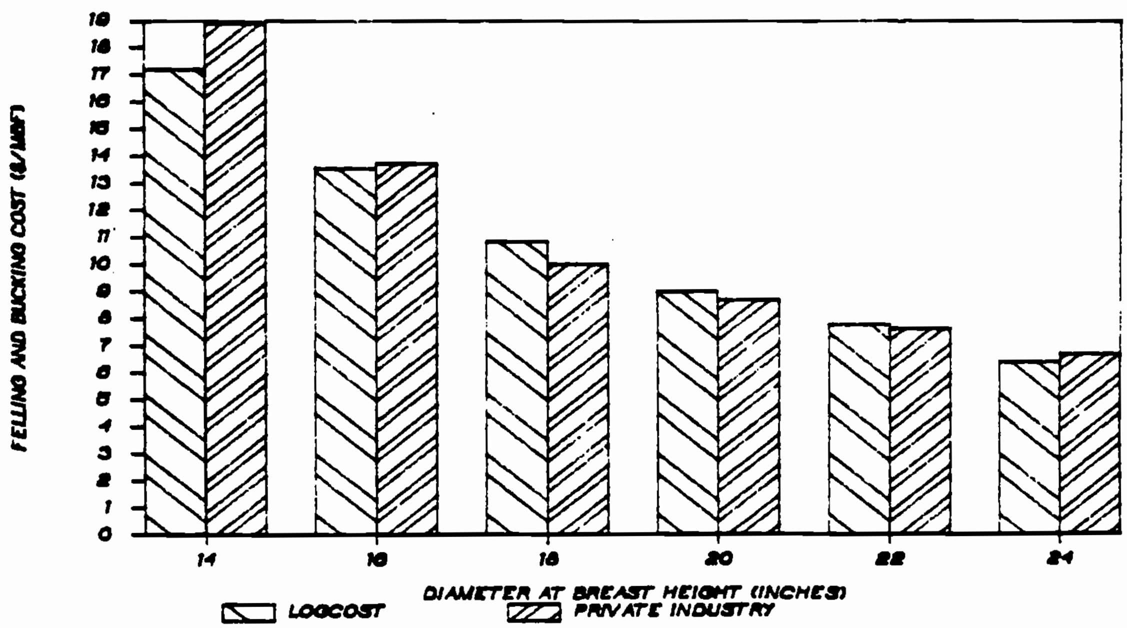

FIGURE 6. Comparison of LOGCOST versus Felling and Bucking Cost from Industry.

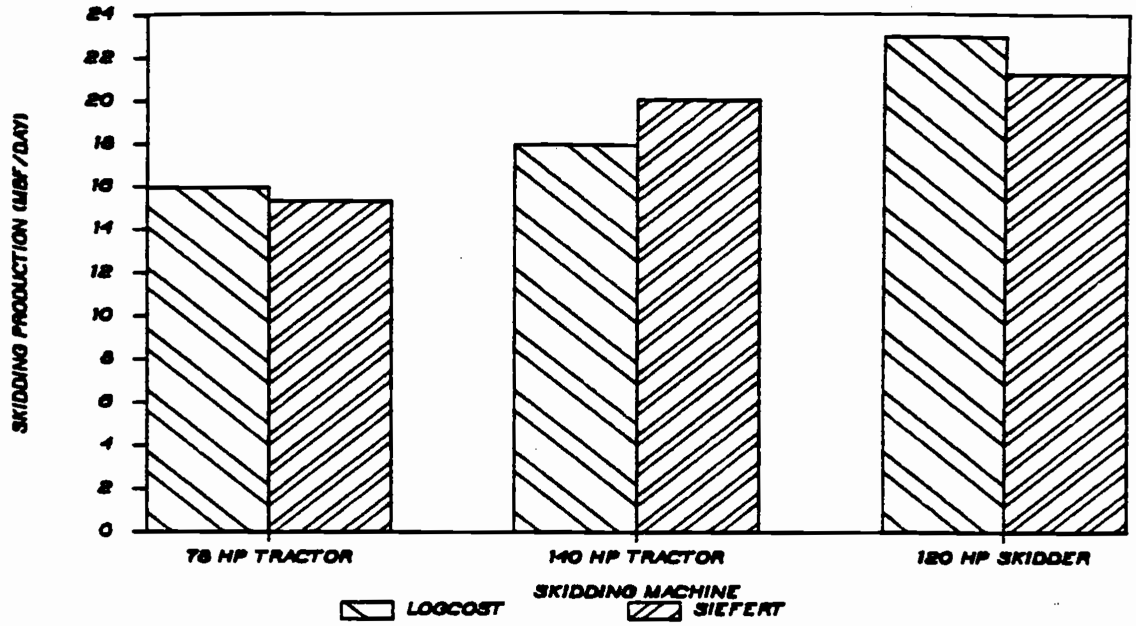

FIGURE 7. Skidding Production of LOGCOST versus Siefert.

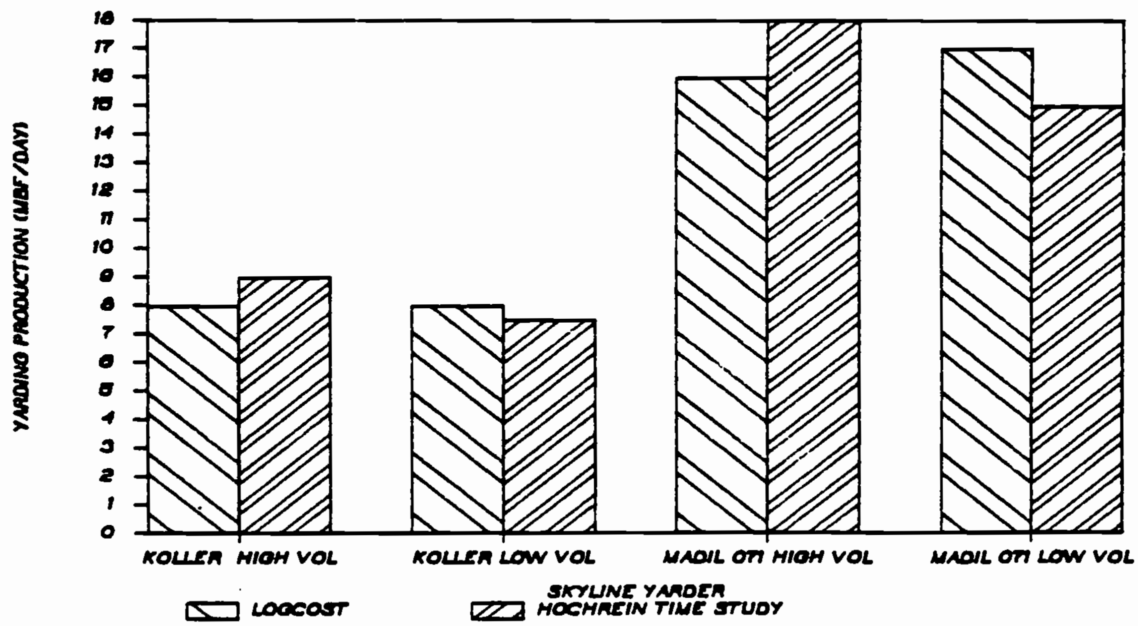

FIGURE 8. Skyline Yarding Production From LOGCOST versus Hochrein.

Figure 8). The cut volume per acre and average log size were 11.5 mbf and 55 bf for the high stocked stand, and 5.4 mbf and 65 bf for the lower stocked stand. Hochrein's study found a slight decrease in productivity when thinning the lower stocked stand. LOGCOST predicted nearly the same daily production; this is probably because the fewer logs per turn (a function of fewer cut trees per acre) was offset by the larger volume per log. LOGCOST matched production estimates from Hochrein's time study within 13 percent.

Felling, bucking and yarding costs computed by LOGCOST for ponderosa pine were also compared with the Region 4 Timber Appraisal Handbook costs (1985). Figures 9 and 10 contrast the differences for different cut tree sizes. All other harvest variables were held constant; 70 trees per acre were cut and skidded 500 feet. The southwestern zone average scaling defect of five percent was assumed. In general, LOGCOST predicts higher costs for the smallest tree size, but lower costs for the medium to large tree sizes. Trees 10 inches and 12 inches in diameter (16, and 57 board feet, respectively) are so small that the number of gross 16 foot logs per mbf, computed for these trees, is beyond the limits of the Region 4 Skidding Cost Adjustment Table. Consequently, the Appraisal Handbook skidding cost adjustment is not appropriate when tree size is very small because no further adjustment is made for log sizes beyond the range of the table. If rubber-tired skidders can be used to skid 16-inch diameter trees, the skidding cost per mbf predicted

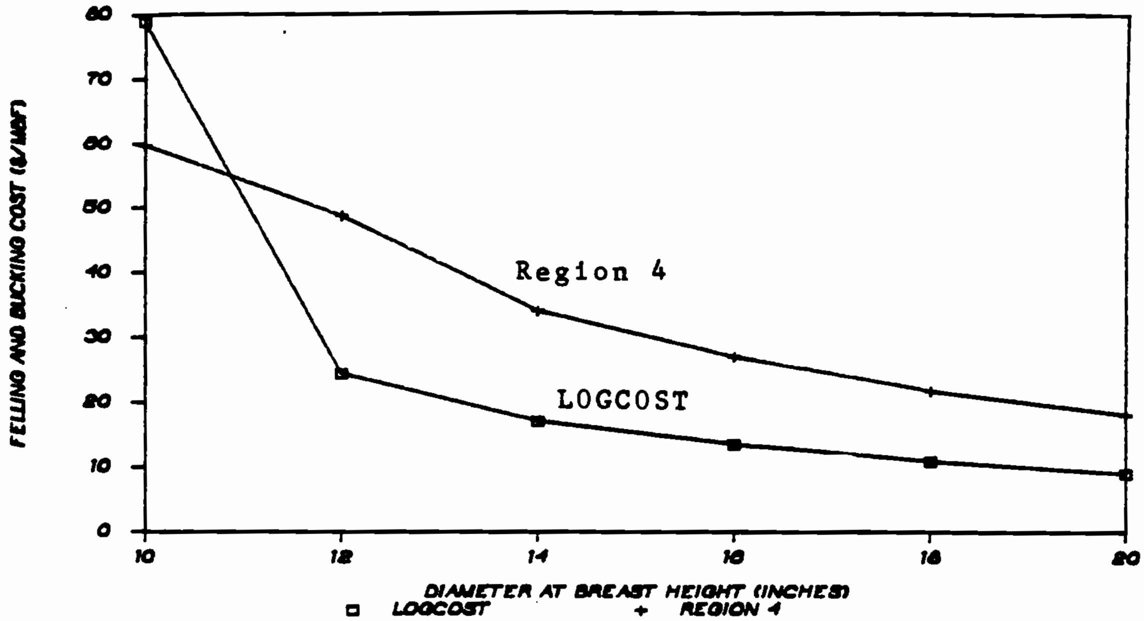

FIGURE 9. Felling and Bucking Costs from LOGCOST versus Region 4, USDA, Forest Service.

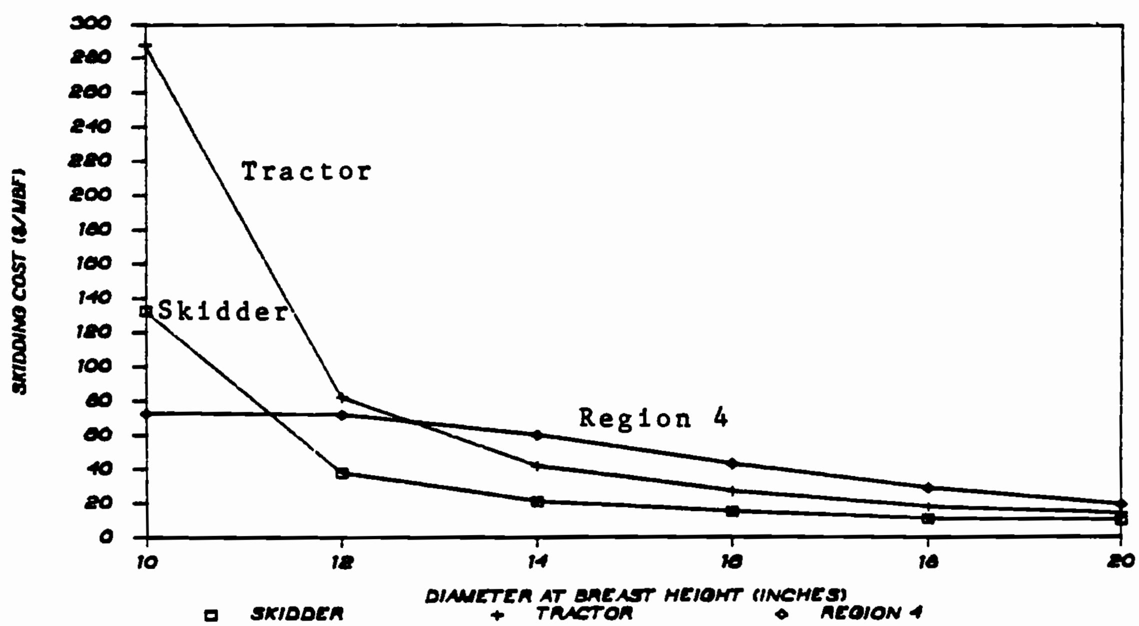

FIGURE 10. Skidding Costs From LOGCOST versus Region 4, USDA, Forest Service.

by LOGCOST is approximately half the cost estimated by the Region 4 Timber Appraisal Handbook. Appraisal costs for skidding large timber (20 inches in diameter) begin to converge with those estimated by LOGCOST.

IMPLICATIONS

To test the sensitivity of harvesting cost to species, tree size, yarding system, and haul distance, a probable thinning prescription was simulated. Figure 11 shows the effect of tree size on harvest cost when all other variables are held constant; 70 ponderosa pine trees per acre (the most common tree species planted in southwestern Idaho) were cut, skidded or yarded 500 feet by rubber tired skidder or skyline yarder, and hauled 30 miles to the mill. Average tree heights, diameters and corresponding volume per tree for ponderosa pine were obtained from timber inventory data on the Boise National Forest in southwestern Idaho, and from Forest Service Region 4 volume tables[1] (see Table 3).

---

[1]Pond values were estimated from average values reported quarterly for southwestern Idaho. Ponderosa pine immature trees have a pond vale of $125/mbf, while mature trees have a pond value of $221/mbf. Generally, immature trees are smaller than 200 bf and mature trees are larger than 300 bf (18 - 20 inches dbh). We assumed the pond value increases linearly with tree size.

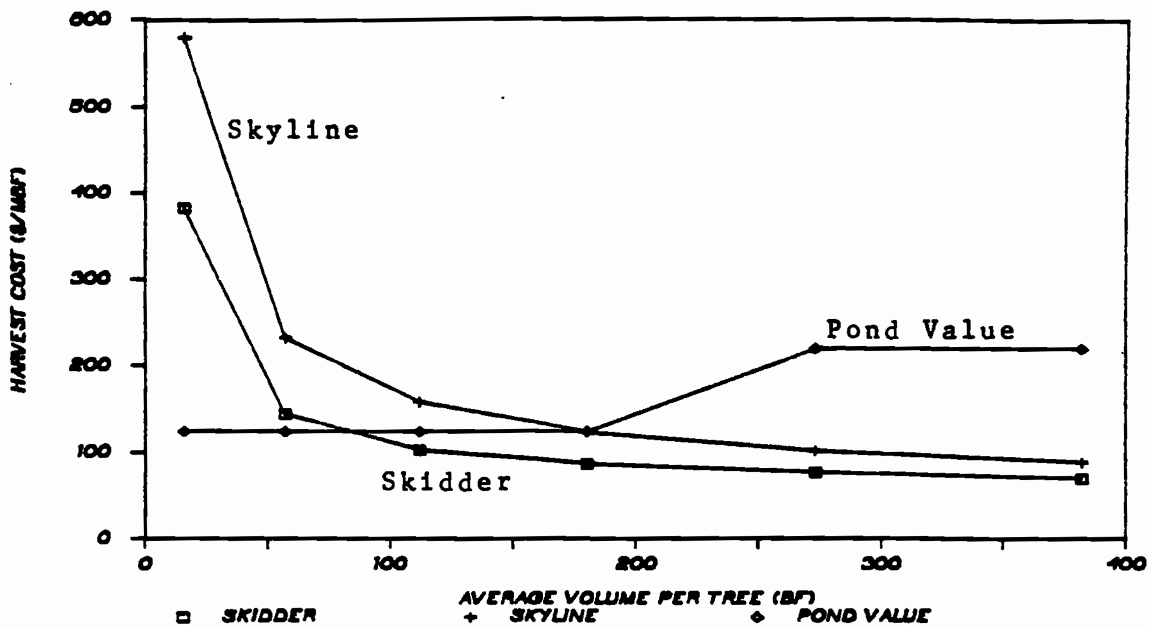

FIGURE 11. Effect of Tree Size on Ponderosa Pine Harvest Cost.

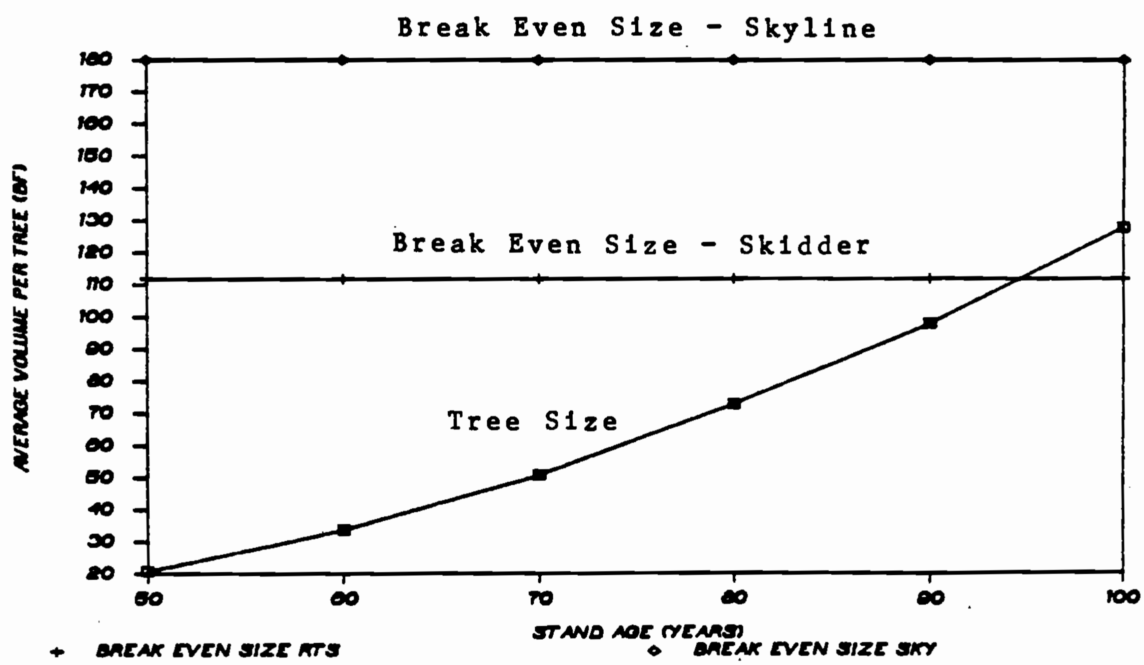

FIGURE 12. Relationship of Ponderosa Pine Tree Size and Stand Age Predicted by PROGNOSIS.

Table 3. Diameter Height Relationship and Corresponding Volume per Tree for Ponderosa Pine From A Typical Site in Southwestern Idaho.

Diameter at Breast Height (inches)	Total Height (feet)	Volume/Tree (bf)
10	55	16
12	62	57
14	69	112
16	75	180
18	83	273
20	90	382

For these specific conditions, commercial thinning of ponderosa pine, using skidders, was feasible when the average tree size was 14 inches (112 bf) or larger; however, skyline thinning was only marginally feasible at a diameter of 16 inches (180 bf). PROGNOSIS was then used to project how long an unmanaged, well-stocked plantation of ponderosa pine must be grown to reach these break even sizes. Figure 12 shows that this stand will not reach a commercial size for harvesting by rubber-tired skidder until age 95; a similar stand growing in steep mountainous terrain would not reach a commercial size for skyline yarding within the 100 year period. The culmination of mean annual increment (measured in cubic feet) occurred at age 80. For these stand conditions and a 30 mile haul, precommercial thinning would be required if a financially feasible thinning is anticipated for stands younger than 90 years.

In addition to size, tree species also affects harvesting costs and revenues. Ponderosa pine is heavier than most conifers in southwestern Idaho. Because of lumber degrade problems associated with juvenile wood, it also has the lowest pond value for immature trees. These two factors result in a larger tree size required to break even when thinning young ponderosa pine stands. Lodgepole pine is representative of the conifers that have moderate pond values and low green wood densities. To illustrate the differences in harvest cost and stumpage between these two species, the ponderosa pine tree sizes used in Table 3 were also used for lodgepole pine. The same stand and harvesting conditions described above were also used. Figure 13 shows the effect of a lighter, higher-value species on the tree size-harvest cost curves. More opportunities exist for commercial thinning lodgepole pine stands at an earlier age. Higher pond values and lower harvest costs result in a smaller break-even tree size in lodgepole pine for both skyline or ground-based systems than ponderosa pine.

Haul distance from the mill is also an important factor. Haul distance was varied from 10 miles to 70 miles to test the sensitivity of the break-even tree size of ponderosa pine to distance from the mill. Three different tree sizes, 12 inches (57 bf), 14 inches (112 bf) and 16 inches (180 bf), were commercially thinned using the model with harvest variables assumed for the examples above. In this case, only ground skidding using rubber-tired skidders was simulated. Figure 14 shows that all three of the tree sizes are profitable if the stand is 10 miles or less from the mill. However, stands with an average tree size of 16

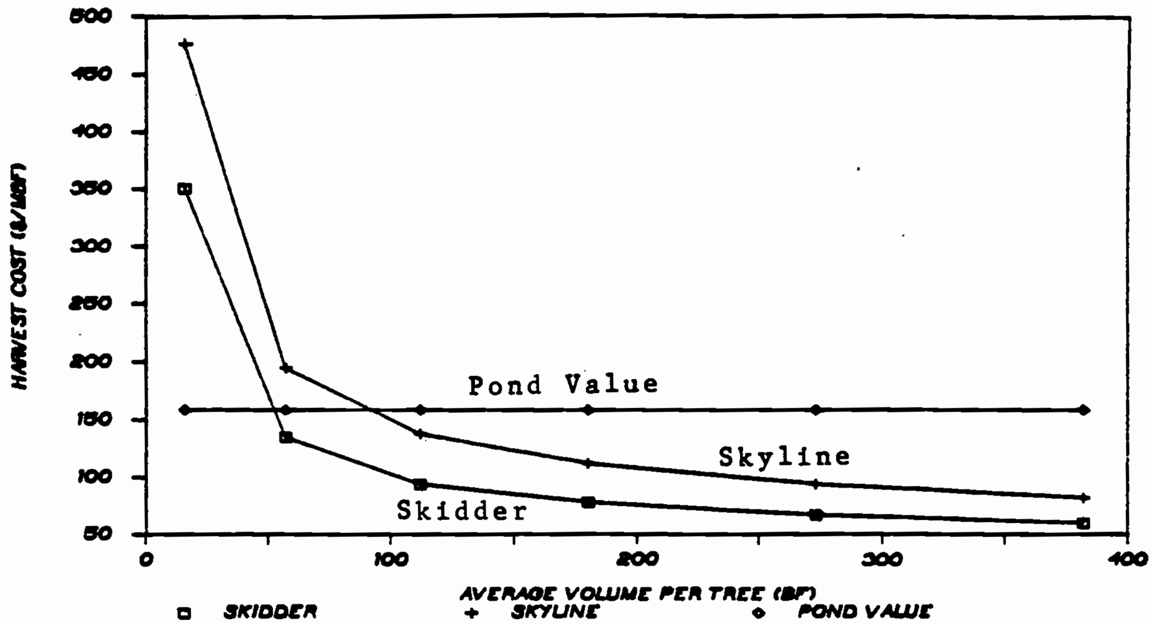

FIGURE 13. Effect of Lodgepole Pine Tree Size on Harvest Cost.

