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: ______________

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 User's 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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APPROVED:

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Date paper is presented: May 1, 1986
Typed by Judith Sessions for Robert S. Giles
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I am also grateful to my supervisor Donald Studier and to the USDA, Forest Service employees on the Boise and Payette National Forests for their help and encouragement.

A special acknowledgement is in order to Boise Cascade Corporation, Boise, Idaho, for the data and advice offered. Much of their data filled in the gaps in the Forest Service data.

I also thank my wife Kathleen and children, Karen and Steven, for their moral support and patience throughout this project.
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*Estimated truck standby time. This time includes a 20-minute waiting time, an 11-minute unload time, and variable load time. (Reproduction from USDA, Forest Service)
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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 = (___.___)
- Enter the stand acres
- Enter the stand average scaling defect (in percent)
- Enter species code (PP, GF, DF, LP, ES, WL, AF) - (Type END to quit)
- Enter the following data for the tree species harvested:
- Enter cut trees/ac, gross vol/ac (BF) - ___.
- Enter quad men, ave total height - ___.
- Enter pond value (load price, FOB, $/MILL)
- Enter species code (PP, GF, DF, LP, 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
  - SRTS = Small Rubber Tired Skidder, LRTS = Large Skidder
  - Choose: -30, -25, -20, -15, -10, -5, 0, +5, +10
- Enter the ave slope yarding distance in feet
- Enter the one-way miles of paved haul road
- Enter the one-way miles of unpaved haul road
- Enter the miles of road construction or repairs charged
  to this stand (include both specified and temporary roads)
- Enter the miles of road to be maintained
- Enter the ave variable cost for road maintenance (?/BF-MILE)

FIGURE 2. Logging System Input
### Figure 3. Environmental and Administration Input

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enter the sale area improvement cost/AC</td>
<td>$310</td>
</tr>
<tr>
<td>Enter the erosion control cost/AC</td>
<td>$310</td>
</tr>
<tr>
<td>Enter the slash disposal cost/AC</td>
<td>$310</td>
</tr>
<tr>
<td>Enter the sale prep and admin cost/AC</td>
<td>$3100</td>
</tr>
</tbody>
</table>

### Figure 4. Output Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand area</td>
<td>40 acres</td>
</tr>
<tr>
<td>Net volume</td>
<td>479 NF</td>
</tr>
<tr>
<td>Net volume per acre</td>
<td>112.0 NF</td>
</tr>
<tr>
<td>Trees per acre</td>
<td>70 TP</td>
</tr>
<tr>
<td>Quadratic mean diameter</td>
<td>14 inches</td>
</tr>
<tr>
<td>Average total height</td>
<td>75 FT</td>
</tr>
<tr>
<td>Average gross log volume</td>
<td>180 BP</td>
</tr>
<tr>
<td>Average stem length</td>
<td>31 FT</td>
</tr>
<tr>
<td>Yarding system</td>
<td>500 FT</td>
</tr>
<tr>
<td>Average slope yarding distance</td>
<td>-15 percent</td>
</tr>
<tr>
<td>Yarding and loading production</td>
<td>19 NSF/DAY</td>
</tr>
<tr>
<td>Distance to the mill</td>
<td>30 MILES</td>
</tr>
<tr>
<td>Felling and bucking cost</td>
<td>15.62 $/MBF</td>
</tr>
<tr>
<td>Yarding and loading cost</td>
<td>28.56 $/MBF</td>
</tr>
<tr>
<td>Hauling cost</td>
<td>31.19 $/MBF</td>
</tr>
<tr>
<td>General logging overhead cost</td>
<td>6.42 $/MBF</td>
</tr>
<tr>
<td>Stump to mill logging cost</td>
<td>79.77 $/MBF</td>
</tr>
<tr>
<td>Spec and temp road cost</td>
<td>3.00 $/MBF</td>
</tr>
<tr>
<td>Sale, ec, and no cost</td>
<td>2.08 $/MBF</td>
</tr>
<tr>
<td>Total harvest cost</td>
<td>86.84 $/MBF</td>
</tr>
<tr>
<td>Profit and risk (12 percent)</td>
<td>13.39 $/MBF</td>
</tr>
<tr>
<td>Average stumpage</td>
<td>24.08 $/MBF</td>
</tr>
<tr>
<td>Sale prep and admin cost</td>
<td>196 $/ACRE</td>
</tr>
<tr>
<td>Net revenue (not discounted)</td>
<td>100 $/ACRE</td>
</tr>
<tr>
<td>Net present value (1 + 4%)</td>
<td>100 $/ACRE</td>
</tr>
</tbody>
</table>
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 stochastically 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.

<table>
<thead>
<tr>
<th>Machine Type</th>
<th>Max. Payload (pounds)</th>
<th>Net Flywheel Horsepower (hp)</th>
<th>Max. Tower Span (feet)</th>
<th>Height (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small crawler tractor</td>
<td>13,000</td>
<td>78</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Large crawler tractor</td>
<td>20,000</td>
<td>140</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Small rubber-tied skidder</td>
<td>7,000</td>
<td>70</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Large rubber-tired skidder</td>
<td>10,000</td>
<td>120</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Small skyline</td>
<td>2,000</td>
<td>65</td>
<td>1,000</td>
<td>23</td>
</tr>
<tr>
<td>Medium skyline</td>
<td>2,000</td>
<td>284</td>
<td>2,000</td>
<td>48</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>Mean Roundtrip Minutes per Mile</th>
<th>Standard Deviation</th>
<th>Standard Error of the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paved</td>
<td>3.92</td>
<td>.36</td>
<td>.052</td>
</tr>
<tr>
<td>Unpaved</td>
<td>5.38</td>
<td>.59</td>
<td>.086</td>
</tr>
</tbody>
</table>

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 LOCCOST, 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 LOCCOST, 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 LOCCOST 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 LOCCOST is less than 10 percent (see Figure 6). LOCCOST 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 LOCCOST compared favorably with production reported by the Siefert (1983) and Hochrein (1966) studies. Siefert estimated daily production, based on the average study conditions and cycle time equations. Using similar stand conditions, LOCCOST 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 Tiefert.

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 tables¹ (see Table 3).

¹Pond values were estimated from average values reported quarterly for southwestern Idaho. Ponderosa pine immature trees have a pond value 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.

<table>
<thead>
<tr>
<th>Diameter at Breast Height (inches)</th>
<th>Total Height (feet)</th>
<th>Volume/Tree (bf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>55</td>
<td>16</td>
</tr>
<tr>
<td>12</td>
<td>62</td>
<td>57</td>
</tr>
<tr>
<td>14</td>
<td>69</td>
<td>112</td>
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<td>16</td>
<td>75</td>
<td>180</td>
</tr>
<tr>
<td>18</td>
<td>83</td>
<td>273</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
<td>382</td>
</tr>
</tbody>
</table>

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 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.
LITERATURE CITED


PERSONAL COMMUNICATIONS


Johnson, K. N. 1985. Assoc. Professor of Forest Management, College of Forestry, Oregon State University, Corvallis, Oregon.


APPENDICES
APPENDIX A

Cut Tree Parameters
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:

\[ NVPP = \frac{(GVPAPP \times (1-SCDEF) \times ACRES)}{1000} \]

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 2.
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).

\[ MLPP = 0.8381 \times THPP + 7.299 \times SQR(QMDPP) - 41.14 \]

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.

\[ LFMPP = (MLPP/16)/(AVPTPP/1000) \]

Where \( LFMPP \) 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.

\[ PCPTPP = 0.1469 + 0.01954 \times THPP + 0.0002468 \times QMDPP \times \frac{THPP}{QMDPP} - 2.717/QMDPP \]

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

\[ \text{PCSZPP} = \frac{\text{AVPTPP}}{\text{PCPTPP}} \]

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:

\[ \text{LBBFPP} = 12.09 - 0.01397 \times \text{PCSZPP} + 8.81 \times 10^{-06} \times \text{PCSZPP}^2 + 187.6/\text{PCSZPP} \]

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.

\[ \text{NVOLPA} = \text{GVPA} \times (1 - \text{SCDEF})/1000 \]

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:

\[
FBTPM = -53.24 - (1.205 \times QMD) + (.07987 \times NVPTSDC) + 110.9 \times \log_{10} (QMD) + 28.31 / (\log_{10} (NVPTSDC)) - 42.09 \times \log_{10} (NVPTSDC)
\]

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:

\[ TFBTPM = \frac{FBTPM}{1 - DELAYFB} \]

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):

\[ FBCPM = \frac{CPHBF}{60} \times TFBTPM \]
APPENDIX C

Yarding
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 yader  spans to 1,000 feet
(2) medium skyline yader  spans to 2,000 feet

The Koller K300 was selected as the small yader 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 yader. This yader 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 of 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.