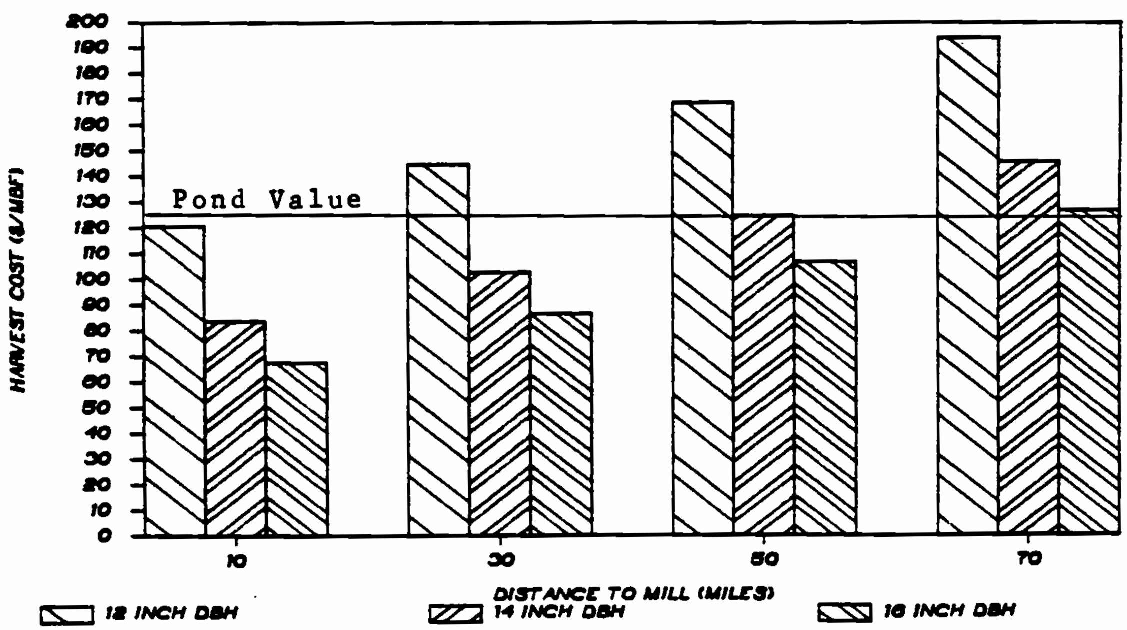

FIGURE 14. Effect of Haul Distance on Ponderosa Pine Harvest Cost.

inches or less that are further than 70 miles from the mill may not be financially feasible to thin. Under these conditions, silvicultural prescriptions for young stands growing in the same productivity zone may be different if haul distance is significantly different; stands closer to the mill have more opportunity to yield a commercial thinning.

The risk of a financially infeasible thinning is particularly important in the ponderosa pine and lodgepole pine timber types, because of their susceptibility to bark beetle outbreaks when stand density is high (Thier, 1986; Cahill, 1986). Precommercial thinning may be required to produce timber stands with adequate tree size to ensure financial feasibility.

CONCLUSIONS

The LOGCOST model significantly decreases the time required for foresters to estimate the cost of thinning the major species in southwestern Idaho. Costs are more sensitive to stand and terrain variables than the present appraisal system. Stratifying stands by species, tree size, topography, and log haul distance to the mill is essential. Achieving pest management guidelines may depend heavily upon the financial feasibility of thinning. Data from LOGCOST should provide valuable information for stand optimization models which seek to identify the most economical prescription to meet management objectives.

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PERSONAL COMMUNICATIONS

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Jacobsen, G. 1985. Forester, USDA, Forest Service, Payette National Forest, Region 4.

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APPENDICES

APPENDIX A

Cut Tree Parameters

APPENDIX A.

Characteristics of the cut trees, such as gross volume per tree, average piece size and pound to board feet ratio, are computed in the cut tree parameter subroutine before LOGCOST begins computing the logging costs. The cut tree parameters are computed for each species separately, and then weighted averages or totals are computed for the stand.

The equations used to compute cut tree parameters are similar for the seven species considered in LOGCOST. The equations and variables for ponderosa pine are discussed below.

Total net volume in mbf is computed first:

NVPP=(GVPAPP x (1-SCDEF) x ACRES)/1000

Where NVPP is the net volume harvested,

GVPAPP is the gross cut volume per acre, a user input,

SCDEF is the scaling defect, a user input expressed as a decimal,

ACRES is the stand area entered by the user.

Average gross volume per tree is then computed in board feet, by dividing the gross volume per acre by the trees per acre.

Next, the merchantable length is determined; this is the length of the tree from the stump (assumed to be one foot high) to the merchantable top, which is six inches in diameter, inside the bark. USDA, Forest Service, Region 4 developed equations which predict merchantable length as a function of total height and diameter at breast height, for each of the seven tree species (Intermountain Region Timber Appraisal Handbook, 1985).

MLPP = .8381 x THPP + 7.299 x SQR(QMDPP) - 41.14

Where MLPP is the merchantable length in feet,

THPP is the average total height in feet, of the cut trees, a user input,

SQR(QMDPP) is the square root of the quadratic mean diameter, in inches, of the cut trees.

QMDPP is a user input.

The number of gross 16 feet logs per mbf (an indicator of tree size) is then computed.

LPMPP = (MLPP/16)/(AVPTPP/1000)

Where LPMPP is the number of gross logs per mbf, and

AVPTPP is the average gross volume per tree in board feet.

Equations developed by private industry in southwestern Idaho are used by LOGCOST to predict the number of pieces per tree, and the average piece size in board feet. This information is then used to predict the pound to board feet ratio as a function of tree size for each species.

The number of pieces (bucked logs) per tree is a function of the total height and quadratic mean diameter.

PCPTPP = .1469 + .01954 x THPP + .0002468 x QMDPP x THPP - 2.717/QMDPP

Where PCPTPP is the number of pieces per tree, Average piece size in board feet is then computed:

PCSZPP = AVPTPP/PCPTPP

where AVPTPP is the average gross volume per tree in board feet.

The pound to board feet ratio, a function of piece size, for a given species, is then computed:

LBBFPP = 12.09-.01397 x PCSZPP+8.81E-06 x PCSZPP **2
+ 187.6/PCSZPP

LOGCOST repeats this sequence for each species harvested and then computes the stand totals and averages.

Gross volume per acre in board feet is the sum of the gross volumes of each species harvested. Net volume per acre is then computed.

NVOLPA = GVPA x (1-SCDEF)/1000

Where NVOLPA is the net volume per acre in mbf, and GVPA is the gross volume per acre in board feet.

The total number of cut trees per acre and the net volume in mbf are computed by summing the values of the individual species together.

The quadratic mean diameter of all the cut trees is then computed by first computing the average basal area per tree in square inches, and then computing the square root of the quantity, average basal area per tree divided by .7854.

The stand average gross volume per tree is computed by dividing the total gross volume per acre by the total number of cut trees per acre.

Stand average gross 16 feet logs per mbf, piece size in board feet, and pound to board feet ratio are computed using a weighted average. Each species' parameter is weighted by its gross volume per acre. These products are summed together and the total is divided by the total gross volume per acre. The stand average total height and merchantable length are computed in a similar manner, except each species' parameter is weighted by the number of trees per acre instead of gross volume. The products are summed together and then divided by the total number of cut trees per acre.

The average number of bucked logs per acre is computed by dividing the gross volume per acre by the average piece size, both in board feet.

Average weight per tree and weight per log are computed by multiplying the average gross volume per tree, and average gross volume per log, by the average pound to board feet ratio.

Stand average pond value is computed by summing the products of each species' value times its net volume, and then dividing this sum by the total net volume.

APPENDIX B

Felling and Bucking

APPENDIX B

The Intermountain Region, USDA, Forest Service, developed an equation to predict the average felling and bucking time per thousand board feet (mbf) for trees in southwestern Idaho. The time (minutes per mbf) is assumed to be delay-free, and is a function of the diameter at breast height (dbh), and the net board feet volume (Scribner Decimal C) of a tree:

$$FBTPM = -53.24 - (1.205 \times QMD) + (.07987 \times NVPTSDC) + 110.9 \times \text{Log}_{10}(QMD) + 28.31 / (\text{Log}_{10}(NVPTSDC)) - 42.09 \times \text{Log}_{10}(NVPTSDC)$$

Where FBTPM is the delay-free time in minutes per mbf,
QMD is the quadratic mean diameter,
NVPTSDC is the net volume per tree measured in Scribner Decimal C scale.

The average delay free time/mbf is used by the Forest Service to adjust the average felling and bucking cost up or down, depending on whether the sale average tree size is larger or smaller than the southwestern Appraisal Zone average.

LOGCOST does not use the adjustment procedure described above; it computes the cost per mbf based upon hourly production and cost.

To compute the total time per mbf to fell and buck, a 25 percent delay time is used, based on Gebhardt's study (1977) of felling and bucking in eastern Oregon. Such activities as walking between and swamping around cut trees, saw sharpening, personal delays and other miscellaneous delays are included in the estimate of total delay. Total time per mbf, including delays, is estimated by the following equation:

TFBTPM = (FBTPM) /(1 - DELAYFB)

where DELAYFB is the delay factor .25.

A total cost per hour (CPHBF) of $18.33, is used to compute felling and bucking cost per mbf (FBCPM):

FBCPM = (CPHFB/60) x TFBTPM

APPENDIX C

Yarding

APPENDIX C

Ground based systems and skyline yarding systems are modeled by LOGCOST. The user may choose a yarding system within the following constraints:

(1) Crawler tractors may be chosen if the slope is less than or equal to 45 percent. Adverse skidding up to 10 percent is allowed.

(2) Rubber tired skidders are permitted on slopes up to 30 percent. Adverse skidding is limited to slopes less than or equal to 10 percent.

(3) Only skyline yarding is allowed on slopes steeper than 45 percent. Downhill skyline logging is not considered. If desired, skyline yarding may be selected for gentler terrain.

LOGCOST provides flexibility in selecting a yarding machine so that the equipment size can be matched to the average size of timber. For example, on gentle slopes a small rubber tired skidder might be selected for a commercial thin. The following yarding machines are available:

Ground based systems

(1) small crawler tractor	78 horsepower
(2) large crawler tractor	140 horsepower
(3) small rubber tired skidder	70 horsepower
(4) large rubber tired skidder	120 horsepower

Skyline systems

(1) small skyline yarder	spans to 1,000 feet
(2) medium skyline yarder	spans to 2,000 feet

The Koller K300 was selected as the small yarder representative of European standing skylines designed to yard small logs at distances less than 1,000 feet. The mechanically clamping carriage is designed to support loads up to 2,000 pounds. The tower height is approximately 23 feet. The Madil 071 represents the medium skyline yarder. This yarder is used on slopes up to 2,000 feet, and can be rigged with a haulback for yarding across a canyon. The tower height of the Madil 071 is approximately 48 feet.

Regression equations were used to predict cycle times for both ground based and skyline yarding systems. The equations for crawler tractors and rubber tired skidders are based on Siefert's (1982) study in northern Idaho. The skyline equations were developed by Hochrein (1986) from data collected in western Oregon. The equations are applicable to partial cutting and would probably underestimate production in clear cut harvests.

Siefert's study did not include small rubber tired skidders; rather than extrapolate from the large skidder, a mobility model developed by Olsen and Gibbons (1983) was used to predict inhaul and outhaul velocity. The lateral cycle time, decking and miscellaneous elements of the total cycle time are assumed to be similar for the small and large rubber tired skidder; Siefert's equations for the large skidder are used to estimate these elements of the cycle time for both skidders. Olsen and Gibbons previously validated the mobility model using field data collected for the large skidder by Siefert.

Each yarding machine is assigned a maximum payload in pounds. The maximum payloads were estimated using the following criteria:

(1) the vehicle can travel up a 10 percent slope;

(2) excessive slip (greater than 30 percent for skidders) does not occur;

(3) a speed greater than or equal to one mile per hour can be maintained;

(4) the Caterpillar Performance Handbook (edition 14) was used to predict mobility and speed of crawler tractors, for the purpose of computing maximum payload;

(5) the Skidder Mobility Model by Olsen and Gibbons was used to predict mobility and speed of skidders.

Skyline system maximum payloads are a function of the terrain and system capabilities; the small skyline yarder's carriage is limited to payloads up to 2,000 pounds. Since most skyline settings can achieve this payload, the maximum payload for the small yarder is assumed to be 2,000 pounds. The larger yarder's payload may be limited by terrain in many cases; for this reason the user will supply an estimate of the maximum payload. Skyline payload analysis programs such as "LOGGER", can be used to predict payload for a given yarder and skyline profile. Field data or topographic maps can be used to generate skyline profiles.

Maximum payloads used by LOGCOST are listed below.

<u>Ground based systems</u>

Large crawler tractor	20,000 pounds
Small crawler tractor	13,000 pounds
Large rubber tire skidder	10,000 pounds
Small rubber tire skidder	7,000 pounds

<u>Skyline yarding systems</u>

Large skyline yarder	Input by user
Small skyline yarder	2,000 pounds

Lateral yarding time is a significant part of the total cycle time of ground based and skyline yarding systems. Cycle time equations of LOGCOST use variables such as logs per turn, that are dependent upon cut tree characteristics such as piece size (board feet), cut trees per acre, and tree species. LOGCOST determines variables such as logs per turn by simulating lateral yarding in the stand conditions (cut tree characteristics) the user inputs. The lateral yarding simulation is similar for ground based and skyline yarding systems; 100 logs are laterally yarded and the average number of logs per turn is computed.

Crawler tractors and skidders yard tree length logs in LOGCOST. Siefert's cycle time equations were based on tree length skidding. Although some tree species are more susceptible to skidding damage caused by logs rubbing against trees, it is not clear from a review of the literature or from field observations, that tree length skidding in young stands results in more stand damage than conventional log length skidding (Murphy, 1986). Yarding productivity is generally increased in young stands when tree length logs are skidded.

Figure 15 is a flow chart of the lateral yarding simulation subroutine for ground based systems. First, the logs are randomly distributed throughout the rectangular cutblock. Maximum lateral yarding distance is assumed to be 50 feet. Next, the logs are sorted by their X coordinate, from closest to farthest from the landing (measured in the X direction). The skidding machine is moved to the back of the cutblock at a point 7.5 feet in the X direction from the last log (see Figure 16). Candidate logs are then identified; these are logs that lie within a 15 by 50 foot rectangular band perpendicular to the designated skid trail.

FLOWCHART OF LATERAL YARDING SIMULATION FOR GOUND BASED SYSTEMS

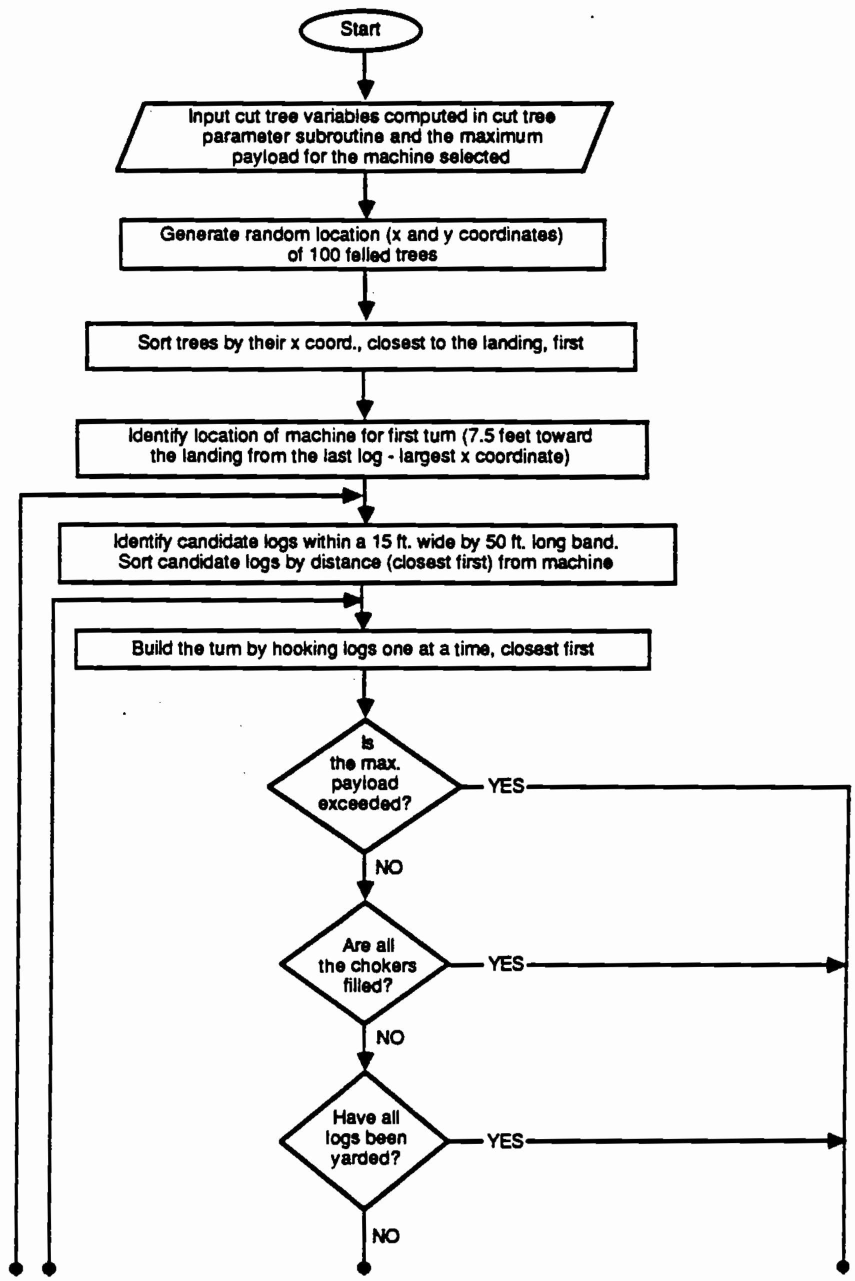


Figure 15. Flowchart of lateral yarding simulation for ground-based systems

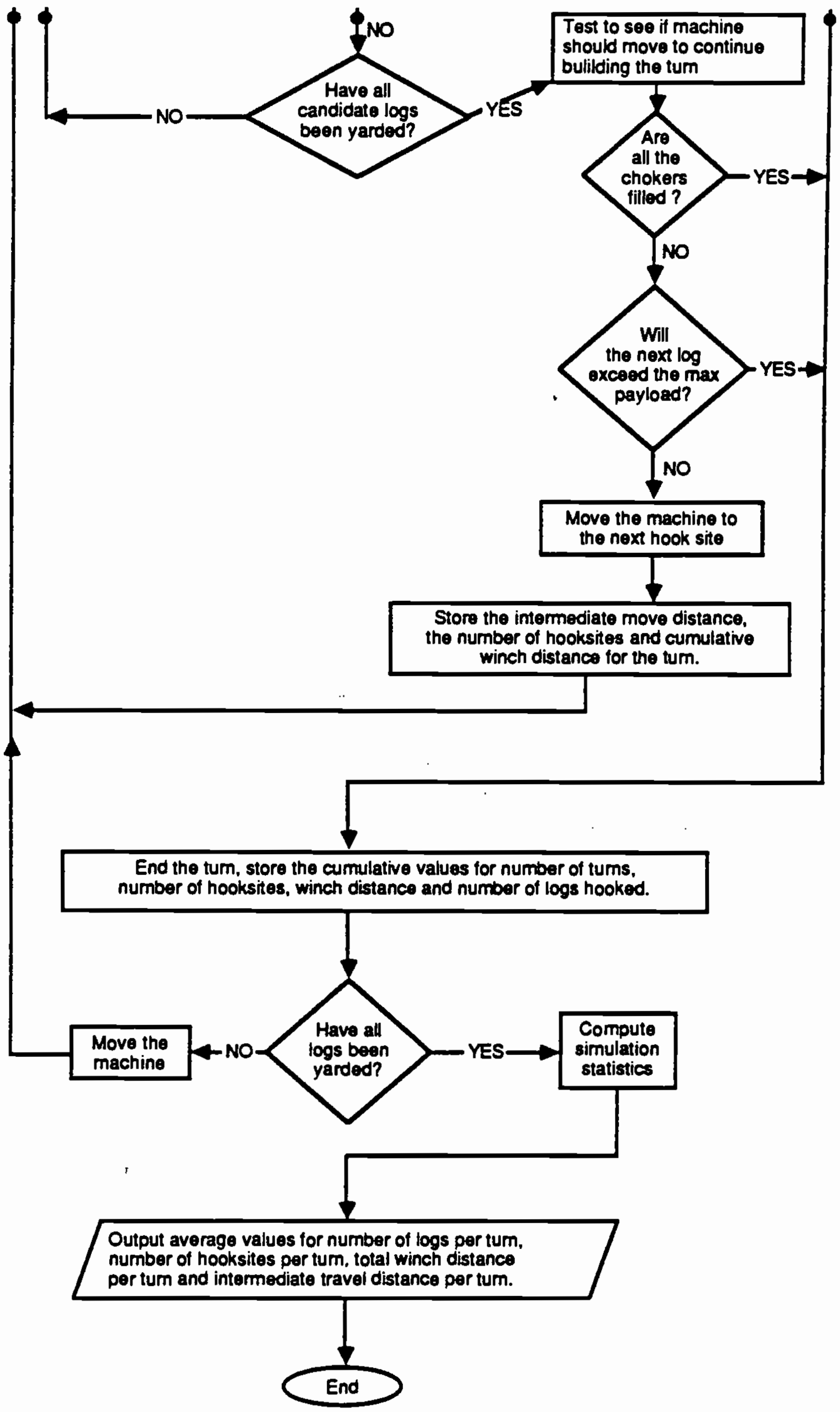
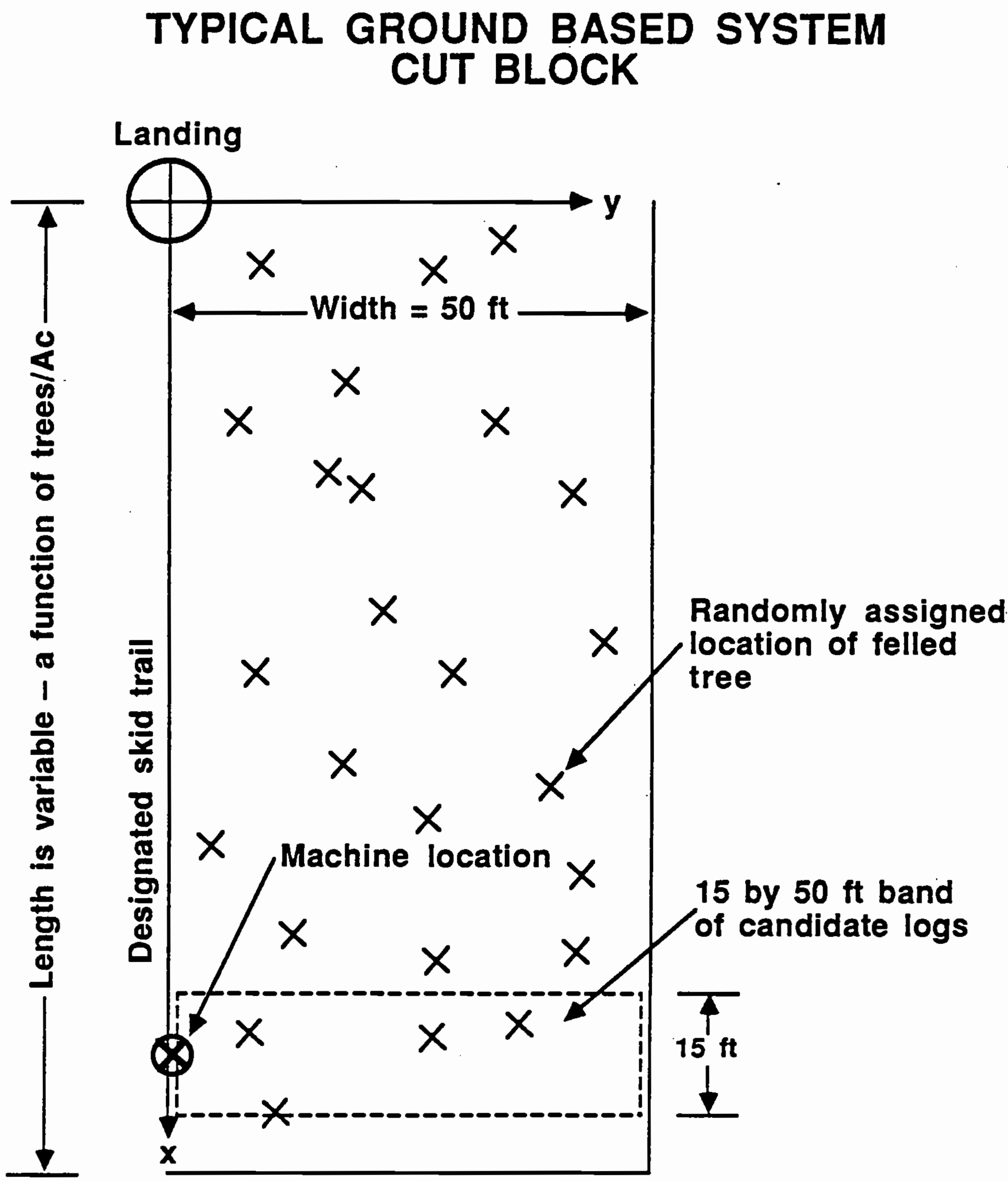


Figure 15 (continued)



Note: Only 25 logs are shown in this diagram to simplify the illustration. LOGCOST simulates the lateral yarding of 100 tree length logs.