Ground based systems

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

Skyline yarding systems

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.
Sort trees by their x coord., closest to the landing, first

Identify location of machine for first turn (7.5 ft. inward from the landing from the last log - largest x coord.)

Identify candidate logs within a 15 ft. wide by 50 ft. long band. Sort candidate logs by distance (closest first) from machine

Build the turn by hooking logs one at a time, closest first


does the next log clear?

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

Have all logs been visited?

Compute simulation statistics

Test to see if machine should move to continue building the turn

Are all the skidders tied?

Will the next log exceed the max payloader?

Store the intermediate move distance, number of hooksites and cumulative winch distance for the turn.

End the turn, store the cumulative values for number of turns, number of individual skidders, winch distance and number of logs hooked.

End
TYPICAL GROUND BASED SYSTEM CUT BLOCK

Landing

Width = 50 ft

Randomly assigned location of felled tree

15 by 50 ft band of candidate logs

Machine location

Randomly assigned location of felled tree

15 by 50 ft band of candidate logs

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

\[
TRAVEL = 0.03 + 0.002705 \times OIDIST + 0.000105 \times \text{WEIGHT}
\]

Where TRAVEL is in minutes.

OIDIST is the outhaul plus inhaul distance, in feet.
OIDIST = (2\times AYD \times (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.

\[ NWEIGHT = WTPT \times (1 - SCDEF) \times LOGSPRT \]

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) LOGSPRT 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 0.5341 for all machines.

Using these values, the position time in minutes,

\[
\text{POSITION} = 0.5341 \times (0.41 + 0.01063 \times 50)
\]

\[
= 0.3878
\]

(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.

\[
\text{WINCH} = 0.13 + 0.0252 \times \text{TWDPT} + 0.0001577 \times \text{TWDPT} \times 11
\]

\[
= 0.13 + 0.02693 \times \text{TWDPT}
\]

Where WINCH is in minutes,

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

(4) Hook time

\[
\text{HOOK} = 0.10 + 1.041 \times \log_{5} \text{PT} + 0.01933 \times \text{TWDPT}
\]

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 + .0048\times IMDPT + .258\times (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 + .671\times LOGSPT + .1556\times .46\times LOGSPT + .3\times 3
= 1.26 + .7426\times LOGSPT

Where LANDING is in minutes.

(7) Pile slash time

Average occurrence is .1791 for all machines.

PSLASH = .1791 \times .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.

\[
\text{TRAVEL} = 0.35 + 0.00309x\text{OIDIST} + 0.00147x\text{NWEIGHT} \\
+ 0.000398x\text{AYD}(1 + \text{WEAVE}) \times \text{OUTSLOPE}
\]

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

\[
\text{POSITION} = 0.5674x(0.16 + 0.01273x50)
\]

= 0.4519

(3) Winch time

\[
\text{WINCH} = 0.31 + 0.0335x\text{TWDPT}
\]

(4) Hook time

\[
\text{HOOK} = -0.18 + 0.115x\text{LOGSPT} + 0.0119x\text{TWDPT} + 0.225x\text{HKSITESPT}
\]

(5) Intermediate travel time

\[
\text{IMTRAVEL} = 0.06 + 0.00623x\text{IMDPT} + 0.2468x(\text{HKSITESPT} - 1)
\]

(6) Landing time

\[
\text{LANDING} = 0.52 + 0.2424x\text{LOGSPT} + 0.3116x + 0.46x\text{LOGSPT} + 0.1093x + 0.00014x\text{NWEIGHT}
\]

= 0.8485 + 0.5675x\text{LOGSPT} + 0.00014x\text{NWEIGHT}

(7) Pile slash time
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).
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.