Figure 16. Typical Ground-based System Cut Block

Because sliders are often used to build maximum payloads, the dimensions of the narrow band are designed to minimize stand damage caused by winching logs that are too spread out. Most leave tree spacing in commercial thins is greater than 15 feet.

Once candidate logs have been identified, they are sorted by distance from the skidding machine (closest first), and then the model tests to see if (1) the maximum allowable payload will be exceeded or (2) all of the chokers are full. If not, the log is hooked. If either of the two conditions occur, the log is not hooked, and the turn is ended.

Sometimes, there are too few logs in the 15 by 50 foot band to fill the chokers or achieve maximum payload; when this occurs, the machine will move up the designated skid trail toward the landing (Siefert calls this an intermediate move and the distance moved is an independent variable in the cycle time equation). The machine is moved to a point 7.5 feet ahead of the X coordinate of the next log, and a new band is established to identify more candidate logs. Siefert's study observed an average of 2 or more intermediate moves by the large tractor in order to fill all of the chokers. LOGCOST permits up to two intermediate moves per turn. Once the machine is moved it begins building turns as described above.

After all the logs have been laterally yarded, the total winch distance, intermediate distance, number of intermediate moves, and the total number of logs are divided by the number of turns to compute the average total winch distance, intermediate distance, number of intermediate moves, and average logs per turn.

Delay-free cycle time is then computed using Siefert's cycle time equations. Cycle time is divided into the following components:

(1) Travel time

(2) Position time

(3) Winch time

(4) Hook time

(5) Intermediate travel time

(6) Landing time

(7) Pile slash time

For the large crawler tractor, the cycle time equations for the components listed above are as follows:

(1) Travel time

TRAVEL = .03+.002705xOIDIST+.000105xNWEIGHT

Where TRAVEL is in minutes.

OIDIST is the outhaul plus inhaul distance, in feet.

OIDIST = (2xAYDx(1+WEAVE))-IMDPT

Where AYD is the average yarding distance in feet, and is input by the user,

WEAVE is the factor .10,

IMDPT is the intermediate distance per turn, in feet, and is computed in the lateral yarding subroutine.

NWEIGHT is the net turn weight in pounds.

NWEIGHT = WTPTx(1-SCDEF)xLOGSPT

Where WTPT is the average weight per tree length log in pounds,

SCDEF is the average scaling defect for the stand, input by the user, (decimal)

LOGSPT is the number of tree length logs per turn, computed in the lateral yarding subroutine.

(2) Position time

Siefert reported a normalized position distance equal to 50 feet and position occurrence of .5341 for all machines.

Using these values, the position time in minutes,

POSITION = .5341x(.41+.01063x50)

= .3878

(3) Winch time

LOGCOST assumes winch occurs every cycle with designated skid trails. The normalized winch slope Siefert observed, 11 percent uphill, is also used for all machines.

WINCH = .13+.0252xTWDPT+.0001577xTWDPTx11

= .13+.02693xTWDPT

Where WINCH is in minutes,

TWDPT is the total winch distance per turn in feet, computed in the lateral yarding subroutine.

(4) Hook time

HOOK = .10+1.041xLOGSPT+.01933xTWDPT

Where HOOK is in minutes.

(5) Intermediate travel time

LOGCOST assumes intermediate travel also occurs every cycle; if cut tree density is high and intermediate moves are not common, the average intermediate distance per turn predicted by the lateral yarding subroutine will be small. Consequently, the intermediate travel time would also be a small portion of the total cycle time, even though it is assumed to occur each turn.

IMTRAVEL = .01+.0048xIMDPT+.258x(HKSITESPT-1)

Where IMTRAVEL is in minutes,

IMDPT is the average intermediate distance per turn in feet, computed in the lateral yarding subroutine and

HKSITESPT is the number of hook sites per turn, also computed in the lateral yarding subroutine.

(6) Landing time

The average deck height and total limb factor per stem reported by Siefert were three feet, and .46, respectively, for all machines.

LANDING = .66+.6710xLOGSPT+.1556x.46xLOGSPT+.2x3

= 1.26+.7426xLOGSPT

Where LANDING is in minutes.

(7) Pile slash time

Average occurrence is .1791 for all machines.

PSLASH = .1791x.87
= .1558

Where PSLASH is in minutes.

The cycle time equations for the small crawler tractor are as follows:

(1) Travel time

Siefert found that the outhaul time was related to the slope for the small tractor if the slope in the direction of the unloaded vehicle was positive. When the unloaded tractor is traveling uphill, the variable OUTSLOPE, applies.

TRAVEL = .35+.00309xOIDIST+.000147xNWEIGHT

+.0000398xAYDx(1+WEAVE)xOUTSLOPE

Where OUTSLOPE is the positive or absolute value of slope, and only applies if the unloaded tractor is moving uphill during outhaul.

(2) Position time

POSITION = .5674x(.16+.01273x50)

= .4519

(3) Winch time

WINCH = .31+.0335xTWDPT

(4) Hook time

HOOK = -.18+.9315xLOGSPT+.0119xTWDPT+.2251xHKSITESPT

(5) Intermediate travel time

IMTRAVEL = .06+.00623xIMDPT+.2468x(HKSITESPT-1)

(6) Landing time

LANDING = .52+.4242xLOGSPT+.3116x.46xLOGSPT+.1095x3

+.00014xNWEIGHT

= .8485+.5675xLOGSPT+.00014xNWEIGHT

(7) Pile slash time

PSLASH = .1791x1.20
= .2149

The cycle time components for the rubber-tired skidders are the same as for the crawler tractors; however, travel time is based on the mobility model discussed earlier. The assumptions used to predict travel time are as follows:

(1) The maximum allowable velocity in miles per hour (considering such factors as operator comfort and safety) for an unloaded skidder is 7.9. Siefert reported this as the average velocity for an unloaded skidder on flat ground. The skidder is assumed to operate on a designated skid trail.

(2) The maximum allowable velocity for a loaded skidder is 6.0 miles per hour.

(3) The average tree length log is approximately 50 feet long.

(4) The average cone index for the soil in the skid trail is 100.

Using these assumptions, the mobility model was used to establish a relationship between outhaul velocity and slope, and a regression equation for predicting inhaul velocity as a function of payload for each slope class.

Using the mobility model, predicted outhaul velocity was always greater than the safe operating speed (7.9 miles per hour) on slopes less than 15 percent; if the slope in the direction of outhaul is less than 15 percent, LOGCOST sets the inhaul velocity to 7.9 miles per hour. For other slopes, the predicted outhaul velocities are listed in Table 4 for the small and large skidders.

Table 4 Predicted outhaul velocity of a small and large skidder on slopes steeper than 10 percent.

Outhaul Slope (Percent)	Velocity of Small Skidder (mph)	Velocity of Large Skidder (mph)
15	6.43	6.56
20	5.34	5.45
25	4.58	4.68
30	4.04	4.13

The mobility model predicted speeds greater than 6.0 miles per hour for loaded skidders operating on favorable grades steeper than five percent; on these slopes, LOGCOST sets the inhaul velocity to 6.0 miles per hour. Table 5 lists the regression equations developed from output of the mobility model that are used to predict inhaul velocity on adverse grades, flat terrain, or a five percent favorable grade. The R^2 values were greater than .990 for all equations.

Table 5 Equations to predict inhaul velocity of a small and large skidder on a five percent favorable grade, flat grade, and two adverse grades, as a function of the logarithm of payload.

Inhaul Slope (Percent)	Velocity of Small Skidder (mph)	Velocity of Large Skidder (mph)
-5	54.23-5.56xLOG(WEIGHT)	56.73-5.58xLOG(WEIGHT)
0	38.08-3.856xLOG(WEIGHT)	40.4-3.93xLOG(WEIGHT)
+5	28.36-2.834xLOG(WEIGHT)	29.97-2.877xLOG(WEIGHT)
+10	20.39-1.982xLOG(WEIGHT)	22.27-2.095xLOG(WEIGHT)

LOGCOST tests the output of the equations in Table 5 above to see if predicted velocities are greater than the assumed safe operating speed; if they are, the inhaul velocity is set to 6.0 miles per hour.

Next, the inhaul and outhaul travel times are computed as follows:

(1) Velocity is converted to feet per minute.

VELOUT = (the velocity in mph)x5280/60

Where VELOUT is the outhaul velocity in feet per minute.

VELIN = VMPHx5280/60

Where VELIN is the inhaul velocity in feet per minute and VMPH is the inhaul velocity in miles per hour.

(2) Outhaul and inhaul distances are computed in feet.

ODIST = AYDx(1+WEAVE)

Where ODIST is the outhaul distance.

IDIST = ODIST-IMDPT

Where IDIST is the inhaul distance.

(3) Outhaul and inhaul times in minutes are then computed.

OUTHAUL = ODIST/VELOUT

INHAUL = IDIST/VELIN.

TRAVEL = OUTHAUL+INHAUL

LOGCOST then computes the other cycle time components using Siefert's equations for the large skidder:

(2) Position time

POSITION = .5674x(.29+.00747x50)

= .3765

(3) Winch time

WINCH = .25+.0221xTWDPT+.000202xTWDPTx11

= .25+.02432xTWDPT

(4) Hook time

HOOK = .24+.5926xLOGSPT+.007xTWDPT+.35xHKSITESPT

(5) Intermediate travel time

IMTRAVEL = .07+.00316xIMDPT+.13x(HKSITESPT-1)

(6) Landing time

LANDING = .44+.2171xLOGSPT+.2248x.46xLOGSPT+.0784x3

+.000082xNWEIGHT

= .6752+.3205xLOGSPT+.000082xNWEIGHT

(7) Pile slash time

PSLASH = .1791x.87

= .1558

The total cycle time in minutes is then computed for the ground based system selected:

CYCLETIME = TRAVEL+POSITION+WINCH+HOOK
+IMTRAVEL+LANDING+PSLASH

Daily production measured in thousand board feet (mbf) and yarding cost per mbf are computed as follows:

Daily production, NVYPD, (mbf)

NVYPD = (480xEFFxLOGSPTx(1-SCDEF)x(AVPT/1000)x.9756)/
CYCLETIME

Where EFF is the efficiency of the machine,

AVPT/1000 is the average gross volume per tree length log, in mbf, and .9756 represents the ratio of the logs landed and decked, to the logs hooked.

Cost per mbf, YCPM

YCPM = FDC/NVYPD

Where FDC is the fixed daily cost of the machine, operator, and landing sawyer.

Table 6 lists the machine efficiency, and the hourly and daily costs including operator and landing sawyer. Values for efficiency are from Siefert (1982). The efficiency of the small rubber-tired skidder (not studied by Siefert), is assumed to be similar to the large skidder.

Table 6 Efficiency, hourly and daily costs (including operator and landing sawyer) of a small and large crawler tractor, and a small and large rubber-tired skidder.

Skidding Machine	Net flywheel Horsepower	Efficiency	Cost Hourly ($)	Daily ($)
Small tractor	78	.79	38.51	308
Large tractor	140	.78	54.56	436
Small skidder	70	.74	34.84	279
Large skidder	120	.74	40.18	321

Skyline yarding production and cost per mbf are computed by first determining the number of logs per turn using simulation, and then computing production using Hochrein's cycle time equations. The lateral yarding simulation used to model skyline systems is similar to the ground-based simulation, except the carriage is not allowed to move (no intermediate moves) up and down the corridor to hook more logs during a single turn. Figure 17 is a flow chart of the lateral skyline model in LOGCOST.

Bucked logs are randomly distributed throughout the rectangular cutblock. Maximum lateral yarding distance is set equal to 125 feet. Next, the logs are sorted by their X coordinate, from closest to farthest to the landing (measured in the X direction). The carriage is moved out the skyline corridor approximately one choker length beyond the log closest to the landing (measured in the X direction). Effective choker lengths used in LOGCOST include a ten foot travel allowed by using sliders. The effective choker

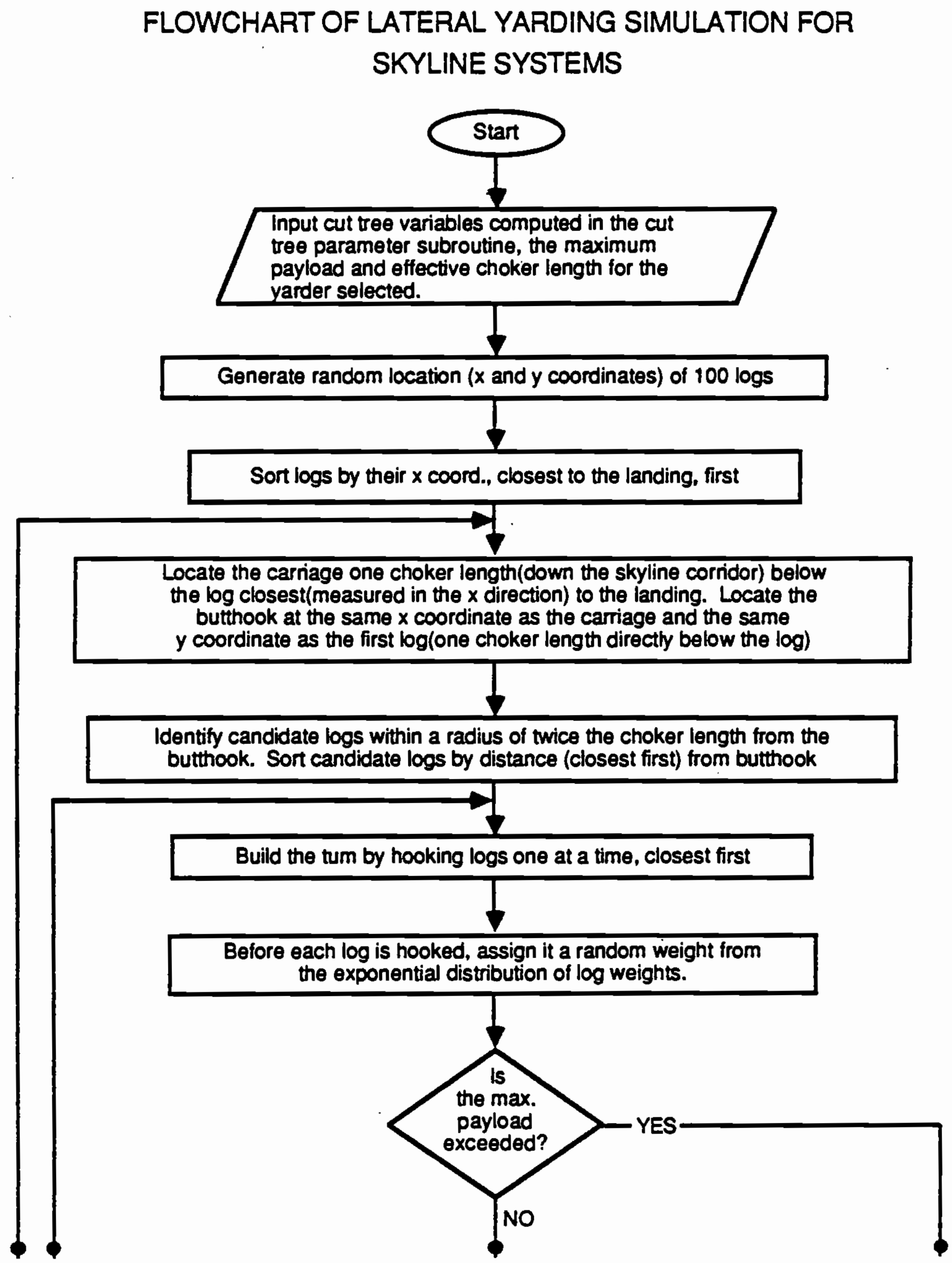


Figure 17. Flowchart of lateral yarding simulation for skyline systems.

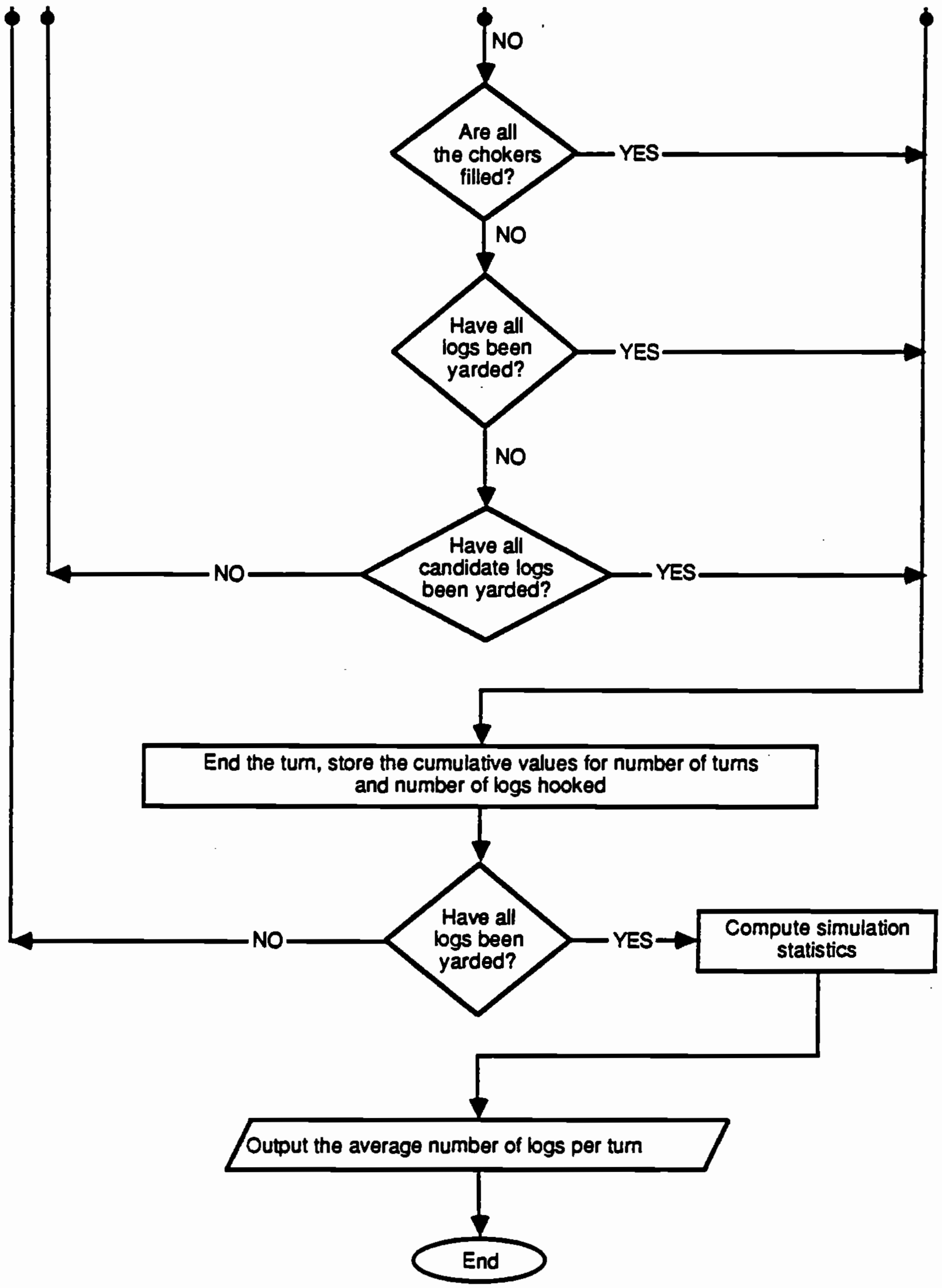


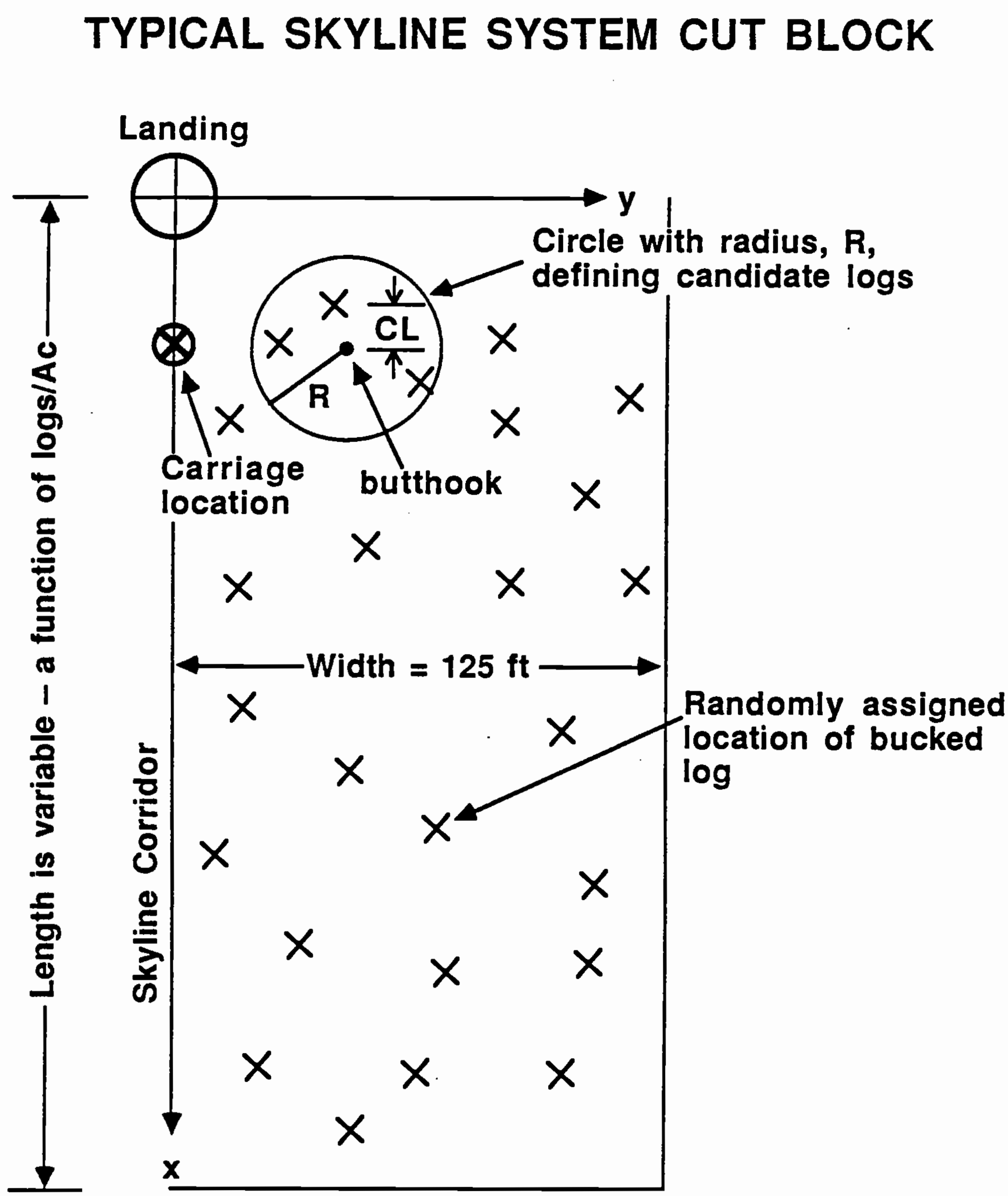
Figure 17 (continued)

lengths are 18 feet for the small yarder and 22 feet for the medium yarder. Some operators may pull the mainline further than 10 feet of travel between chokers, but more stand damage is likely. The X and Y coordinates of the butthook are then identified: the X coordinate is equal to the X coordinate of the carriage, and the Y coordinate is equal to the Y coordinate of the first log (see Figure 18).

Next, candidate logs within reach of twice the chokers effective length are identified and sorted by distance (closest first) from the butthook. A circular area with radius equal to twice the effective choker length is searched.

Although LOGCOST computes the average log size in board feet and average log weight in pounds, bucked logs in the woods are not all the same size or weight. To approximate this field condition, an exponential distribution of log weights is used. Sessions (1979) and Peters (1973) observed distributions of log sizes (log weight is simply the board feet volume times the pound to board feet ratio) that approximates an exponential distribution. The smallest log size permitted in the distribution is ten board feet and the largest log size is five times the mean log size. Before a log is hooked, it is randomly assigned a log weight from the exponential distribution.

RLOGWT = -WTPLxLOG(1-RND)



Note: R = 2 times the effective choker length
R = 2 x 18 = 36 ft for the small yarder, and
2 x 22 = 44 ft for the medium yarder.
Only 25 logs are shown in this diagram to simplify the illustration. LOGCOST simulates the lateral yarding of 100 logs.

Figure 18. Typical skyline system cut block,

Where RLOGWT is the randomly assigned log weight in pounds, WTPL is the average weight per log, and RND is a random number between zero and one.

Using this type of distribution, small logs are more common than larger logs, a phenomenon commonly observed in the woods (Murphy, 1986).

Next, the simulation model tests to see if (1) the maximum allowable payload will be exceeded or (2) all of the chokers are full. If not, the log is hooked. If either of the two conditions occur, the log is not hooked, and the turn is ended. The model continues hooking logs and testing the two conditions above until a turn is completed, then the model begins a new turn by repositioning the carriage and identifying a new set of candidate logs. This process is continued until all of the logs in the cutblock are yarded. LOGCOST models the lateral yarding of 100 logs per simulation. At the end of the simulation, the average logs per turn is computed by dividing the number of logs yarded by the number of turns.

Delay-free cycle time is then computed using Hochrein's equations. For the small skyline yarder, the cycle time in minutes is computed below:

CYCLETIME = 3.587+.003672xAYD+.01657xALYD+.2337xLOGSPT
-.01009xABS(SLOPE)

Where AYD is the average slope yarding distance in feet, entered by the user, ALYD is the average lateral yarding distance, which is assumed to be 50 feet[1], LOGSPT is the average number of logs per turn determined by the lateral simulation model discussed above, and SLOPE is the average percent slope of the skyline unit. The average lateral yarding distance of 50 feet is based on Hochrein's observations (1985) where trees were felled towards the skyline corridor and the average spacing between skyline landings was about 250 to 300 feet.

Cycle time for the medium size yarder is computed as follows:

CYCLETIME = 1.838+.003403xAYD+.0236xALYD+.1903xLOGSPT

Hochrein found the effective hour, expressed as a decimal, varied by the cut volume per acre for both yarders studied. Table 7 below lists effective hours for two different yarders in two different cut volumes per acre.

---

[1]Although landing spacing was often greater than 250 feet (external lateral yarding distance equals 125 feet), the average lateral yarding distance reported by Hochrein was less than 50 feet. Presumably, felling to lead, decreased the lateral distance from 62.5 feet to 50 feet.

Table 7 Effective Hour for a Small and Large Skyline Yarder Operating in Low and Moderate Cut Volume Per Acre.

Skyline Yarder Size	Volume/Acre Cut (mbf)	Effective hour (decimal)
Small	5	.68
Small	10	.73
Medium	5	.66
Medium	10	.74

Effective hour includes all delays associated with landing and skyline road changes as well as other delays. Only the move-in and move-out delay, expressed as a fixed cost, needs to be added in.

LOGCOST tests to see whether the cut volume is closer to the low or high cut volume studied by Hochrein, and then selects the appropriate effective hour for the yarder modeled. If the cut volume is greater than 7.5 mbf per acre, the higher effective hour associated with the 10 mbf cut volume is used. If cut volume per acre is less than 7.5 mbf, the lower effective hour is used.

The hourly production, including delays, is computed next:

NVYPH = (EFHRSYx60/CYCLETIME)x(LOGSPTxPCSZx(1-SCDEF)/1000)

Where NVYPH is net volume per hour in mbf,

EFHRSY is the appropriate effective hour (decimal), EFHRSSY is the effective hour of the small yarder, EFHRMSY is the effective hour of the medium yarder, and PCSZ is the board feet volume of the average bucked log.

The average yarding cost per mbf is then computed:

YCPM = FHCSY/NVYPH

Where YCPM is the yarding cost per mbf, and FHCSY is the fixed hourly cost of the skyline yarder modeled (Table 8).

LOGCOST also computes net daily production, assuming an eight hour day, for the output summary.

Table 8. Hourly and Daily Cost of A Small and Medium Size Skyline Yarder, Loader and Crew.

Skyline Yarder Size	Crew Size	Cost Hourly $	Cost Daily $
small	4	94.99	760.00
medium	6	222.45	1,780.00

APPENDIX D

Loading

APPENDIX D

Loading costs for ground based systems are computed using the technique currently in use by the Intermountain Region of the USDA, Forest Service. Schneider (1978) analyzed loading production data from the Boise, Payette, and Salmon National Forests and developed equations to estimate volume and loading time as a function of gross 16 feet logs per mbf. These equations, along with others to account for scaling defect, are used to adjust the average loading cost per mbf in the Southwestern Appraisal Zone.

LOGCOST uses the following Southwestern Zone Averages listed in the Region 4 Timber Appraisal Handbook, August 1985:

average loading cost, SWZALC	=	$10.53/mbf
average scaling defect, SWZAVG7	=	.05
average 16 feet logs per mbf, SWZAVG8	=	13.20

The zone average loading cost is adjusted up or down based upon the timber size (gross logs per mbf) and the scaling defect. A stand of timber that is larger than the zone average, having the same scaling defect, would have a lower loading cost; smaller timber would have a higher than average loading cost. If a stand has a scaling defect less than the zone average, the adjustment for defect lowers the loading cost.

LOGCOST first computes the timber size adjustment factor. Loading time per mbf is computed for the zone average conditions listed above and for the specific stand to be harvested. The timber size adjustment factor is equal to the ratio of the stand loading time per mbf to the zone average loading time per mbf, minus one. If the timber size is larger than the zone average, this adjustment factor is negative; if the timber is smaller than average, the adjustment factor is positive.

The scaling defect adjustment factor is then computed. The ratio defined below is computed for the zone average and the stand:

1/(1-scaling defect)

where scaling defect = .05 for the zone average and is a variable for the stand to be harvested.

The scaling defect adjustment factor is equal to the following ratio:

$$\frac{1/(1-\text{scaling defect of the stand})}{1/(1-\text{zone average scaling defect})}$$

The loading adjustment factor is equal to the sum of the timber size adjustment factor, the scaling defect adjustment factor, and one.

The stand average loading cost per mbf for ground-based systems is equal to the Southwestern Zone average loading cost times the loading adjustment factor.

Skyline yarding systems usually require a loader be present to hold logs while the chaser unhooks the chokers. A loader is also used to build decks on or below the road. For these reasons, loader production is usually limited to skyline yarding production. To compute the skyline loading cost per mbf, the hourly fixed and variable costs of the loader and operator are divided by the net hourly production of the skyline yarder.

APPENDIX E

Hauling

APPENDIX E

The average hauling cost per mbf is computed using a procedure similar to the Region 4 Appraisal System. The haul assumptions below are from the Region 4 Timber Appraisal Handbook, August, 1985:

Net legal highway load = 52,000 lb

Fixed daily cost log truck = $15,885/147 haul days

Fixed daily cost log truck driver = $198.25 ,

Variable cost per paved mile = $.3909

Variable cost per unpaved mile = $1.1728

Average haul day = 720 minutes

LOGCOST first computes the net volume and average standby time per truckload. These averages vary by tree species and by timber size. For example, green ponderosa pine is denser than lodgepole pine, 45 lb/ft^3 verses 39 lb/ft^3 (USDA Handbook No. 72, Wood Handbook). Because the volume is measured in board feet, truckloads of small timber have less volume than large mature timber (the pound to board feet ratio is higher for small timber). Standby time includes the variable load time, a constant 20 minute waiting time, and an 11 minute unload time. Schneider (1978) found load time was proportional to the number of pieces per truckload.

Average net volume per truckload is computed for each species using the generalized equation below:

$$\text{Net volume/truckload} = \frac{(52{,}000 \text{ pounds/(pound/board feet)}}{1000 \text{ board feet/mbf}}$$

The pound to board feet ratio used above is computed for each species harvested in the cut tree subroutine and is a function of tree size for a given species.

The number of loads is then computed for each species by dividing the net species volume in mbf, by the net volume per truckload.

Estimated truck standby time is a function of the gross 16 feet logs per mbf. The Forest Service uses Table B to estimate standby time. Values listed in Table B were used to develop linear regression equations for each species or species group. Equations are used in lieu of the table to permit estimating standby times for small timber where no table values exist (for example, 40 logs/mbf for ponderosa pine. Table 9 displays the species, regression equation and adjusted R squared values.

Table 9. Species Regression Equation to Predict Standby Time Per Trip, and R^2 Value

Species or Species Group	Standby time/trip Regression Equation	R2
ponderosa pine	44.00+1.159xlogs/mbf	.98
Douglas-fir, western larch	47.00+1.086xlogs/mbf	.99
lodgepole pine	56.46+.9893xlogs/mbf	1.00
grand fir, subalpine fir	45.02+1.099xlogs/mbf	.99
Engelmann spruce	48.87+1.324xlogs/mbf	.99

Table B - Estimated Truck Standby Time. This time includes a 20-minute waiting time, an 11-minute unload time, and variable load time.

Gross 15' Logs/M	PP	WF-AF	DF-WL	ES	LP
2	44				
3	47				
4	49				
5	50				
6	52		51		
7	53	53	53	57	
8	54	54	55	59	
9	55	55	57	60	
10	56	56	58	62	
11	57	57	59	64	
12	58	58	61	65	
13	59	59	62	67	68
14	60	60	63	68	69
15	61	61	64	69	70
16	62	63	65	71	72
17	63	64	66	72	73
18	65	65	67	73	75
19	66	66	68	74	75
20		67	69	75	77
21			71	77	78
22			71	77	79
23			72	79	80
24			74	80	81
25			74		82
26			75		83
27			76		84
28			78		85
29			78		85
30			79		86
31			80		87
32			81		88
33			82		89
34			84		90
35			85		91
36			86		92
37					93
38					94
39					94
40					95

Total standby time is computed for each species by multiplying the average standby time per roundtrip by the number of truckloads.

The stand average volume per truckload is computed by dividing the total stand net volume by the total number of truckloads. Average standby time per truckload is equal to the total standby time divided by the total number of truckloads.

Next, LOGCOST computes the total roundtrip travel time, including delays. Average roundtrip delay-free minutes per one-way mile was computed, based on appraisal data, for both paved and unpaved surfaces for each of 48 timber sales (25 from the Boise National Forest, and 23 from the Payette National Forest) sampled in southwestern Idaho. Mean values were then computed for each National Forest and compared using an unpaired t-test. Forest averages were not statistically different; consequently, the data was combined to compute the zone average roundtrip minutes per mile for paved and unpaved surfaces (see Table 10).

Table 10. Mean Roundtrip Minutes Per Mile for Paved and Unpaved Surfaces, Based on a Sample of 48 Timber Sales in Southwestern Idaho.

Surface Type	Mean Roundtrip Minutes/Mile	Standard Deviation	Standard Error of the Mean
Paved	3.92	.36	.052
Unpaved	5.38	.59	.086

Roundtrip travel time per truckload equals 3.92 times the one-way paved miles plus 5.38 times the one-way unpaved miles plus the average standby (delay) time.

The number of truckloads per day is equal to 720 minutes per day divided by the total round trip travel time per load. Net volume hauled per day is the product of the number of truckloads per day and the net volume per load.

The total daily cost of timber haul is equal to the fixed daily cost of the log truck and driver plus the variable cost per mile for paved and unpaved surfaces. The variable cost is computed as follows:

VCPDH = (2xMIPxVCPMIP+2xMIUPxVCPMIUP)xNTLPD

where MIP is the number of one-way paved miles,

MIUP is the number of one-way unpaved miles,

VCPMIP is the variable cost per paved mile of travel, $.3909, VCPMIUP is the variable cost per unpaved mile of travel, $1.1728, and

NTLPD is the number of truckloads per day.

Average haul cost per mbf equals the total cost per day divided by the net volume hauled per day.

APPENDIX F

Road Construction, Reconstruction, Maintenance, Environmental, and Move-In, Move-out Costs

APPENDIX F.

Road construction, reconstruction and maintenance costs associated with timber harvest are entered by the user as a variable cost per mile for construction/reconstruction and as a cost per mbf-mile for maintenance. LOGCOST then computes the total road cost per mbf, based on the variable costs and the miles of road to which they apply.

Environmental costs directly associated with a timber sale may also be included. Costs per acre for sale area improvement (abbreviated as SAI), erosion control (EC) and slash disposal (BD) are optional input. LOGCOST assumes these variable costs are charged to all of the acres in the stand when it computes the total environmental cost per mbf. If only a portion of the stand is to be treated, the cost per acre should be lowered so the total cost is correct. For example, if the total stand area is 40 acres, only 15 acres are to be planted, and the average planting cost is $300/acre, the user should first compute the adjusted SAI cost per acre as follows.

$$\text{Adjusted Cost/Acre} = \frac{\text{acres treated x per acre cost}}{\text{total stand acres}}$$

$$= \frac{\text{15 Acres x \$300/Acre}}{\text{40 acres}}$$

$$= \$112.50/\text{acre}$$

Then the adjusted SAI cost per acre of \$112.50 is entered, and LOGCOST computes the cost per mbf by multiplying \$112.50 x 40 and dividing this product by the total net volume harvested from the stand.

Miscellaneous logging costs, such as the move-in and move-out of large equipment, are also considered. LOGCOST assumes the move cost will be spread over 250 acres (the estimated area harvested per logging season by a single yarding system). Fight et al. (1983) estimated the move cost for skyline yarders and loaders typically used to thin Douglas-fir in western Oregon with the following equation.

Move Cost = 1240 + 12.55 x Roundtrip miles

LOGCOST assumes that the move costs of ground based systems, such as crawler tractors or skidders, and skyline systems, are similar; consequently, the above equation is used to compute the move-in, move-out cost of any yarding system.

One change is made to avoid double counting the move cost of the loader, only if a ground based system is selected. When the user selects any ground based system, the move cost is divided by two to represent only the cost of moving the skidder or crawler tractor. The Region 4 zone average loading cost already includes the loader's move-in, move-out cost.

Move costs are generally less than ten dollars per acre, and often less than one or two dollars per mbf. For example, if 10 mbf per acre was harvested from a 40-acre stand, 30 miles from the mill, using a skyline system, the move cost per acre is equal to:

(1240 + 12.55 x 60)/250

= 1,933/250

= $7.73

the move cost per mbf is:

7.73/10

= $.77.

APPENDIX G

Model Validation - Comparison

APPENDIX G

Some activities, such as log loading associated with ground based systems, and timber haul, are modeled by LOGCOST nearly the same as the Region 4 Timber Appraisal Handbook, and are assumed to be representative of typical costs experienced by industry in southwestern Idaho. Because the felling and bucking and yarding cost centers use a different approach, they were compared with other studies and with the Forest Service, Region Four Appraisal Estimates.

Felling and bucking daily production predicted by LOGCOST was compared with production experienced by private industry in southwestern Idaho, for trees ranging from 14 inches to 24 inches dbh; industry's measure of production, trees per hour, was multiplied by eight hours per day, and by the average volume per tree in mbf, to compare with LOGCOST. Figure 19 shows that daily production predicted by LOGCOST matches industry's estimates throughout the range of tree sizes most commonly harvested. If an hourly cost of $18.33 is used to compare felling and bucking cost per mbf, the difference between industry's cost and LOGCOST is less than 10 percent for all tree sizes reported (see Figure 20).

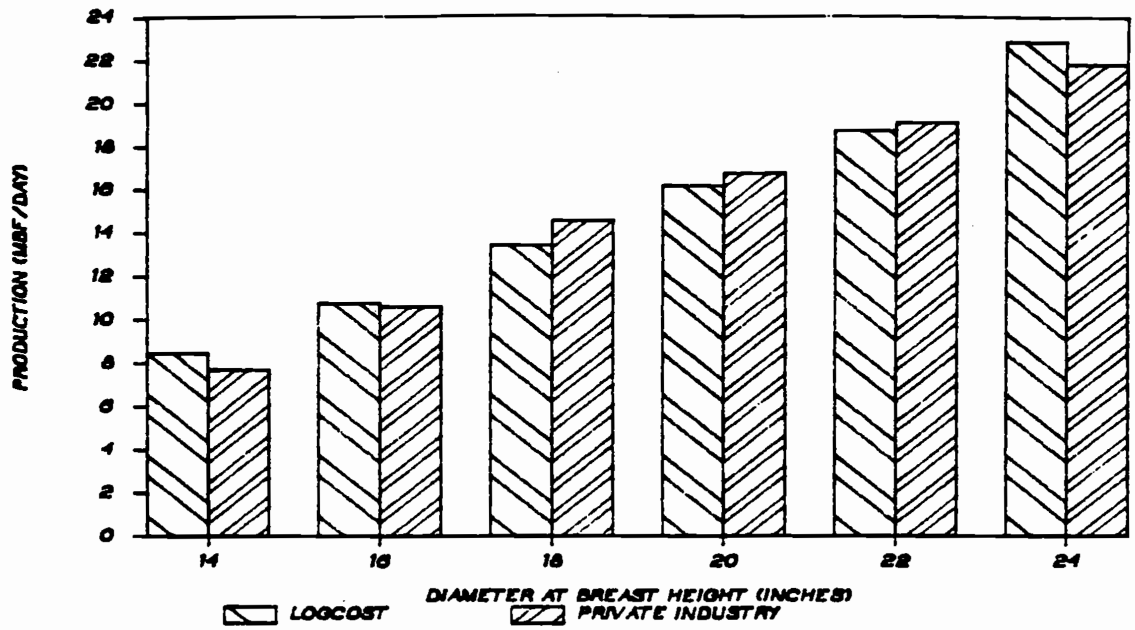


Figure 19. Comparison of LOGCOST Versus Felling and Bucking Production From Industry.

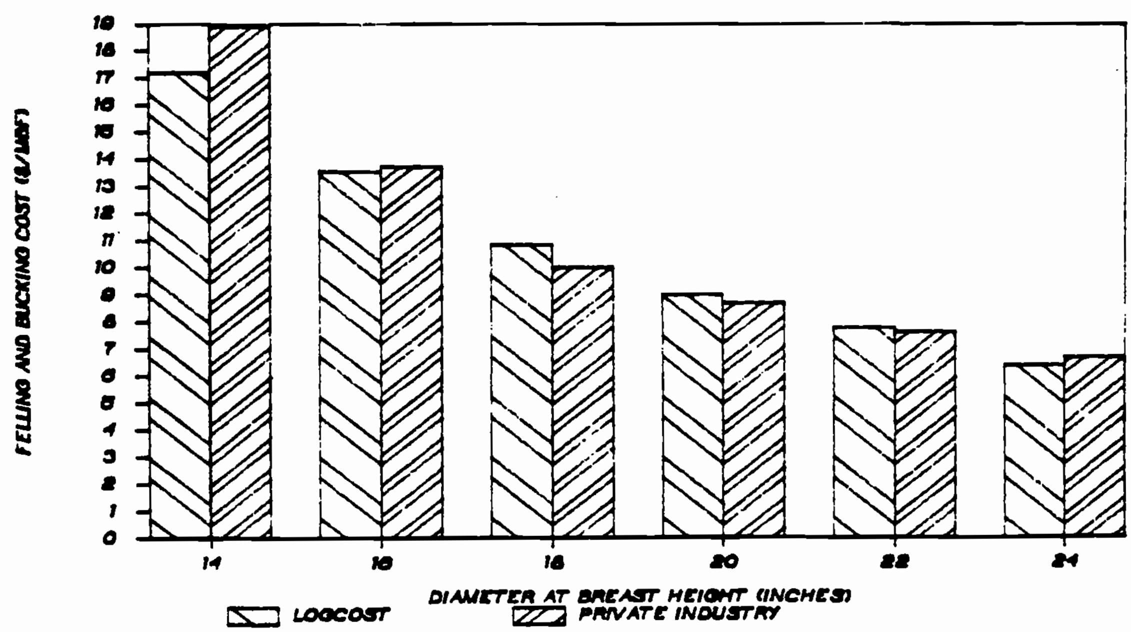


Figure 20. Comparison of LOGCOST versus Felling and Bucking Cost from Industry.

Yarding production for both ground based and skyline systems, computed by LOGCOST compared favorably with production reported by two studies. Siefert (1983) estimated daily production for three different machines that can be modeled by LOGCOST, based on average study conditions and cycletime equations. Using similar stand conditions, LOGCOST matched Siefert's production within 10 percent for each of three machines (see Figure 21).

Skyline yarding production was compared with Hochrein's time study results for two different stand conditions (see Figure 22). The cut volume per acre and average log size were 11.5 mbf and 55 bf for the high volume stand, and 5.4 mbf and 65 bf for the lower volume stand. Hochrein's study found a slight decrease in productivity when thinning the lower volume stand. LOGCOST predicted nearly the same daily production; this is probably because the fewer logs per turn (a function of fewer cut trees per acre) was offset by the larger volume per log (65 bf for the lower volume stand versus 55 bf). LOGCOST matched time study production reported by Hochrein within 13 percent.

Felling, bucking and yarding costs computed by LOGCOST were also compared with the Region 4 Appraisal Costs. Figures 23 and 24 contrast the differences. The assumed conditions were as follows: average yarding distance, 500 feet, cut trees per acre, 70, distance to the mill (for move-in, move-out cost), 30 miles, scaling defect, five

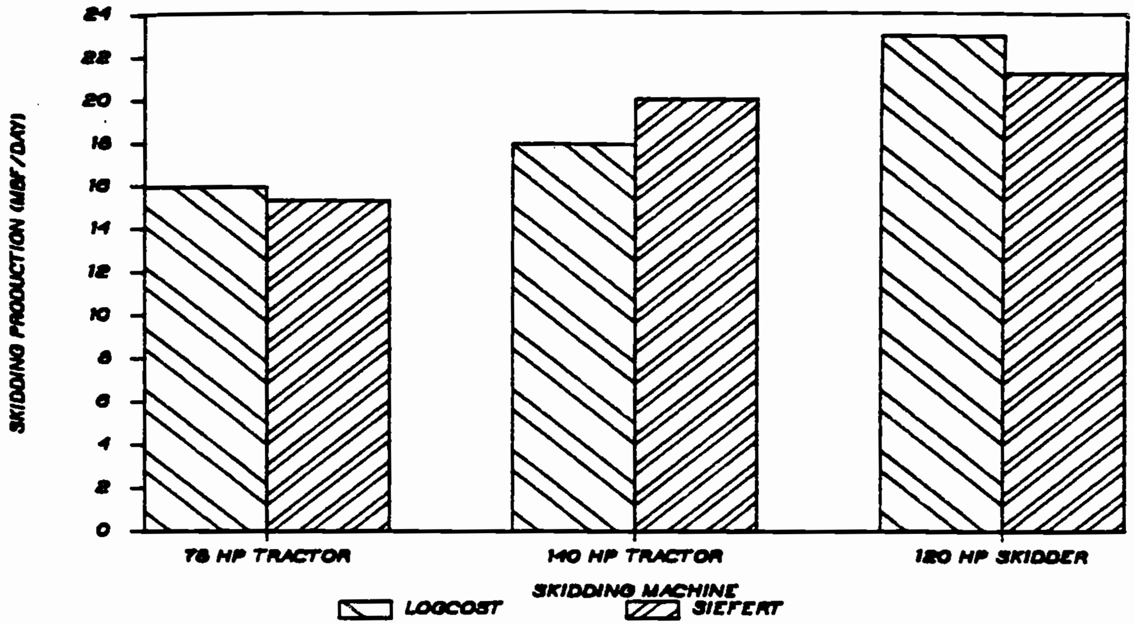


Figure 21. Skidding Production of LOGCOST versus Siefert.

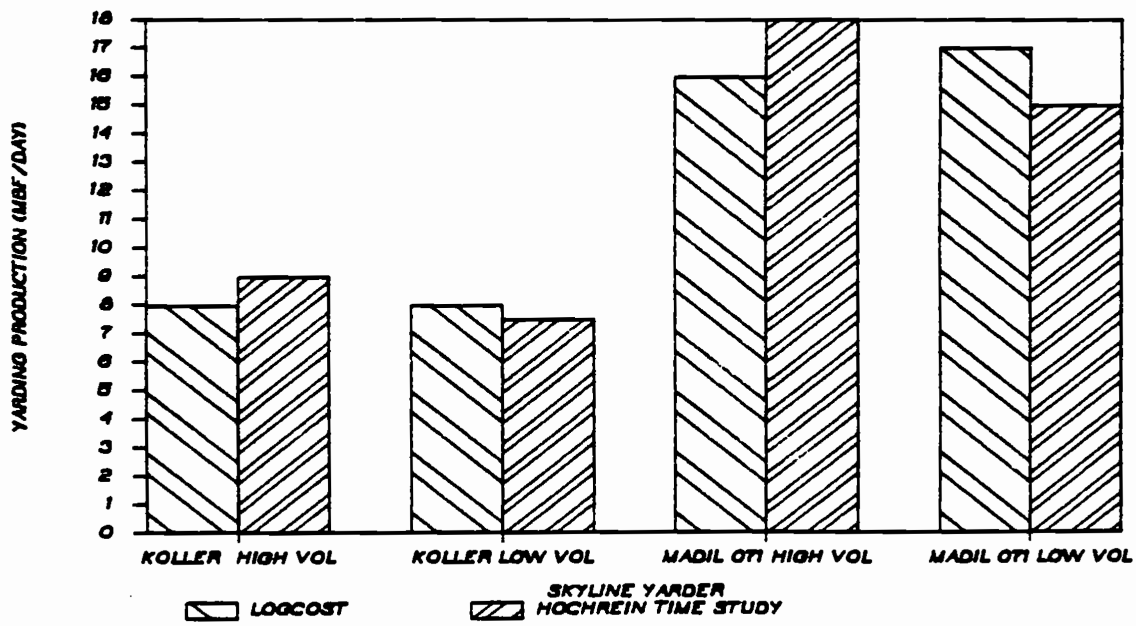


Figure 22. Skyline Yarding Production From LOGCOST versus Hochrein.

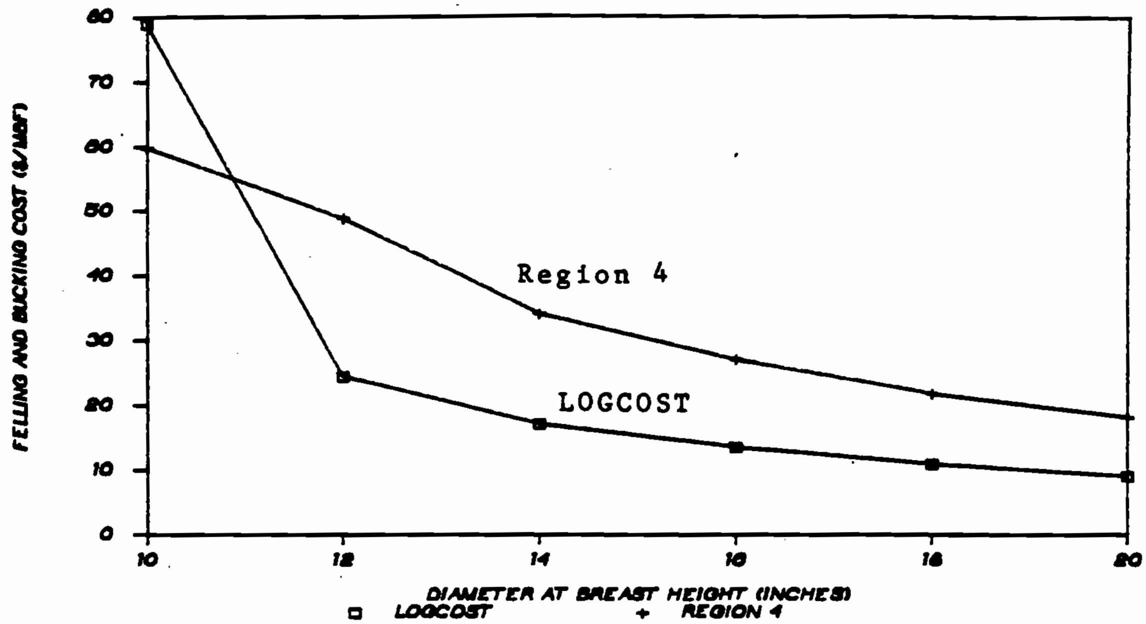


Figure 23. Felling and Bucking Costs from LOGCOST versus Region 4, USDA, Forest Service.

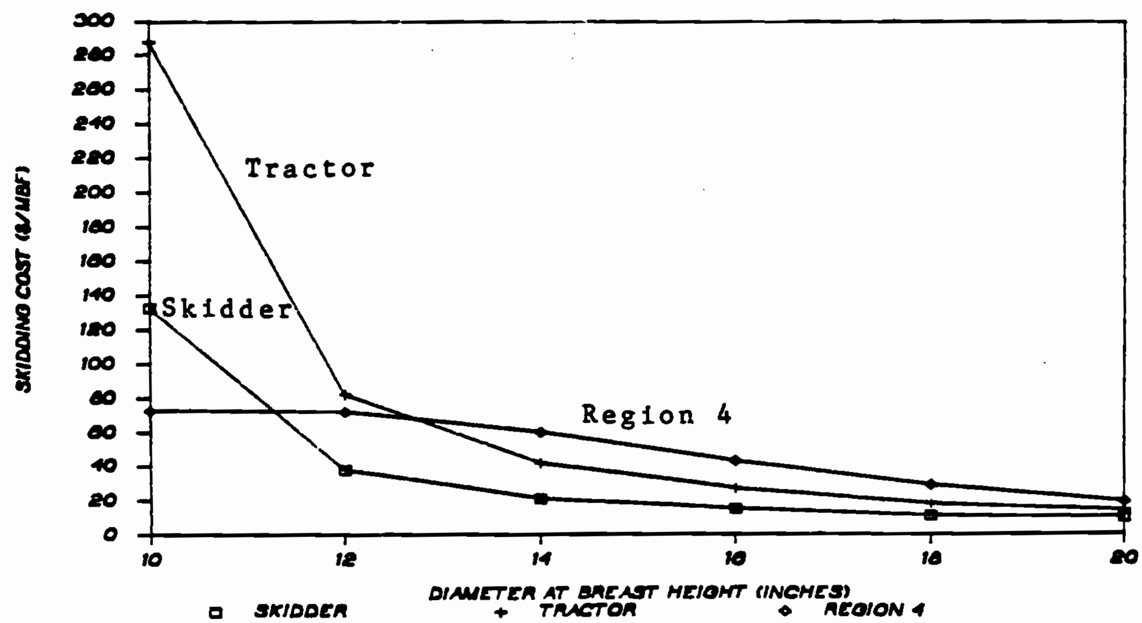


Figure 24. Skidding Costs From LOGCOST versus Region 4, USDA, Forest Service.

percent. In general, LOGCOST predicts higher costs for the smallest tree. Ten inch and 12 inch diameter trees (16, and 57 board feet, respectively) are so small that the number of gross 16 foot logs associated with these trees is beyond the limits of the chart used by the Region 4 Timber Appraisal Handbook. For this reason, the skidding cost adjustment associated with logs per mbf is not meaningful when tree size is very small. In addition, LOGCOST estimates about a $15/mbf lower cost for both felling, bucking, and skidding 16-inch trees (with a large crawler tractor) than the Region 4 Timber Appraisal. If rubber-tired skidders can be used, skidding costs computed by LOGCOST are about one-half the cost estimated by the appraisal handbook for 16-inch trees. Appraisal costs for skidding large timber (20 inches in diameter) begin to converge with those computed by LOGCOST.

APPENDIX H

Hourly Costs of Felling and Bucking
and Yarding systems

APPENDIX H.

The felling and bucking hourly cost includes one faller with saw, transportation, and supervision. Labor and saw rental costs are from the Region 4 Timber Appraisal Handbook, August, 1985.

1. Direct Labor Cost = \$9.90/hour. This includes health, welfare, holiday, and vacation costs.

2. Overtime pay for travel:

   \$9.90/hour x 1.5 x 1 hour/day = \$14.85/hour

3. Total Direct Labor Cost, based on an eight hour field day:

   (\$9.90/hour x 8 hours + \$14.85 x 1hour)/8 hours

   = \$11.76/hour, charged eight hours per day.

4. Supervision = 25% of Direct Labor Cost

   = .25 x \$11.76/hour

   = \$2.94/hour

5. Total Labor Cost = (\$11.76 + \$2.94)/hour

   = \$14.70/hour

6. Saw Rental = \$2.69/hour

7. Transportation Cost:

$$\frac{(25 \text{ miles one-way} \times 2) \times (\$.30/\text{mile})}{\text{crew of } 2}$$

= \$7.50 per person, per day

Hourly transportation cost per person

= (\$7.50/person)/(8 hours/person)

= \$.94/hour

8. **Total Cost Per Hour** = (\$14.70 + \$2.69 + \$.94)/hour

   = **\$18.33**

HOURLY AND DAILY COSTS OF GROUND-BASED SYSTEMS

Small Crawler Tractor - International Harvester TD-8E with operator, landing sawyer and saw.

1.	Depreciation	=	$ 5.44/hour
2.	Operating Costs	=	$ 9.88/hour
3.	Labor	=	$23.19/hour
	Total		**$38.51/hour**

Total Daily Cost = $308

Large Crawler Tractor - Caterpillar D6D with operator, landing sawyer and saw.

1.	Depreciation	=	$13.12/hour
2.	Operating Costs	=	$18.12/hour
3.	Labor	=	$23.19/hour
	Total		**$54.56/hour**

Total Daily Cost = $436

Small Rubber-Tired Skidder - John Deere 440 with operator, landing sawyer, and saw.

1.	Depreciation	=	$ 4.13/hour
2.	Operating Costs	=	$ 7.52/hour
3.	Labor	=	$23.19/hour
	Total		**$34.84/hour**

Total Daily Cost = $279

Large Rubber-Tired Skidder - Caterpillar 518 with operator, landing sawyer, and saw.

1.	Depreciation	=	$ 6.80/hour
2.	Operating Costs	=	$10.19/hour
3.	Labor	=	$23.19/hour
	Total		**$40.18/hour**

Total Daily Cost = $321

HOURLY COSTS OF SKYLINE SYSTEMS

Small Skyline System - Koller K300 with small truck-mounted loader.

		Yarder ($/hour)	Loader ($/hour)	Yarder and Loader ($/hour)
1.	Depreciation	5.08	4.14	9.22
2.	Maintenance, Repair, Fuel and Lube	4.51	6.80	11.31
3.	Lines & Chokers	.51	-	.51
4.	Labor	54.23	19.72	73.95
	Total	**64.33**	**30.66**	**94.99**

Medium Skyline System - Madil 071 with medium size self-propelled crawler mounted loader.

		Yarder ($/hour)	Loader ($/hour)	Yarder and Loader ($/hour)
1.	Depreciation	28.34	12.50	40.84
2.	Maintenance, Repair, Fuel and Lube	33.06	16.66	49.72
3.	Lines & Chokers	4.24	-	4.24
4.	Labor	107.93	19.72	127.65
	Total	**173.57**	**48.88**	**222.45**

APPENDIX I

LOGCOST Program List

```
10 REM ────────────────────────────────────────────────
20 REM ────────────────────────────────────────────────
30 REM THIS IS AN INTERACTIVE PROGRAM THAT COMPUTES LOGGING COSTS, STUMPAGE
40 REM AND NET PRESENT VALUE FOR EVENAGED TIMBER STANDS IN SOUTHWESTERN IDAHO.
50 REM FILE NAME IS "LOGCOST" DATE 4-16-86 AUTHOR ROBERT S. GILES
60 REM ────────────────────────────────────────────────
70 REM ────────────────────────────────────────────────
80 REM
90 REM
100 REM ***** DIMENSION ARRAYS *****
110 REM
120 DIM X(101),Y(101),A(101),B(101),STACK(12)
130 DIM KOUNT(101),X1(101),Y1(101),D1(101)
140 REM
150 CLS : KEY OFF
160 PRINT
170 PRINT
180 PRINT TAB(36) "LOGCOST"
190 PRINT
200 PRINT
210 PRINT TAB(17) "A TIMBER HARVEST ECONOMIC MODEL WHICH ESTIMATES"
220 PRINT TAB(18) "LOGGING COSTS, STUMPAGE AND NET PRESENT VALUE"
230 PRINT
240 PRINT TAB(16) "LOGCOST WAS DEVELOPED FOR USE IN EVEN-AGED STANDS"
250 PRINT TAB(30) "IN SOUTHWESTERN IDAHO"
260 PRINT
270 PRINT TAB(31) "BY ROBERT S. GILES"
280 PRINT
290 PRINT TAB(26) "USFS ADVANCED LOGGING SYSTEMS"
300 PRINT TAB(27) "TECHNICAL TRAINING PROGRAM"
310 PRINT TAB(32) "CORVALLIS, OREGON"
320 PRINT
330 PRINT TAB(35) "MARCH, 1986
340 PRINT
350 PRINT TAB(23) "MAKE SURE THE CAPS LOCK KEY IS ON!"
360 TLX=5 : TRX=75 : TLY=2 : BLY=23
370 GOSUB 11400
380 LOCATE 22,26 : INPUT "PRESS RETURN TO CONTINUE --->",KEY1$
390 CLS
400 LOCATE 5,12 : PRINT "THREE TYPES OF USER INPUT ARE REQUIRED TO RUN THE MODEL
:"
410 LOCATE 9,15 : PRINT "(1) STAND AND CUT TREE DATA"
420 LOCATE 12,15 : PRINT "(2) LOGGING AND ROAD CONSTRUCTION DATA"
430 LOCATE 15,15 : PRINT "(3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA"
440 TLX=5 : TRX=75 : TLY=2 : BLY=23
450 GOSUB 11400
460 LOCATE 22,26 : INPUT "PRESS RETURN TO CONTINUE --->",KEY2$
470 CLS
480 PRINT "(1) STAND DATA AND CUT TREE CHARACTERISTICS"
490 PRINT "────────────────────────────────────────────"
500 PRINT
510 INPUT "ENTER THE ANALYSIS YEAR, HARVEST YEAR - (_____,_____)
       FOR EXAMPLE, 1986,1995                        -->
",ANYEAR,HARVYEAR
520 INPUT "ENTER THE STAND ACRES                         -->
",ACRES
```

```
530 INPUT "ENTER THE STAND AVERAGE SCALING DEFECT (IN PERCENT)            —>
",PSCDEF : SCDEF=PSCDEF/100
540 INPUT "ENTER SPECIES CODE (PP,DF,LP,GF,AF,ES,WL) – (TYPE END TO QUIT)   —>
",SPECIES$
550 IF SPECIES$="END" THEN 680
560 PRINT "ENTER THE FOLLOWING DATA FOR THE TREE SPECIES HARVESTED:"
570 INPUT "ENTER CUT TREES/AC, GROSS VOL/AC (BF) – (____,______)          —>
",ZTPA,ZGVPA
580 INPUT "ENTER QUAD MEAN DBH, AVE TOTAL HEIGHT – (__,__,__)             —>
",ZQMD,ZTH
590 INPUT "ENTER THE POND VALUE (LOG PRICE FOB, MILL)                     —>
",ZPV
600 IF SPECIES$="PP" THEN TPAPP=ZTPA:GVPAPP=ZGVPA:QMDPP=ZQMD:THPP=ZTH:PVPP=ZPV
610 IF SPECIES$="DF" THEN TPADF=ZTPA:GVPADF=ZGVPA:QMDDF=ZQMD:THDF=ZTH:PVDF=ZPV
620 IF SPECIES$="LP" THEN TPALP=ZTPA:GVPALP=ZGVPA:QMDLP=ZQMD:THLP=ZTH:PVLP=ZPV
630 IF SPECIES$="GF" THEN TPAGF=ZTPA:GVPAGF=ZGVPA:QMDGF=ZQMD:THGF=ZTH:PVGF=ZPV
640 IF SPECIES$="AF" THEN TPAAF=ZTPA:GVPAAF=ZGVPA:QMDAF=ZQMD:THAF=ZTH:PVAF=ZPV
650 IF SPECIES$="ES" THEN TPAES=ZTPA:GVPAES=ZGVPA:QMDES=ZQMD:THES=ZTH:PVES=ZPV
660 IF SPECIES$="WL" THEN TPAWL=ZTPA:GVPAWL=ZGVPA:QMDWL=ZQMD:THWL=ZTH:PVWL=ZPV
670 GOTO 540
680 CLS
690 PRINT "(2) LOGGING SYSTEM AND TERRAIN INPUTS"
700 PRINT "————————————————————————
710 PRINT
720 INPUT "ENTER THE YARDING TYPE
       GBS = GROUND BASED SYSTEM, SKY = SKYLINE SYSTEM                —>
",YARDSYS$
730 IF YARDSYS$="SKY" THEN 830
740 INPUT "ENTER A SKIDDING MACHINE
       STRAC = SMALL CRAWLER TRACTOR,    LTRAC = LARGE TRACTOR
       SRTS  = SMALL RUBBER TIRED SKIDDER, LRTS = LARGE SKIDDER        —>
",GBSYS$
750 IF GBSYS$="STRAC" THEN 800
760 IF GBSYS$="LTRAC" THEN 800
770 INPUT "ENTER THE AVE SLOPE IN THE DIRECTION OF LOADED SKIDDER
       (CHOOSE -30,-25,-20,-15,-10,-5,0,+5,+10)                    —>
",SLOPE
780 INPUT "ENTER THE AVE SLOPE YARDING DISTANCE IN FEET                  —>
",AYD
790 GOTO 890
800 INPUT "ENTER THE AVE SLOPE IN THE DIRECTION OF LOADED CRAWLER TRACTOR
       (CHOOSE -45,-40,-35,-30,-25,-20,-15,-10,-5,0,+5,+10)          —>
",SLOPE
810 INPUT "ENTER THE AVE SLOPE YARDING DISTANCE IN FEET                  —>
",AYD
820 GOTO 890
830 INPUT "ENTER A SKYLINE YARDER – (SMALL OR MED)                       —>
",SKYSYS$
840 IF SKYSYS$="MED" THEN 860
850 GOTO 870
860 INPUT "ENTER YOUR ESTIMATE OF MAXIMUM SKYLINE PAYLOAD                —>
",MPLMSY
870 INPUT "ENTER THE AVE PERCENT SLOPE, (ABSOLUTE VALUE OF SLOPE)
       (CHOOSE 10,20,30,40,50,60,70,80,90)                       —>
",SLOPE
880 INPUT "ENTER THE AVE SLOPE YARDING DISTANCE IN FEET
```

```
      (MAXIMUM EXTERNAL YARDING DIST IS 1000 FEET FOR SMALL
       AND 2000 FEET FOR MEDIUM SKYLINE YARDERS)              —>
",AYD
890 PRINT
900 INPUT "ENTER THE ONE-WAY MILES OF PAVED HAUL ROAD                —>
",MIP
910 INPUT "ENTER THE ONE-WAY MILES OF UNPAVED HAUL ROAD              —>
",MIUP
920 PRINT
930 INPUT "ENTER THE MILES OF ROAD CONSTRUCTION OR RECONSTR CHARGED
      TO THIS STAND (INCLUDE BOTH SPECIFIED AND TEMPORARY ROADS)      —>
",RCMI
940 IF RCMI=0 THEN 960
950 INPUT "ENTER THE COST PER MILE FOR ROAD CONSTRUCTION/RECONSTR
      ($/MILE)                              —>
",RCCPMI
960 INPUT "ENTER THE MILES OF ROAD TO BE MAINTAINED                  —>
",MTCMI
970 IF MTCMI=0 THEN 990
980 INPUT "ENTER THE AVE VARIABLE COST FOR ROAD MAINTENANCE ($/MBF-MILE)   —>
",VMTCC
990 CLS
1000 PRINT "(3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA"
1010 PRINT "----------------------------------------------"
1020 PRINT
1030 INPUT "ENTER THE SALE AREA IMPROVEMENT COST/AC                  —
>",SAICPA
1040 INPUT "ENTER THE EROSION CONTROL COST/AC                        —
>",ECCPA
1050 INPUT "ENTER THE SLASH DISPOSAL COST/AC                         —
>",BDCPA
1060 INPUT "ENTER THE SALE PREP AND ADMIN COST/AC                    —
>",ADMINCPA
1070 REM
1080 REM ===============================================
1090 REM  DEFINE STATIC VARIABLES RESIDENT TO THE PROGRAM
1100 REM ===============================================
1110 REM
1120 REM ***** FELLING AND BUCKING VARIABLES *****
1130 REM
1140 DELAYFB=.25            'DELAY AS FRACTION OF TOTAL TIME
1150 CPHFB=18.33            'HOURLY COST ($)
1160 REM
1170 REM
1180 REM ***** AVERAGE GROUND BASED SYSTEM OR SKYLINE SYSTEM ACRES *****
1190 REM
1200 AVSYSAC=250            'AVERAGE GROUND BASED SYSTEM OR SKYLINE
1210 REM                 'SYSTEM ACRES HARVESTED PER LOGGING SEASON
1220 REM
1230 REM ***** GROUND BASED YARDING SYSTEM VARIABLES *****
1240 REM
1250 WEAVE=.1              'WEAVE FACTOR
1260 EFFLTRAC=.78            'EFFICIENCY, LARGE CRAWLER TRACTOR
1270 EFFSTRAC=.79            'EFFICIENCY, SMALL CRAWLER TRACTOR
1280 EFFRTS= .74            'EFFICIENCY, RUBBER TIRE SKIDDER
1290 FDCLTRAC=436            'FIXED DAILY COST, LARGE TRACTOR ($)
```

```
1300 FDCSTRAC=308          'FIXED DAILY COST, SMALL TRACTOR ($)
1310 FDCLRTS= 321          'FIXED DAILY COST, LARGE SKIDDER ($)
1320 FDCSRTS= 279          'FIXED DAILY COST, SMALL SKIDDER ($)
1330 REM
1340 REM ***** SKYLINE YARDING SYSTEM VARIABLES *****
1350 REM
1360 MPLSSY=2000           'MAXIMUM PAYLOAD, SMALL SKYLINE YARDER (LBS)
1370 ALYD=50              'AVERAGE LATERAL YARDING DISTANCE (FT)
1380 FHCSSY=94.99          'FIXED HOURLY COST, SMALL YARDER ($)
1390 FHCMSY=222.45         'FIXED HOURLY COST, MEDIUM YARDER ($)
1400 REM
1410 REM ***** LOADING VARIABLES *****
1420 REM
1430 SWZAVG7=.05           'SW ZONE AVE SCALING DEFECT (DEC)
1440 SWZAVG8=13.2          'SW ZONE AVE GROSS 16 FT LOGS/MBF
1450 SWZALC=10.53          'SW ZONE AVE LOADING COST ($/MBF)
1460 REM
1470 REM ***** HAULING VARIABLES *****
1480 REM
1490 NLHWY=52000!          'NET LEGAL HIGHWAY LOAD (LBS)
1500 RTMPMIP=3.92          'AVE ROUNDTRIP MIN/MI ON PAVED SURFACES
1510 RTMPMIUP=5.38         'AVE ROUNDTRIP MIN/MI ON UNPAVED SURFACES
1520 FDCLT=15885/147       'FIXED DAILY COST, LOG TRUCK ($)
1530 FDCLTD=198.25         'FIXED DAILY COST, LOG TRUCK DRIVER ($)
1540 VCPMIP=.3909          'VARIABLE COST/MI, PAVED SURFACES ($/MI)
1550 VCPMIUP=1.1728        'VARIABLE COST/MI, UMPAVED SURFACES ($/MI)
1560 REM
1570 REM ***** GENERAL LOGGING OVERHEAD *****
1580 REM
1590 GLOHCPM=8.42          'GENERAL LOGGING OVERHEAD ($/MBF)
1600 REM
1610 REM ==================================================
1620 REM COMPUTE CUT TREE PARAMETERS FOR MERCHANTABLE TREES
1630 REM ==================================================
1640 CLS
1650 REM
1660 GOSUB 3290
1670 REM
1680 REM =====================================================
1690 REM COMPUTE VARIABLE LOGGING COSTS IN $/MBF, STUMP TO MILL
1700 REM =====================================================
1710 REM
1720 PRINT "              PROGRAM IS COMPUTING LOGGING COSTS"
1730 PRINT
1740 PRINT "                       PLEASE WAIT"
1750 REM
1760 REM ***** COMPUTE FALLING AND BUCKING COST PER MBF *****
1770 REM
1780 GOSUB 5320
1790 REM
1800 REM ***** COMPUTE YARDING COST PER MBF *****
1810 REM
1820 IF YARDSYS$="GBS" THEN 1860      'GROUND BASED SYSTEM SELECTED
1830 GOSUB 7140                      'SKYLINE YARDING SYSTEM SELECTED
1840 GOTO 1920
1850 REM
```

```
1860 GOSUB 5580
1870 REM
1880 REM ***** COMPUTE LOADING COST PER MBF *****
1890 REM
1900 GOSUB 10010
1910 REM
1920 REM ***** COMPUTE HAULING COST PER MBF *****
1930 REM
1940 GOSUB 10400
1950 REM
1960 REM ***** COMPUTE MOVE IN MOVE OUT COST, YARDING AND LOADING *****
1970 REM ***** PRODUCTION, AND TOTAL LOGGING COST PER MBF        *****
1980 REM
1990 IF YARDSYS$="SKY" THEN MOVECOST=1240+12,55*(2*DISTMILL) ELSE MOVECOST=,5*(1
240+12,55*(2*DISTMILL))
2000 MOVECPA=MOVECOST/AVSYSAC
2010 MOVECPM=MOVECPA/NVOLPA
2020 IF YARDSYS$="GBS" THEN YLPPD=NVYPD : ELSE: YLPPD=NVYPH*8
2030 YLCPM=MOVECPM+YCPM+LCPM : LOGCPM=FBCPM+YLCPM+HCPM+GLOHCPM
2040 REM
2050 REM =====================================================
2060 REM COMPUTE COST OF ROAD CONSTRUCTION, RECONSTRUCTION AND
2070 REM MAINTENANCE, INCLUDING TEMPORARY ROADS, IN $/MBF
2080 REM =====================================================
2090 REM
2100 RCCPM=RCMI*RCCPMI/NVOL
2110 MTCCPM=MTCMI*VMTCC
2120 RCPM=RCCPM+MTCCPM
2130 REM
2140 REM ======================================================
2150 REM COMPUTE ENVIRONMENTAL AND ADMINISTRATIVE COSTS PER MBF
2160 REM ======================================================
2170 REM
2180 REM ***** COMPUTE ENVIRONMENTAL COST PER MBF *****
2190 REM
2200 SAICPM=SAICPA*ACRES/NVOL : ECCPM=ECCPA*ACRES/NVOL : BDCPM=BDCPA*ACRES/NVOL
2210 ENVICPM=SAICPM+ECCPM+BDCPM
2220 REM
2230 REM ***** COMPUTE ADMINISTRATIVE COST PER MBF *****
2240 REM
2250 ADMINCPM=ADMINCPA*ACRES/NVOL
2260 REM
2270 REM ===============================================================
2280 REM COMPUTE TOTAL HARVEST COST, GROSS STUMPAGE AND NET PRESENT VALUE
2290 REM ===============================================================
2300 REM
2310 THCPM=LOGCPM+RCPM+ENVICPM
2320 PRRI=,1071*PDVALUE
2330 GSTUMPAGE=PDVALUE-(THCPM+PRRI)
2340 NRETURN=(GSTUMPAGE-ADMINCPM)*(NVOLPA)
2350 DTIME=HARVYEAR-ANYEAR
2360 NPVPA=NRETURN*(1/1,04^DTIME)
2370 REM
2380 REM ================================
2390 REM PRINT OUT THE SUMMARY OF RESULTS
2400 REM ================================
```

```
2410 CLS
2420 PRINT TAB(16) "—————————————————————————————————————————————"
2430 PRINT TAB(16) "TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
2440 PRINT TAB(16) "—————————————————————————————————————————————"
2450 PRINT
2460 PRINT
2470 F1$="           STAND AREA                   —>#### ACRES"
2480 F2$="           NET VOLUME                   —>#### MBF"
2490 F3$="           NET VOLUME PER ACRE             —>##.# MBF"
2500 F4$="           TREES PER ACRE               —>#### TPA"
2510 F5$="           QUADRATIC MEAN DIAMETER          —>#### INCHES"
2520 F6$="           AVERAGE TOTAL HEIGHT           —>#### FEET"
2530 F7$="           AVERAGE GROSS LOG VOLUME         —>#### BF"
2540 F8$="           AVERAGE STEM LENGTH            —>#### FEET"
2550 G1$="           YARDING SYSTEM               —> \      \"
2560 G2$="           AVERAGE SLOPE YARDING DISTANCE    —>#### FEET"
2570 G3$="           AVERAGE SLOPE                —>#### PERCENT"
2580 G4$="           YARDING AND LOADING PRODUCTION     —>#### MBF/DAY"
2590 G5$="           DISTANCE TO THE MILL           —>#### MILES"
2600 H1$="           FELLING AND BUCKING COST         —>####.## $/MBF"
2610 H2$="           YARDING AND LOADING COST         —>####.## $/MBF"
2620 H3$="           HAULING COST                 —>####.## $/MBF"
2630 O1$="           GENERAL LOGGING OVERHEAD COST     —>####.## $/MBF"
2640 H4$="           STUMP TO MILL LOGGING COST        —>####.## $/MBF"
2650 H5$="           SPEC AND TEMP ROAD COST          —>####.## $/MBF"
2660 H6$="           SAI,EC AND BD COST             —>####.## $/MBF"
2670 H7$="           TOTAL HARVEST COST             —>####.## $/MBF"
2680 H8$="           PROFIT AND RISK (12 PERCENT)      —>####.## $/MBF"
2690 I1$="          AVERAGE POND VALUE              —>####.## $/MBF"
2700 I2$="          ESTIMATED STUMPAGE              —>####.## $/MBF"
2710 H9$="           SALE PREP AND ADMIN COST         —>#####  $/ACRE"
2720 I3$="          NET REVENUE (NOT DISCOUNTED)      —>#####  $/ACRE"
2730 I4$="          NET PRESENT VALUE (i = 4%)        —>#####  $/ACRE"
2740 PRINT USING F1$;ACRES
2750 PRINT USING F2$;NVOL
2760 PRINT USING F3$;NVOLPA
2770 PRINT USING F4$;TPA
2780 PRINT USING F5$;QMD
2790 PRINT USING F6$;AVETH
2800 IF YARDSYS$="GBS" THEN PRINT USING F7$;AVPT : GOTO 2820
2810 PRINT USING F7$;PCSZ
2820 PRINT USING F8$;AVEML
2830 PRINT
2840 IF YARDSYS$="GBS" THEN PRINT USING G1$;GBSYS$ : GOTO 2860
2850 PRINT USING G1$;SKYSYS$+YARDSYS$
2860 PRINT USING G2$;AYD
2870 PRINT USING G3$;SLOPE
2880 PRINT USING G4$;YLPPD
2890 PRINT USING G5$;DISTMILL
2900 PRINT
2910 PRINT
2920 INPUT "                PRESS RETURN TO CONTINUE —>",KEY3$
2930 CLS
2940 PRINT TAB(16) "—————————————————————————————————————————————"
2950 PRINT TAB(16) "TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
2960 PRINT TAB(16) "—————————————————————————————————————————————"
```

```
2970 PRINT TAB(35) "(CONTINUED)"
2980 PRINT
2990 PRINT
3000 PRINT USING H1$;FBCPM
3010 PRINT USING H2$;YLCPM
3020 PRINT USING H3$;HCPM
3030 PRINT USING O1$;GLOHCPM
3040 PRINT USING H4$;LOGCPM
3050 PRINT USING H5$;RCPM
3060 PRINT USING H6$;ENVICPM
3070 PRINT USING H7$;THCPM
3080 PRINT USING H8$;PRRI
3090 PRINT USING I1$;PDVALUE
3100 PRINT USING I2$;GSTUMPAGE
3110 PRINT
3120 PRINT USING H9$;ADMINCPA
3130 PRINT USING I3$;NRETURN
3140 PRINT USING I4$;NPVPA
3150 PRINT
3160 PRINT
3170 INPUT "     PRESS H AND RETURN FOR HARD COPY OF SUMMARY, PRESS RETURN TO CO
NTINUE  —>",HCOPY$ : IF HCOPY$="H" THEN 3190
3180 GOTO 3200
3190 GOSUB 11530
3200 CLS
3210 INPUT "DO YOU WANT TO TRY ANOTHER LOGGING SYSTEM (YES, NO) —>";ANOTHER$
3220 IF ANOTHER$="YES" THEN 680
3230 INPUT "DO YOU WANT TO START OVER OR QUIT (START, QUIT)     —>";QUIT$
3240 IF QUIT$="START" THEN 3250 ELSE 3260
3250 RUN 10
3260 END
3270 REM
3280 REM ——————————————————————————————————————————————
3290 REM ***** SUBROUTINE TO COMPUTE CUT TREE PARAMETERS *****
3300 REM ——————————————————————————————————————————————
3310 REM THIS SUBROUTINE COMPUTES CUT TREE PARAMETERS FOR THE FALLING
3320 REM AND BUCKING, YARDING, LOADING, AND HAULING SUBROUTINES.
3330 REM
3340 REM ***** TEST TO SEE IF PONDEROSA PINE TREES WERE CUT *****
3350 REM
3360 IF TPAPP=0 THEN 3710
3370 REM
3380 REM ******************************************************
3390 REM      COMPUTE PONDEROSA PINE CUT TREE PARAMETERS
3400 REM ******************************************************
3410 REM
3420 REM ***** COMPUTE TOTAL NET VOLUME IN MBF *****
3430 REM
3440 NVPP=(GVPAPP*(1-SCDEF)*ACRES)/1000
3450 REM
3460 REM ***** COMPUTE AVERAGE GROSS VOL/TREE IN BF *****
3470 REM
3480 AVPTPP=GVPAPP/TPAPP
3490 REM
3500 REM ***** COMPUTE MERCHANTABLE LENGTH IN FEET *****
3510 REM
```

```
3520 MLPP=.8381*THPP+7.299*SQR(QMDPP)-41.14
3530 REM
3540 REM ***** COMPUTE GROSS 16 FT LOGS/MBF *****
3550 REM
3560 LPMPP=(MLPP/16)/(AVPTPP/1000)
3570 REM
3580 REM ***** COMPUTE AVERAGE NUMBER OF PIECES/TREE *****
3590 REM
3600 PCPTPP=.1469+.01954*THPP+.0002468*QMDPP*THPP-2.717/QMDPP
3610 IF PCPTPP<1 THEN PCPTPP=1
3620 REM
3630 REM ***** COMPUTE AVERAGE PIECE SIZE IN BF *****
3640 REM
3650 PCSZPP=AVPTPP/PCPTPP
3660 REM
3670 REM ***** COMPUTE POUNDS/BOARD FOOT RATIO *****
3680 REM
3690 LBBFPP=12.09-.01397*PCSZPP+8.809999E-06*PCSZPP^2+187.6/PCSZPP
3700 REM
3710 REM ***** TEST TO SEE IF DOUGLAS-FIR TREES WERE CUT *****
3720 REM
3730 IF TPADF=0 THEN 3870
3740 REM
3750 REM ****************************************************
3760 REM      COMPUTE DOUGLAS-FIR CUT TREE PARAMETERS
3770 REM ****************************************************
3780 REM
3790 NVDF=(GVPADF*(1-SCDEF)*ACRES)/1000
3800 AVPTDF=GVPADF/TPADF
3810 MLDF=.8919*THDF+5.658*SQR(QMDDF)-35.62
3820 LPMDF=(MLDF/16)/(AVPTDF/1000)
3830 PCPTDF=-2.037+.04311*THDF-3.9E-07*THDF^3+64.64/THDF+9.78E-06*QMDDF^3-3.843/
QMDDF : IF PCPTDF<1 THEN PCPTDF=1
3840 PCSZDF=AVPTDF/PCPTDF
3850 LBBFDF=11.66-.01517*PCSZDF+1.295E-05*PCSZDF^2+101.8/PCSZDF
3860 REM
3870 REM ***** TEST TO SEE IF LODGEPOLE PINE TREES WERE CUT *****
3880 REM
3890 IF TPALP=0 THEN 4030
3900 REM
3910 REM ******************************************************
3920 REM      COMPUTE LODGEPOLE PINE CUT TREE PARAMETERS
3930 REM ******************************************************
3940 REM
3950 NVLP=(GVPALP*(1-SCDEF)*ACRES)/1000
3960 AVPTLP=GVPALP/TPALP
3970 MLLP=.6488*THLP+16.54*SQR(QMDLP)-60.41
3980 LPMLP=(MLLP/16)/(AVPTLP/1000)
3990 PCPTLP=.7838+1.034E-05*QMDLP*THLP^2 : IF PCPTLP<1 THEN PCPTLP=1
4000 PCSZLP=AVPTLP/PCPTLP
4010 LBBFLP=11.38-.03304*PCSZLP+67.73001/PCSZLP
4020 REM
4030 REM ***** TEST TO SEE IF GRAND FIR TREES WERE CUT *****
4040 REM
4050 IF TPAGF=0 THEN 4200
4060 REM
```

```
4070 REM **************************************************
4080 REM      COMPUTE GRAND FIR CUT TREE PARAMETERS
4090 REM **************************************************
4100 REM
4110 NVGF=(GVPAGF*(1-SCDEF)*ACRES)/1000
4120 AVPTGF=GVPAGF/TPAGF
4130 MLGF=.7691*THGF+8.18*SQR(QMDGF)-39.82
4140 LPMGF=(MLGF/16)/(AVPTGF/1000)
4150 PCPTGF=.9309+.01639*THGF+1.3E-07*THGF^3-8.533/QMDGF
4160 IF PCPTGF<1 THEN PCPTGF=1
4170 PCSZGF=AVPTGF/PCPTGF
4180 LBBFGF=8.105+370.4/PCSZGF
4190 REM
4200 REM ***** TEST TO SEE IF SUBALPINE FIR TREES WERE CUT *****
4210 REM
4220 IF TPAAF=0 THEN 4370
4230 REM
4240 REM ******************************************************
4250 REM      COMPUTE SUBALPINE FIR CUT TREE PARAMETERS
4260 REM ******************************************************
4270 REM
4280 NVAF=(GVPAAF*(1-SCDEF)*ACRES)/1000
4290 AVPTAF=GVPAAF/TPAAF
4300 MLAF=.6175*THAF+9.004501*SQR(QMDAF)-33.62
4310 LPMAF=(MLAF/16)/(AVPTAF/1000)
4320 PCPTAF=.9309+.01639*THAF+1.3E-07*THAF^3-8.533/QMDAF
4330 IF PCPTAF<1 THEN PCPTAF=1
4340 PCSZAF=AVPTAF/PCPTAF
4350 LBBFAF=8.105+370.4/PCSZAF
4360 REM
4370 REM ***** TEST TO SEE IF ENGELMANN SPRUCE TREES WERE CUT *****
4380 REM
4390 IF TPAES=0 THEN 4530
4400 REM
4410 REM *********************************************************
4420 REM      COMPUTE ENGELMANN SPRUCE CUT TREE PARAMETERS
4430 REM *********************************************************
4440 REM
4450 NVES=(GVPAES*(1-SCDEF)*ACRES)/1000
4460 AVPTES=GVPAES/TPAES
4470 MLES=.7887*THES+6.2505*SQR(QMDES)-36.75
4480 LPMES=(MLES/16)/(AVPTES/1000)
4490 PCPTES=-.4128+.02441*THES+.0007364*QMDES^2 : IF PCPTES<1 THEN PCPTES=1
4500 PCSZES=AVPTES/PCPTES
4510 LBBFES=8.439-.004477*PCSZES+199.9/PCSZES
4520 REM
4530 REM ***** TEST TO SEE IF WESTERN LARCH TREES WERE CUT *****
4540 REM
4550 IF TPAWL=0 THEN 4710
4560 REM
4570 REM ******************************************************
4580 REM      COMPUTE WESTERN LARCH CUT TREE PARAMETERS
4590 REM ******************************************************
4600 REM
4610 NVWL=(GVPAWL*(1-SCDEF)*ACRES)/1000
4620 AVPTWL=GVPAWL/TPAWL
```

```
4630 MLWL=.767*THWL+11.1*SQR(QMDWL)-53!
4640 LPMWL=(MLWL/16)/(AVPTWL/1000)
4650 PCPTWL=-.1998+.0158*THWL+.0007924*QMDWL*THWL-E.08E-6*QMDWL*THWL^2
4660 IF PCPTWL<1 THEN PCPTWL=1
4670 PCSZWL=AVPTWL/PCPTWL
4680 LBBFWL=11.66-.01517*PCSZWL+1.295E-05*PCSZWL^2+101.8/PCSZWL
4690 REM
4700 REM *****************************************************************
4710 REM     COMPUTE TOTAL OR WEIGHTED AVERAGE CUT TREE PARAMETERS
4720 REM *****************************************************************
4730 REM
4740 REM ***** COMPUTE GROSS VOLUME/AC IN BF AND NET VOLUME/AC IN MBF *****
4750 REM
4760 GVPA=GVPAPP+GVPADF+GVPALP+GVPAGF+GVPAAF+GVPAES+GVPAWL
4770 NVOLPA=GVPA*(1-SCDEF)/1000
4780 REM
4790 REM ***** COMPUTE TOTAL TREES PER ACRE *****
4800 REM
4810 TPA=TPAPP+TPADF+TPALP+TPAGF+TPAAF+TPAES+TPAWL
4820 REM
4830 REM ***** COMPUTE TOTAL NET VOLUME IN MBF *****
4840 REM
4850 NVOL=NVPP+NVDF+NVLP+NVGF+NVAF+NVES+NVWL
4860 REM
4870 REM ***** COMPUTE QUADRATIC MEAN DIAMETER IN INCHES *****
4880 REM
4890 BAPTREE=(TPAPP*.7854*QMDPP^2+TPADF*.7854*QMDDF^2+TPALP*.7854*QMDLP^2+TPAGF*
.7854*QMDGF^2+TPAAF*.7854*QMDAF^2+TPAES*.7854*QMDES^2+TPAWL*.7854*QMDWL^2)/TPA
4900 QMD=SQR(BAPTREE/.7854)
4910 REM
4920 REM ***** COMPUTE AVERAGE GROSS VOL/TREE IN BF *****
4930 REM
4940 AVPT=GVPA/TPA
4950 REM
4960 REM ***** COMPUTE AVERAGE GROSS 16 FT LOGS/MBF *****
4970 REM
4980 LPM=(LPMPP*GVPAPP+LPMDF*GVPADF+LPMLP*GVPALP+LPMGF*GVPAGF+LPMAF*GVPAAF+LPMES
*GVPAES+LPMWL*GVPAWL)/GVPA
4990 REM
5000 REM ***** COMPUTE AVERAGE PIECE SIZE IN BF *****
5010 REM
5020 PCSZ=(PCSZPP*GVPAPP+PCSZDF*GVPADF+PCSZLP*GVPALP+PCSZGF*GVPAGF+PCSZAF*GVPAAF
+PCSZES*GVPAES+PCSZWL*GVPAWL)/GVPA
5030 REM
5040 REM ***** COMPUTE AVERAGE MERCHANTABLE LENGTH AND TOTAL HEIGHT *****
5050 REM
5060 AVEML=(MLPP*TPAPP+MLDF*TPADF+MLLP*TPALP+MLGF*TPAGF+MLAF*TPAAF+MLES*TPAES+ML
WL*TPAWL)/TPA
5070 AVETH=(THPP*TPAPP+THDF*TPADF+THLP*TPALP+THGF*TPAGF+THAF*TPAAF+THES*TPAES+TH
WL*TPAWL)/TPA
5080 REM
5090 REM ***** COMPUTE AVERAGE NUMBER OF BUCKED LOGS PER ACRE *****
5100 REM
5110 NLOGSPA=GVPA/PCSZ
5120 REM
5130 REM ***** COMPUTE AVERAGE POUND/BOARD FOOT RATIO *****
```

```
5140 REM
5150 LBBF=(LBBFPP*GVPAPP+LBBFDF*GVPADF+LBBFLP*GVPALP+LBBFGF*GVPAGF+LBBFAF*GVPAAF
+LBBFES*GVPAES+LBBFWL*GVPAWL)/GVPA
5160 REM
5170 REM ***** COMPUTE AVERAGE WEIGHT/TREE IN LBS *****
5180 REM
5190 WTPT=AVPT*LBBF
5200 REM
5210 REM ***** COMPUTE AVERAGE WEIGHT/LOG IN LBS *****
5220 REM
5230 WTPL=PCSZ*LBBF
5240 REM
5250 REM ***** COMPUTE WEIGHTED AVERAGE POND VALUE *****
5260 REM
5270 PDVALUE=(PVPP*NVPP+PVDF*NVDF+PVLP*NVLP+PVGF*NVGF+PVAF*NVAF+PVES*NVES+PVWL*N
VWL)/NVOL
5280 REM
5290 RETURN
5300 REM
5310 REM -----------------------------------------------------------------
5320 REM ***** SUBROUTINE TO COMPUTE FELLING AND BUCKING COST PER MBF *****
5330 REM -----------------------------------------------------------------
5340 REM
5350 REM ***** COMPUTE AVE NET VOL/TREE (SCRIBNER DEC C) *****
5360 REM
5370 NVPTSDC=(AVPT*(1-SCDEF))/10 : IF NVPTSDC<1.1 THEN NVPTSDC=1.1
5380 REM
5390 REM ***** DEFINE LOG BASE TEN OF QMD AND NVPTSDC *****
5400 REM
5410 LGTQMD=LOG(QMD)/2.303
5420 LGTNVPTSDC=LOG(NVPTSDC)/2.303
5430 REM
5440 REM ***** COMPUTE DELAY FREE FALLING AND BUCKING TIME IN MIN/MBF *****
5450 REM
5460 FBTPM=-53.24-1.205*QMD+.07987*NVPTSDC+110.9*LGTQMD+28.31/LGTNVPTSDC-42.09*L
GTNVPTSDC
5470 REM
5480 REM ***** COMPUTE TOTAL FALLING AND BUCKING TIME INCLUDING DELAYS *****
5490 REM
5500 TFBTPM=FBTPM/(1-DELAYFB)
5510 REM
5520 REM ***** COMPUTE AVERAGE FALLING AND BUCKING COST/MBF *****
5530 REM
5540 FBCPM=(CPHFB/60)*TFBTPM
5550 RETURN
5560 REM
5570 REM ---------------------------------------------------------
5580 REM ***** SUBROUTINE TO COMPUTE YARDING COST PER MBF FOR *****
5590 REM ***** GROUND BASED SYSTEMS INCLUDING SMALL AND MEDIUM *****
5600 REM ***** SIZE CRAWLER TRACTORS AND RUBBER TIRED SKIDDERS *****
5610 REM ---------------------------------------------------------
5620 REM
5630 REM ***** ASSIGN MAXIMUM PAYLOAD IN LBS TO THE SELECTED SYSTEM *****
5640 REM
5650 IF GBSYS$="LTRAC" THEN MAXPL=20000
5660 IF GBSYS$="STRAC" THEN MAXPL=13000
```

```
5670 IF GBSYS$="LRTS"  THEN MAXPL=10000
5680 IF GBSYS$="SRTS"  THEN MAXPL= 7000
5690 REM
5700 REM ***** GO TO LATERAL YARDING SUBROUTINE *****
5710 REM
5720 GOSUB 7530
5730 REM
5740 REM ***** GO TO THE GROUND BASED SYSTEM SELECTED *****
5750 REM
5760 IF GBSYS$="LTRAC" THEN 5820
5770 IF GBSYS$="STRAC" THEN 6050
5780 IF GBSYS$="LRTS"  THEN 6290
5790 IF GBSYS$="SRTS"  THEN 6600
5800 REM
5810 REM *********************************
5820 REM      LARGE CRAWLER TRACTOR
5830 REM *********************************
5840 REM
5850 REM ***** COMPUTE CYCLE TIME *****
5860 REM
5870 OIDIST=(2*AYD*(1+WEAVE))-IMDPT
5880 NWEIGHT=WTPT*(1-SCDEF)*LOGSPT
5890 TRAVEL=.03+.002705*OIDIST+.000105*NWEIGHT
5900 POSITION=.3878
5910 WINCH=.13+.02693*TWDPT
5920 HOOK=.1+1.041*LOGSPT+.01933*TWDPT
5930 IMTRAVEL=.01+.0048*IMDPT+.258*(HKSITESPT-1)
5940 LANDING=1.26+.7426*LOGSPT
5950 PSLASH=.1558
5960 CYCLETIME=TRAVEL+POSITON+WINCH+HOOK+IMTRAVEL+LANDING+PSLASH
5970 REM
5980 REM ***** COMPUTE DAILY PRODUCTION AND YARDING COST PER MBF *****
5990 REM
6000 NVYPD=(480*EFFLTRAC*LOGSPT*(1-SCDEF)*(AVPT/1000)*.9756)/CYCLETIME
6010 YCPM=FDCLTRAC/NVYPD
6020 RETURN
6030 REM
6040 REM *********************************
6050 REM      SMALL CRAWLER TRACTOR
6060 REM *********************************
6070 REM
6080 REM ***** COMPUTE CYCLE TIME *****
6090 REM
6100 OIDIST=(2*AYD*(1+WEAVE))-IMDPT
6110 NWEIGHT=WTPT*(1-SCDEF)*LOGSPT
6120 IF SLOPE<0 THEN OUTSLOPE=ABS(SLOPE) ELSE OUTSLOPE=0
6130 TRAVEL=.35+.00309*OIDIST+.000147*NWEIGHT+.0000398*AYD*(1+WEAVE)*OUTSLOPE
6140 POSITION=.4519
6150 WINCH=.31+.0335*TWDPT
6160 HOOK=-.18+.9315*LOGSPT+.0119*TWDPT+.2251*HKSITESPT
6170 IMTRAVEL=.06+.00623*IMDPT+.2468*(HKSITESPT-1)
6180 LANDING=.8485+.5675*LOGSPT+.00014*NWEIGHT
6190 PSLASH=.2149
6200 CYCLETIME=TRAVEL+POSITION+WINCH+HOOK+IMTRAVEL+LANDING+PSLASH
6210 REM
6220 REM ***** COMPUTE DAILY PRODUCTION AND YARDING COST PER MBF *****
```

```
6230 REM
6240 NVYPD=(480*EFFSTRAC*LOGSPT*(1-SCDEF)*(AVPT/1000)*.9756)/CYCLETIME
6250 YCPM=FDCSTRAC/NVYPD
6260 RETURN
6270 REM
6280 REM **************************************
6290 REM     LARGE RUBBER TIRED SKIDDER
6300 REM **************************************
6310 REM
6320 REM ***** COMPUTE OUTHAUL VELOCITY IN FEET PER MINUTE *****
6330 REM
6340 OUTSLOPE=-1*SLOPE
6350 IF OUTSLOPE<15 THEN VELOUT=7.9*5280/60
6360 IF OUTSLOPE=15 THEN VELOUT=6.56*5280/60
6370 IF OUTSLOPE=20 THEN VELOUT=5.45*5280/60
6380 IF OUTSLOPE=25 THEN VELOUT=4.68*5280/60
6390 IF OUTSLOPE=30 THEN VELOUT=4.13*5280/60
6400 REM
6410 REM ***** COMPUTE INHAUL VELOCITY IN MPH *****
6420 REM
6430 WEIGHT=WTPT*LOGSPT
6440 IF SLOPE<-5 THEN VMPH=6
6450 IF SLOPE=-5 THEN VMPH=56.73-5.58*LOG(WEIGHT)
6460 IF SLOPE= 0 THEN VMPH=40.4-3.93*LOG(WEIGHT)
6470 IF SLOPE= 5 THEN VMPH=29.97-2.877*LOG(WEIGHT)
6480 IF SLOPE=10 THEN VMPH=22.27-2.095*LOG(WEIGHT)
6490 REM
6500 REM ***** IF PREDICTED VEL > 6 MPH, SET IT = 6 MPH *****
6510 REM
6520 IF VMPH>6! THEN VMPH=6!
6530 REM
6540 REM ***** COMPUTE INHAUL VELOCITY IN FEET PER MINUTE *****
6550 REM
6560 VELIN=VMPH*5280/60
6570 GOTO 6900
6580 REM
6590 REM **************************************
6600 REM     SMALL RUBBER TIRED SKIDDER
6610 REM **************************************
6620 REM
6630 REM ***** COMPUTE OUTHAUL VELOCITY IN FEET PER MINUTE *****
6640 REM
6650 OUTSLOPE=-1*SLOPE
6660 IF OUTSLOPE<15 THEN VELOUT=7.9*5280/60
6670 IF OUTSLOPE=15 THEN VELOUT=6.43*5280/60
6680 IF OUTSLOPE=20 THEN VELOUT=5.34*5280/60
6690 IF OUTSLOPE=25 THEN VELOUT=4.58*5280/60
6700 IF OUTSLOPE=30 THEN VELOUT=4.04*5280/60
6710 REM
6720 REM ***** COMPUTE INHAUL VELOCITY IN MPH *****
6730 REM
6740 WEIGHT=WTPT*LOGSPT
6750 IF SLOPE<-5 THEN VMPH=6!
6760 IF SLOPE=-5 THEN VMPH=54.23-5.56*LOG(WEIGHT)
6770 IF SLOPE= 0 THEN VMPH=38.08-3.856*LOG(WEIGHT)
6780 IF SLOPE= 5 THEN VMPH=28.36-2.834*LOG(WEIGHT)
```

```
6790 IF SLOPE=10 THEN VMPH=20.39-1.932*LOG(WEIGHT)
6800 REM
6810 REM ***** IF PREDICTED VEL > 6 MPH THEN SET IT = 6 MPH *****
6820 REM
6830 IF VMPH>6! THEN VMPH=6!
6840 REM
6850 REM ***** COMPUTE INHAUL VELOCITY IN FEET PER MINUTE *****
6860 REM
6870 VELIN=VMPH*5280/60
6880 REM
6890 REM **************************************************
6900 REM      SMALL AND LARGE RUBBER TIRED SKIDDERS
6910 REM **************************************************
6920 REM
6930 REM ***** COMPUTE CYCLE TIME *****
6940 REM
6950 NWEIGHT= WTPT*LOGSPT*(1-SCDEF) : ODIST=AYD*(1+WEAVE) : IDIST=ODIST-IMDPT
6960 OUTHAUL=ODIST/VELOUT : INHAUL=IDIST/VELIN
6970 TRAVEL=OUTHAUL+INHAUL
6980 POSITION=.3765
6990 WINCH=.25+.02432*TWDPT
7000 HOOK=.24+.5926*LOGSPT+.007*TWDPT+.35*HKSITESPT
7010 IMTRAVEL=.07+.00316*IMDPT+.13*(HKSITESPT-1)
7020 LANDING=.6752+.3205*LOGSPT+.000032*NWEIGHT
7030 PSLASH=.1558
7040 CYCLETIME=TRAVEL+POSITION+WINCH+HOOK+IMTRAVEL+LANDING+PSLASH
7050 REM
7060 REM ***** COMPUTE DAILY PRODUCTION AND YARDING COST PER MBF *****
7070 REM
7080 NVYPD=(480*EFFRTS*LOGSPT*(1-SCDEF)*(AVPT/1000)*.9756)/CYCLETIME
7090 IF GBSYS$="LRTS" THEN FDCRTS=FDCLRTS ELSE FDCRTS=FDCSRTS
7100 YCPM=FDCRTS/NVYPD
7110 RETURN
7120 REM
7130 REM -----------------------------------------------------------
7140 REM ***** SUBROUTINE TO COMPUTE YARDING COST PER MBF FOR *****
7150 REM ***** SMALL AND MEDIUM SIZE SKYLINE SYSTEMS        *****
7160 REM -----------------------------------------------------------
7170 REM
7180 REM ***** ASSIGN MAXIMUM PAYLOAD IN LBS TO THE SELECTED SYSTEM *****
7190 REM ***** AND GO TO THE LATERAL YARDING SUBROUTINE           *****
7200 REM
7210 IF WTPL>1000 THEN SKYSYS$="MED" : GOTO 7230
7220 IF SKYSYS$="SMALL" THEN MAXPL=MPLSSY : CL=8+10
7230 IF SKYSYS$="MED"   THEN MAXPL=MPLMSY : CL=12+10
7240 IF MAXPL=0 THEN MAXPL=5000
7250 GOSUB 9290
7260 REM
7270 REM ***** GO TO THE SKYLINE SYSTEM SELECTED *****
7280 REM
7290 IF SKYSYS$="MED" THEN 7440
7300 REM
7310 REM ****************************************
7320 REM      SMALL SKYLINE YARDING SYSTEM
7330 REM ****************************************
7340 REM
```

```
7350 REM ***** COMPUTE CYCLETIME, HOURLY PRODUCTION, AND COST/MBF *****
7360 REM
7370 CYCLETIME=3.587+.003672*AYD+.01657*ALYD+.2337*LOGSPT-.01009*ABS(SLOPE)
7380 IF GVPA>7500 THEN EFHRSSY=.73 ELSE EFHRSSY=.68
7390 NVYPH=(EFHRSSY*60/CYCLETIME)*(LOGSPT*PCSZ*(1-SCDEF)/1000)
7400 YCPM=FHCSSY/NVYPH
7410 RETURN
7420 REM
7430 REM ****************************************
7440 REM      MEDIUM SKYLINE YARDING SYSTEM
7450 REM ****************************************
7460 REM
7470 CYCLETIME=1.838+.003403*AYD+.0236*ALYD+.1903*LOGSPT
7480 IF GVPA>7500 THEN EFHRMSY=.74 ELSE EFHRMSY=.66
7490 NVYPH=(EFHRMSY*60/CYCLETIME)*(LOGSPT*PCSZ*(1-SCDEF)/1000)
7500 YCPM=FHCMSY/NVYPH
7510 RETURN
7520 REM
7530 REM ----------------------------------------------------------------
7540 REM ***** SUBROUTINE TO SIMULATE LATERAL YARDING OF GROUND *****
7550 REM ***** BASED SYSTEMS SUCH AS TRACTORS AND SKIDDERS     *****
7560 REM ----------------------------------------------------------------
7570 REM THIS SUBROUTINE SIMULATES THE LATERAL YARDING PORTION OF
7580 REM GROUND BASED SYSTEMS SUCH AS CRAWLER TRACTORS AND SKIDDERS.
7590 REM
7600 REM ***** INITIALIZE KEY VARIABLES *****
7610 REM
7620 NTURNS=0 : HKSITES=0 : NLOGS=0 : CS=0 : WDMAX=0 : TWD=0 : IMD=0 : N1=0
7630 WI=50 : CN=5 : N=100
7640 REM
7650 REM ***** COMPUTE THE LENGTH OF CUT BLOCK TO BE MODELED *****
7660 REM
7670 LE=(43560!*N)/(WI*TPA)
7680 REM
7690 REM ***** GENERATE LOCATION OF FELLED TREES *****
7700 REM
7710 FOR I=1 TO N
7720    X(I)=RND*LE
7730    Y(I)=RND*WI
7740 NEXT I
7750 REM
7760 REM ***** SORT TREES BY THEIR X COORDINATE *****
7770 REM
7780 GOSUB 8450
7790 REM
7800 REM ***** IDENTIFY LOCATION OF MACHINE FOR THE FIRST TURN *****
7810 REM
7820 D=X(N)
7830 ML=D-7.5
7840 REM
7850 REM ***** IDENTIFY CANDIDATE LOGS AND CREATE LOG ARRAY *****
7860 REM
7870 N1=0
7880 FOR I=1 TO N
7890    IF X(I)=0 THEN 7960
7900    IF ABS(X(I)-ML)>7.5 THEN 7960
```

```
7910   N1=N1+1
7920   KOUNT(N1)=I
7930   X1(N1)=X(I)
7940   Y1(N1)=Y(I)
7950   D1(N1)=SQR((X(I)-ML)^2+Y(I)^2)
7960 NEXT I
7970 GOSUB 9030
7980 REM
7990 REM ***** BEGIN BUILDING TURN *****
8000 REM
8010 FOR I=1 TO N1
8020   PAYLOAD=PAYLOAD+WTPT
8030   IF PAYLOAD>MAXPL THEN 8310
8040   CS=CS+1
8050   IF CS>CN THEN 8310
8060   NLOGS=NLOGS+1
8070   WD=D1(I)
8080   IF WD>WDMAX THEN WDMAX=WD
8090   X(KOUNT(I))=0
8100   IF NLOGS=N THEN 8310
8110 NEXT I
8120 REM
8130 REM ***** TEST TO SEE IF MACHINE SHOULD CONTINUE BUILDING TURN *****
8140 REM
8150 IF CS=CN THEN 8310          'IF CHOKERS ARE FULL, END THE TURN
8160 NEXTPL=PAYLOAD+WTPT         'LOOK AHEAD TO SEE IF NEXT LOG WILL EXCEED
8170 IF NEXTPL>MAXPL THEN 8310   'MAX PAYLOAD,. IF IT DOES, END THE TURN
8180 IF NMOVES=2 THEN 8310       'ONLY THREE HOOKSITES PER TURN ARE ALLOWED
8190 REM
8200 REM ***** MOVE MACHINE *****
8210 REM
8220 NMOVES=NMOVES+1 : N1=0
8230 GOSUB 9190
8240 REM
8250 REM ***** COMPUTE INTERMEDIATE TURN STATS, CONTINUE BUILDING TURN *****
8260 REM
8270 STIMD=STIMD+MLOLD-ML : STTWD=STTWD+WDMAX
8280 HKSITES=HKSITES+1 : IMD=IMD+MLOLD-ML : TWD=TWD+WDMAX : WDMAX=0
8290 GOTO 7850
8300 REM
8310 REM ***** END THE TURN, COMPUTE STATS, SET VARIABLES=0, MOVE MACH *****
8320 REM
8330 NTURNS=NTURNS+1 : HKSITES=HKSITES+1 : TWD=TWD+WDMAX
8340 IF NLOGS=N THEN 8390
8350 CS=0 : PAYLOAD=0 : WDMAX=0 : N1=0 : NMOVES=0
8360 GOSUB 9190
8370 GOTO 7850
8380 REM
8390 REM ***** COMPUTE SIMULATION STATISTICS *****
8400 REM
8410 LOGSPT=NLOGS/NTURNS : TWDPT=TWD/NTURNS
8420 IMDPT=IMD/NTURNS : HKSITESPT=HKSITES/NTURNS
8430 RETURN
8440 REM
8450 REM ***** "QUICKSORT" SUBROUTINE *****
8460 REM
```

```
8470 FOR I=1 TO N
8480 A(I+1)=X(I)
8490 B(I+1)=Y(I)
8500 NEXT I
8510 M=9
8520 A(1)=0 :B(1)=0
8530 L=2
8540 R=N+1
8550 P=1
8560 I=L+1
8570 J=R+1
8580 V=A(L): V1=B(L)
8590 GOTO 8630
8600 SWAP A(I),A(J)
8610 SWAP B(I),B(J)
8620 I=I+1
8630 IF A(I)<V THEN 8620
8640 J=J-1
8650 IF A(J)>V THEN 8640
8660 IF I<J THEN 8600
8670 SWAP A(I),A(J)
8680 SWAP B(I),B(J)
8690 IF (R-J)>(J-L) THEN 8770
8700 IF (J-L)<=M THEN 8840
8710 IF (R-J)<=M THEN 8820
8720 P=P+2
8730 STACK(P)=L
8740 STACK(P+1)=J-1
8750 L=J+1
8760 GOTO 8560
8770 IF (R-J)<=M THEN 8840
8780 IF (J-L)<=M THEN 8750
8790 P=P+2
8800 STACK(P)=J+1
8810 STACK(P+1)=R
8820 R=J-1
8830 GOTO 8560
8840 L=STACK(P)
8850 R=STACK(P+1)
8860 P=P-2
8870 IF P<0 THEN 8890
8880 GOTO 8560
8890 FOR I=2 TO N
8900 IF A(I+1)>=A(I) THEN 8970
8910 V=A(I+1)  : V1=B(I+1)
8920 J=I
8930 A(J+1)=A(J) : B(J+1)=B(J)
8940 J=J-1
8950 IF A(J)>V THEN 8930
8960 A(J+1)=V :B(J+1)=V1
8970 NEXT I
8980 FOR I= 1 TO N
8990 X(I)=A(I+1)
9000 Y(I)=B(I+1)
9010 NEXT I
9020 RETURN
```

```
9030 REM
9040 REM ***** SORT CANDIDATE LOGS BY DISTANCE FROM MACHINE *****
9050 REM
9060 N2=N1-1
9070 FOR I=1 TO N2
9080    I1=I+1
9090    FOR J=I1 TO N1
9100       IF (D1(I)-D1(J))<=0 THEN 9150
9110       SWAP X1(I),X1(J)
9120       SWAP Y1(I),Y1(J)
9130       SWAP D1(I),D1(J)
9140       SWAP KOUNT(I),KOUNT(J)
9150    NEXT J
9160 NEXT I
9170 RETURN
9180 REM
9190 REM ***** SUBROUTINE TO MOVE MACHINE *****
9200 REM
9210 MLOLD=ML
9220 FOR K=N TO 1 STEP -1
9230    IF X(K)>0 THEN 9250
9240 NEXT K
9250 D=X(K) : ML=D-7.5 : IF ML<=0 THEN ML=.001
9260 RETURN
9270 REM
9280 REM ------------------------------------------------------------
9290 REM ***** SUBROUTINE TO SIMULATE LATERAL YARDING OF SKYLINE *****
9300 REM ***** SYSTEMS INCLUDING SMALL AND MEDIUM YARDERS       *****
9310 REM ------------------------------------------------------------
9320 REM
9330 REM ***** INITIALIZE KEY VARIABLES *****
9340 REM
9350 NTURNS=0 : NLOGS=0 : CS=0 : TLYD=0 : N1=0
9360 WI=125 : CN=5 : N=100
9370 REM
9380 REM ***** COMPUTE THE LENGTH OF THE CUT BLOCK *****
9390 REM
9400 LE=(43560!*N)/(WI*NLOGSPA)
9410 REM
9420 REM ***** GENERATE RANDOM LOCATION OF LOGS *****
9430 REM
9440 FOR I=1 TO N
9450    X(I)=RND*LE
9460    Y(I)=RND*WI
9470 NEXT I
9480 REM
9490 REM ***** SORT LOGS BY THEIR X COORDINATE *****
9500 REM
9510 GOSUB 8450
9520 REM
9530 REM ***** BEGIN LATERAL YARDING *****
9540 REM
9550 REM ***** LOCATE CARRIAGE AND BUTTHOOK, IDENTIFY LOGS WITHIN REACH *****
9560 REM
9570 FOR I=1 TO N
9580    IF X(I)=0 THEN 9600
```

```
9590    CALO=X(I)+CL : XBH=CALO : YBH=Y(I) : GOTO 9610
9600 NEXT I
9610 FOR I=1 TO N
9620    IF X(I)=0 THEN 9670
9630    DIST=SQR((X(I)-XBH)^2+(Y(I)-YBH)^2)
9640    IF DIST>2*CL THEN 9670
9650    N1=N1+1 : KOUNT(N1)=I
9660    X1(N1)=X(I) : Y1(N1)=Y(I) : D1(N1)=DIST
9670 NEXT I
9680 REM
9690 REM ***** SORT LOGS WITHIN REACH BY DISTANCE FROM BUTTHOOK *****
9700 REM
9710 GOSUB 9040
9720 REM
9730 REM ***** BEGIN HOOKING LOGS *****
9740 REM
9750 FOR I=1 TO N1
9760    RLOGWT=-WTPL*LOG(1-RND)
9770    IF RLOGWT<10*LBBF THEN 9760
9780    IF RLOGWT>5*WTPL THEN 9760
9790    PAYLOAD=PAYLOAD+RLOGWT
9800    IF PAYLOAD>MAXPL THEN 9880
9810    CS=CS+1
9820    IF CS>CN THEN 9880
9830    NLOGS=NLOGS+1
9840    X(KOUNT(I))=0
9850    IF NLOGS=N THEN 9880
9860 NEXT I
9870 REM
9880 REM ***** END THE TURN, COMPUTE STATS, SET VARIABLES = 0 *****
9890 REM
9900 NTURNS=NTURNS+1
9910 IF NLOGS=N THEN 9950
9920 CS=0 : PAYLOAD=0 : N1=0
9930 GOTO 9550
9940 REM
9950 REM ***** COMPUTE SIMULATION STATISTICS *****
9960 REM
9970 LOGSPT=NLOGS/NTURNS
9980 RETURN
9990 REM
10000 REM ----------------------------------------------------------------
10010 REM ***** SUBROUTINE TO COMPUTE LOG LOADING COST PER MBF *****
10020 REM ----------------------------------------------------------------
10030 REM THIS SUBROUTINE COMPUTES AVERAGE LOG LOADING COST PER MBF BASED
10040 REM ON THE EQUATIONS USED BY THE REGION FOUR APPRAISAL HANDBOOK FOR
10050 REM THE SOUTHWESTERN APPRAISAL ZONE.
10060 REM
10070 REM ***** COMPUTE LOADING ADJUSTMENT FACTOR *****
10080 REM
10090 DEFAVG=SWZAVG7
10100 ZONAVG=SWZAVG8
10110 VOLAVG=4.8546+9.9256/ZONAVG
10120 VOLPG=4.8546+9.9256/LPM
10130 IF ZONAVG>26! THEN TIMAVG=12.262+1.681*ZONAVG
10140 IF ZONAVG>8! AND ZONAVG<26! THEN TIMAVG=37.262+1.681*ZONAVG-ZONAVG
```

```
10150 IF ZONAVG<6! THEN TIMAVG=32.262+1.681*ZONAVG
10160 IF LPM>26! THEN TIMPG=12.262+1.681*LPM
10170 IF LPM>6! AND LPM<26! THEN TIMPG=37.262+1.681*LPM-LPM
10180 IF LPM<6! THEN TIMPG=32.262+1.681*LPM
10190 ZONTIM=TIMAVG/VOLAVG
10200 PGTIM=TIMPG/VOLPG
10210 DIF=PGTIM/ZONTIM
10220 ALLOWL=DIF-1!
10230 REM
10240 REM ***** COMPUTE DEFECT ADJUSTMENT FACTOR *****
10250 REM
10260 ZDEF=1!/(1!-DEFAVG)
10270 PGDEF=1!/(1!-SCDEF)
10280 DEFECT=(PGDEF/ZDEF)-1!
10290 REM
10300 REM ***** COMPUTE TOTAL LOADING ADJUSTMENT FACTOR *****
10310 REM
10320 ADJLD=ALLOWL+DEFECT+1!
10330 REM
10340 REM ***** COMPUTE LOADING COST PER MBF *****
10350 REM
10360 LCPM=SWZALC*ADJLD
10370 RETURN
10380 REM
10390 REM ----------------------------------------------------------
10400 REM ***** SUBROUTINE TO COMPUTE HAUL COST PER MBF *****
10410 REM ----------------------------------------------------------
10420 REM
10430 REM ***** COMPUTE AVE NET VOL/TRUCKLOAD, NUMBER OF LOADS, *****
10440 REM ***** AND TOTAL STANDBY TIME FOR EACH SPECIES        *****
10450 REM
10460 REM **************************
10470 REM      PONDEROSA PINE
10480 REM **************************
10490 REM
10500 IF TPAPP=0 THEN 10560
10510 GVPLPP=(NLHWY/LBBFPP)/1000 : NVPLPP=GVPLPP*(1-SCDEF)
10520 NLOADSPP=NVPP/NVPLPP
10530 SBTPP=NLOADSPP*(44!+1.159*LPMPP)
10540 REM
10550 REM ***********************
10560 REM      DOUGLAS-FIR
10570 REM ***********************
10580 REM
10590 IF TPADF=0 THEN 10650
10600 GVPLDF=(NLHWY/LBBFDF)/1000 : NVPLDF=GVPLDF*(1-SCDEF)
10610 NLOADSDF=NVDF/NVPLDF
10620 SBTDF=NLOADSDF*(47!+1.096*LPMDF)
10630 REM
10640 REM **************************
10650 REM      LODGEPOLE PINE
10660 REM **************************
10670 REM
10680 IF TPALP=0 THEN 10740
10690 GVPLLP=(NLHWY/LBBFLP)/1000 : NVPLLP=GVPLLP*(1-SCDEF)
10700 NLOADSLP=NVLP/NVPLLP
```

```
10710 SBTLP=NLOADSLP*(56.46+.9893*LPMLP)
10720 REM
10730 REM *********************
10740 REM      GRAND FIR
10750 REM *********************
10760 REM
10770 IF TPAGF=0 THEN 10830
10780 GVPLGF=(NLHWY/LBBFGF)/1000 : NVPLGF=GVPLGF*(1-SCDEF)
10790 NLOADSGF=NVGF/NVPLGF
10800 SBTGF=NLOADSGF*(45.02+1.099*LPMGF)
10810 REM
10820 REM *************************
10830 REM      SUBALPINE FIR
10840 REM *************************
10850 REM
10860 IF TPAAF=0 THEN 10920
10870 GVPLAF=(NLHWY/LBBFAF)/1000 : NVPLAF=GVPLAF*(1-SCDEF)
10880 NLOADSAF=NVAF/NVPLAF
10890 SBTAF=NLOADSAF*(45.02+1.099*LPMAF)
10900 REM
10910 REM ****************************
10920 REM      ENGELMANN SPRUCE
10930 REM ****************************
10940 REM
10950 IF TPAES=0 THEN 11010
10960 GVPLES=(NLHWY/LBBFES)/1000 : NVPLES=GVPLES*(1-SCDEF)
10970 NLOADSES=NVES/NVPLES
10980 SBTES=NLOADSES*(48.37+1.324*LPMES)
10990 REM
11000 REM *************************
11010 REM      WESTERN LARCH
11020 REM *************************
11030 REM
11040 IF TPAWL=0 THEN 11090
11050 GVPLWL=(NLHWY/LBBFWL)/1000 : NVPLWL=GVPLWL*(1-SCDEF)
11060 NLOADSWL=NVWL/NVPLWL
11070 SBTWL=NLOADSWL*(47!+1.036*LPMWL)
11080 REM
11090 REM ***** COMPUTE AVE NET VOL IN MBF AND STANDBY TIME PER LOAD *****
11100 REM
11110 NLOADS=NLOADSPP+NLOADSDF+NLOADSLP+NLOADSGF+NLOADSAF+NLOADSES+NLOADSWL
11120 NVPLOAD=NVOL/NLOADS
11130 SBT=SBTPP+SBTDF+SBTLP+SBTGF+SBTAF+SBTES+SBTWL
11140 SBTPLOAD=SBT/NLOADS
11150 REM
11160 REM ***** COMPUTE TOTAL ROUND TRIP TRAVEL TIME INCLUDING DELAYS *****
11170 REM
11180 RTTTP=MIP*RTMPMIP : RTTTUP=MIUP*RTMPMIUP
11190 TRTTT=RTTTP+RTTTUP+SBTPLOAD
11200 REM
11210 REM ***** COMPUTE NET VOL IN MBF HAULED PER DAY *****
11220 REM
11230 NTLPD=720/TRTTT
11240 NVHPD=NTLPD*NVPLOAD
11250 REM
11260 REM ***** COMPUTE TOTAL HAUL COST PER DAY *****
```

```
11270 REM
11280 FCPDH=FDCLT+FDCLTD
11290 VCPDH=(2*MIP*VCPMIP+2*MIUP*VCPMIUP)*NTLPD
11300 TCPDH=FCPDH+VCPDH
11310 REM
11320 REM ***** COMPUTE HAUL COST PER MBF *****
11330 REM
11340 HCPM=TCPDH/NVHPD
11350 REM
11360 REM ***** COMPUTE THE DISTANCE TO THE MILL (ONE-WAY) *****
11370 REM
11380 DISTMILL=MIP+MIUP
11390 RETURN
11400 REM
11410 REM ----------------------------------------------------------------
11420 REM ***** SUBROUTINE TO CREATE GRAPHICS - WINDOWS AROUND PAGES *****
11430 REM ----------------------------------------------------------------
11440 REM
11450 BLX=TLX :BRX=TRX : TRY=TLY : BRY=BLY
11460 LOCATE TLY,TLX: PRINT CHR$(201) : LOCATE TRY,TRX : PRINT CHR$(187)
11470 LOCATE BLY,BLX: PRINT CHR$(200) :LOCATE BRY,BRX :PRINT CHR$(188)
11480 FOR I=TLX+1 TO TRX-1
11490     LOCATE TLY,I :PRINT CHR$(205)
11500     LOCATE BLY,I : PRINT CHR$(205)
11510 NEXT I
11520 FOR J=TLY+1 TO BLY-1
11530     LOCATE J,TLX: PRINT CHR$(186)
11540     LOCATE J,TRX: PRINT CHR$(186)
11550 NEXT J
11560 RETURN
11570 REM
11580 REM -----------------------------------------------------------
11590 REM ***** SUBROUTINE TO PRINT A HARD COPY OF THE SUMMARY *****
11600 REM -----------------------------------------------------------
11610 REM
11620 LPRINT
11630 LPRINT
11640 LPRINT
11650 LPRINT TAB(16) "------------------------------------------------------------"
11660 LPRINT TAB(16) "TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
11670 LPRINT TAB(16) "------------------------------------------------------------"
11680 LPRINT
11690 LPRINT
11700 LPRINT USING F1$;ACRES
11710 LPRINT USING F2$;NVOL
11720 LPRINT USING F3$;NVOLPA
11730 LPRINT USING F4$;TPA
11740 LPRINT USING F5$;QMD
11750 LPRINT USING F6$;AVETH
11760 IF YARDSYS$="GBS" THEN LPRINT USING F7$;AVPT : GOTO 11780
11770 LPRINT USING F7$;PCSZ
11780 LPRINT USING F8$;AVEML
11790 LPRINT
11800 IF YARDSYS$="GBS" THEN LPRINT USING G1$;GBSYS$ : GOTO 11820
11810 LPRINT USING G1$;SKYSYS$+YARDSYS$
11820 LPRINT USING G2$;AYD
```

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11830 IF YARDSYS$="GBS" THEN LPRINT USING G3$;SLOPE : GOTO 11850
11840 LPRINT USING G3$;SLOPE
11850 LPRINT USING G4$;YLPPD
11860 LPRINT USING G5$;DISTMILL
11870 LPRINT
11880 LPRINT
11890 LPRINT
11900 LPRINT USING H1$;FBCPM
11910 LPRINT USING H2$;YLCPM
11920 LPRINT USING H3$;HCPM
11930 LPRINT USING O1$;GLOHCPM
11940 LPRINT USING H4$;LOGCPM
11950 LPRINT USING H5$;RCPM
11960 LPRINT USING H6$;ENVICPM
11970 LPRINT USING H7$;THCPM
11980 LPRINT USING H8$;PRRI
11990 LPRINT USING I1$;PDVALUE
12000 LPRINT USING I2$;GSTUMPAGE
12010 LPRINT
12020 LPRINT USING H9$;ADMINCPA
12030 LPRINT USING I3$;NRETURN
12040 LPRINT USING I4$;NPVPA
12050 RETURN
```

APPENDIX J

User's Guide to LOGCOST

APPENDIX J

USER'S GUIDE TO LOGCOST

Introduction

LOGCOST is an interactive computer program that predicts stump to mill logging costs, stumpage and net present value of a harvest based on stand data, pond value, and logging parameters, entered by the user. The program is intended for use by foresters to evaluate the economics of different stand prescriptions. It is also useful in deciding whether commercial thinning an existing stand is profitable. Although LOGCOST was developed for use in even-aged stands in southwestern Idaho, minor changes could be made which would extend the applicability to other parts of the USDA, Forest Service, Intermountain Region.

Approximately two minutes is required to enter data, and program execution takes approximately 15 seconds, using an IBM Personal Computer. LOGCOST is compiled in BASIC and will run on microcomputers that have at least 256K RAM and are IBM compatible. Documentation of the model is included in the appendices of the MF Paper LOGCOST, A Harvest Cost Model for Southwestern Idaho, by Robert S. Giles, 1986, College of Forestry, Oregon State University.

Description of Example Problem

Suppose you wanted to decide if thinning a 14-inch diameter ponderosa pine stand on gentle terrain will yield positive stumpage. In addition, you want to identify the least cost skidding machine that would meet silvicultural and environmental objectives. Assume the cut tree characteristics are as follows.

(1) Trees per acre, 70

(2) Gross volume per acre, 7840 bf

(3) Quadratic mean diameter, 14 inches

(4) Average height, 69 feet

(5) Pond value is 125/mbf

First, a small 70 horsepower rubber tired skidder will be used. Assume the following logging parameters apply.

(1) Average slope, -15 percent (downhill)

(2) Average yarding distance, 500 feet

(3) All haul roads are in place; miles of road construction and reconstruction = zero.

(4) Distance to the mill is 30 miles, 20 miles paved, 10 miles unpaved.

(5) Road maintenance cost is $.50 per mbf/mile for the 10 mile unpaved road system.

Environmental, sale preparation, and administrative costs per acre are listed below.

(1) Sale area improvement (SAI), $10 per acre

(2) Erosion control (EC), $5 per acre

(3) Slash disposal (BD), $10 per acre

(4) Sale preparation and administration, $100 per acre

After this yarding system is evaluated, the program will be run again with the same data, except a small 78 horsepower crawler tractor will be used.

Running the Program

Example Problem #1

Load your DOS (Disk Operating System) disk in the A drive and the LOGCOST disk in the B drive. Turn the computer on; enter the date and time. Wait for the prompt A and then type B:LOGCOST to load the program. The program credits will appear on the screen, and at the bottom of the screen a notice reminds you to "MAKE SURE THE CAPS LOCK KEY IS ON"--the program does not recognize lower case letters used in response to Input Statements. Depress the return key (enter key) to proceed. The next screen lists the three types of data required to run LOGCOST. Depress the return key to continue.

Now you are ready to enter data. This screen will prompt for all of the input associated with stand data and cut tree characteristics.

(1) STAND DATA AND CUT TREE CHARACTERISTICS

ENTER THE ANALYSIS YEAR, HARVEST YEAR - (----,----)
For Example, 1986,1995

For Problem #1, assume the harvest will take place this year. Enter 1986,1986.

ENTER THE STAND ACRES

Assume the stand is 40 acres; Enter 40.

ENTER THE STAND AVERAGE SCALING DEFECT (in percent)

Possible defect values range from 0 to 99 percent
Enter the Southwestern Appraisal Zone Average, 5 for this example.

ENTER SPECIES CODE (PP,DF,LP,GF,AF,ES,WL) - (TYPE END TO QUIT)

Enter the two letter alpha code for a tree species harvested. Enter PP for this example.

ENTER THE FOLLOWING DATA FOR THE TREE SPECIES HARVESTED:
ENTER CUT TREES/AC, GROSS VOL/AC (BF) - (----,----)

Note: This data only applies to the species selected above, PP. Cut trees and volume per acre may be estimated from cruise records, stand examinations, or obtained from a growth model such as PROGNOSIS. Commas can not be used within a number, but must be used to separate the two numbers, trees per acre and gross volume per acre. Enter 70,7840.

ENTER QUAD MEAN DBH, AVE TOTAL HEIGHT - (----,----)

Quadratic mean diameter of the cut trees may be entered to the nearest tenth of an inch, for example, 14.0, and total height may be entered to the nearest foot. Enter 14,69.

ENTER THE POND VALUE (LOG PRICE, FOB, MILL)

Pond value is the average price the mill pays for delivered logs (free on board at the mill) for a particular tree species. These values are published quarterly for the Southwest Zone in the Primary Wood Processors' Log Price Report.[1] Enter 125.

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[1] Idaho Forest Products Marketing Bulletin; Department of Forest Products, College of Forestry Wildlife and Range Sciences and Cooperative Extension Service, University of Idaho, Moscow, Idaho, 83843

ENTER SPECIES CODE (PP,DF,LP,GF,AF,ES,WL) - (TYPE END TO QUIT)

Many stands are composed of several tree species in southwestern Idaho. If you want to harvest more than one species, enter the alpha code of the next tree species. The program will then prompt you for the cut tree data associated with that species. You may enter tree data, in this manner, for up to seven species. For this example, only ponderosa pine will be harvested; enter END to move to the next screen.

Now enter the logging and terrain data. The following prompts will appear on this screen.

(2) LOGGING SYSTEM AND TERRAIN DATA

ENTER THE YARDING TYPE
GBS = GROUND BASED SYSTEM, SKY = SKYLINE SYSTEM

These are the machines available if you choose GBS:

small crawler tractor, 78 horsepower
large crawler tractor, 140 horsepower
small rubber-tired skidder, 70 horsepower
large rubber-tired skidder, 120 horsepower

If you choose, SKY, then two yarders are available:

small skyline yarder, 65 horsepower, 23 foot tower
medium skyline yarder, 284 horsepower, 48 foot tower
(small skyline can yard up to 1,000 feet spans
medium yarder up to 2,000 feet).

Enter GBS

ENTER A SKIDDING MACHINE
STRAC = Small Crawler Tractor, LTRAC = Large Tractor
SRTS = Small Rubber Tired Skidder, LRTS = Large Skidder

Enter SRTS

ENTER THE AVE SLOPE IN THE DIRECTION OF LOADED SKIDDER
(Choose -30,-25,-20,-15,-10,-5,0,+5,+10)

Note: Positive numbers, +5 or +10 represent adverse skidding, negative numbers are for favorable (downhill) skidding. Enter the slope to the nearest five percent from the choices listed above. Enter -15.

ENTER THE AVE SLOPE YARDING DISTANCE IN FEET

Enter 500

ENTER THE ONE-WAY MILES OF PAVED HAUL ROAD

Enter 20

ENTER THE ONE-WAY MILES OF UNPAVED HAUL ROAD

Enter 10

ENTER THE MILES OF ROAD CONSTRUCTION OR RECONSTRUCTION CHARGED TO THIS STAND (Include both Specified and Temporary roads)

Caution: The intent is to enter the miles of reconstruction and/or construction needed for this stand. If other stands share the road system, it will be necessary to determine how many miles this stand is expected to pay for by itself.

For example: If 10 stands all use the same 2-mile section of road that must be reconstructed, and each stand contributes a similar harvest volume, you might enter 2 divided by 10 or .2 mile for each stand analyzed.

Enter 0 for this example.

If you did enter a number greater than zero, the program would prompt you to enter the average cost per mile. Since new construction and reconstruction are lumped together, you must enter an average cost per mile for these two activities. Note also that temporary spur road construction is included in this part of the input.

ENTER THE MILES OF ROAD TO BE MAINTAINED

These are only roads which the timber sale maintains--for example, county roads and state highways are not included.
Enter 10.

ENTER THE AVE VARIABLE COST FOR ROAD MAINTENANCE ($/MBF-MILE)

Road maintenance costs charged to a timber sale are a function of the miles of road to be maintained, and the number of loads (volume of timber) hauled. Maintenance records often report this cost as dollars per mbf-mile. The user should enter the total miles of haul road maintenance required for timber to be hauled from this stand; and the cost per mbf-mile.

If maintenance costs average $5/mbf in your area, you can compute the cost per mbf-mile by dividing the average cost per mbf by the total miles of road maintenance required by the stand. In Problem #1, this would be ($5/mbf) / (10 miles) = $.50/mbf-mile.
Enter .50

The next screen prompts you for the environmental costs and sale preparation/administration costs. Although these costs are optional, most stands will require some cost per acre for one or more of these activities. Environmental costs, sale area improvement (SAI), erosion control (EC), and slash disposal (BD) are charged against the sale as a harvest cost; they do affect the stumpage price. Sale preparation and administration do not affect stumpage price but are included in the calculation of net revenue per acre and net present value per acre.

(3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA

ENTER THE SALE AREA IMPROVEMENT COST/AC

There may be only a small cost associated with commercial thinning--maybe just the cost of inspecting the stand a few years later to see if the trees are responding to the thinning. Enter 10.

ENTER THE EROSION CONTROL COST/AC

Enter 5.

ENTER THE SLASH DISPOSAL COST/AC

Assume lopping and scattering is the only fuels treatment needed Enter 10.

ENTER THE SALE PREP AND ADMIN COST/AC

Enter 100.

The next screen will display the following message:

PROGRAM IS COMPUTING LOGGING COSTS

PLEASE WAIT

After approximately 15 seconds, the first output screen will appear. See upper half of Figure 23. This screen summarizes harvest and production data. If ground based systems are selected, the gross log volume is the same as the average gross volume per tree, because tree length logs are skidded. The average stem length (merchantable tree length) is reported so foresters can determine if residual stand damage would be a problem. When skyline systems are selected, the average gross log volume is the volume of the average bucked log (often referred to as average piece size). Yarding and loading production is reported to the nearest mbf and assumes an eight hour day; production is net mbf/day.

Depress the return key to continue.

This screen reports the stump to mill logging costs, pond value, stumpage and net present value. See bottom half of Figure 23. It is intended to serve as a simplified appraisal to aid foresters in evaluating not only the net present value per acre, but also the probability of selling the timber sale. Negative stumpage implies that the harvest costs exceed the pond value. If stumpage is -50/mbf, it is highly unlikely the sale will be purchased.

The road maintenance cost per mbf is included in the **SPEC AND TEMP ROAD COST** row. The discount rate used to determine the net present value is 4%.

For Problem #1, the stumpage is positive, $8.46/mbf, and the net present value per acre is negative, $-37/acre. To get a hard copy of this output, type H and depress the return key. Figure 23 represents the one page summary of the Harvest output.

After the printer is finished, the next screen will ask:

DO YOU WANT TO TRY ANOTHER LOGGING SYSTEM (YES, NO)?
Answer YES and depress the return key. This response allows you to use the same stand and cut tree data with a new logging system.

Next, we will try Problem #2 to determine if the small crawler tractor is a lower cost alternative. The program will prompt:

(2) LOGGING SYSTEM AND TERRAIN DATA

ENTER THE YARDING TYPE
GBS = GROUND BASED SYSTEM, SKY = SKYLINE SYSTEM

Enter GBS

ENTER A SKIDDING MACHINE
STRAC = SMALL CRAWLER TRACTOR, LTRAC = LARGE TRACTOR
SRTS = SMALL RUBBER TIRED SKIDDER, LRTS = LARGE SKIDDER

Enter STRAC

ENTER THE AVE SLOPE IN THE DIRECTION OF LOADED CRAWLER TRACTOR
(CHOOSE -45,-40,-35,-30,-25,-20,-15,-10,-5,0,+5,+10)

Enter -15

ENTER THE AVE SLOPE YARDING DISTANCE IN FEET

Enter 500

The rest of the data would be entered exactly as in Problem #1, above.

The output (Figure 24) shows that the small crawler tractor produces about 4 mbf/day less than the rubber-tired skidder and costs (approximately $11/mbf more. For these stand and terrain conditions, the rubber-tired skidder is the least cost alternative.

To begin the analysis of a new stand, answer the 1st prompt NO and the second prompt START:

DO YOU WANT TO TRY ANOTHER LOGGING SYSTEM (YES, NO) NO
DO YOU WANT TO TRY ANOTHER LOGGING SYSTEM (START, QUIT) START

After START is entered, the program begins with the credit screen, and the user may proceed as in Problem #1. If you wanted to exit LOGCOST, you would have typed QUIT, and depressed the return key.