<table>
<thead>
<tr>
<th>Outhaul Slope (Percent)</th>
<th>Velocity of Small Skidder (mph)</th>
<th>Velocity of Large Skidder (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>6.43</td>
<td>6.56</td>
</tr>
<tr>
<td>20</td>
<td>5.34</td>
<td>5.45</td>
</tr>
<tr>
<td>25</td>
<td>4.58</td>
<td>4.68</td>
</tr>
<tr>
<td>30</td>
<td>4.04</td>
<td>4.13</td>
</tr>
</tbody>
</table>

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.

<p>| Inhaul Velocity of | Velocity of |</p>
<table>
<thead>
<tr>
<th>Slope</th>
<th>Small Skidder (mph)</th>
<th>Large Skidder (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>54.23-5.56xLOG(WEIGHT)</td>
<td>56.73-5.58xLOG(WEIGHT)</td>
</tr>
<tr>
<td>0</td>
<td>38.08-3.856xLOG(WEIGHT)</td>
<td>40.4-3.93xLOG(WEIGHT)</td>
</tr>
<tr>
<td>+5</td>
<td>28.36-2.834xLOG(WEIGHT)</td>
<td>29.97-2.877xLOG(WEIGHT)</td>
</tr>
<tr>
<td>+10</td>
<td>20.39-1.982xLOG(WEIGHT)</td>
<td>22.27-2.095xLOG(WEIGHT)</td>
</tr>
</tbody>
</table>

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.
   
   \[ \text{VELOUT} = (\text{the velocity in mph}) \times \frac{5280}{60} \]
   
   Where VELOUT is the outhaul velocity in feet per minute.

   \[ \text{VELIN} = \text{VMPH} \times \frac{5280}{60} \]
   
   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.
   
   \[ \text{ODIST} = \text{AYD} \times (1+\text{WEAVE}) \]
   
   Where ODIST is the outhaul distance.

   \[ \text{IDIST} = \text{ODIST} - \text{IMDPT} \]
   
   Where IDIST is the inhaul distance.
(3) Outhaul and inhaul times in minutes are then computed.

\[
\text{OUTHHAUL} = \frac{ODIST}{VELOUT} \\
\text{INHAUL} = \frac{IDIST}{VELIN} \\
\text{TRAVEL} = \text{OUTHHAUL} + \text{INHAUL}
\]

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

(2) Position time

\[
\text{POSITION} = 0.5674 \times (0.29 + 0.00747 \times 50) \\
= 0.3765
\]

(3) Winch time

\[
\text{WINCH} = 0.25 + 0.0221 \times TWDPT + 0.000202 \times TWDPT^{2} \\
= 0.25 + 0.02432 \times TWDPT
\]

(4) Hook time

\[
\text{HOOK} = 0.24 + 0.5526 \times LOGSPT + 0.007 \times TWDPT + 0.35 \times HKSITESPT
\]

(5) Intermediate travel time

\[
\text{IMTRAVEL} = 0.07 + 0.00316 \times IMDPT + 0.13 \times (HKSITESPT - 1)
\]

(6) Landing time

\[
\text{LANDING} = 0.44 + 0.2171 \times LOGSPT + 0.2248 \times 0.46 \times LOGSPT + 0.0784 \times 3 \\
+ 0.000082 \times NWEIGHT \\
= 0.6752 + 0.3205 \times LOGSPT + 0.000082 \times NWEIGHT
\]

(7) Pile slash time

\[
\text{PSLASH} = 0.1791 \times 87 \\
= 0.1558
\]
The total cycle time in minutes is then computed for
the ground based system selected:

\[
\text{CYCLETIME} = \text{TRAVEL} + \text{POSITION} + \text{WINCH} + \text{HOOK} \\
+ \text{IMTRAVEL} + \text{LANDING} + \text{PSLASH}
\]

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

Daily production, NVYPD, (mbf)

\[
\text{NVYPD} = \frac{480 \times \text{EFF} \times \text{LOGSPT} \times (1 - \text{SCDEF}) \times (\text{AVPT}/1000) \times 0.9756}{\text{CYCLETIME}}
\]

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

\[
\text{YCPM} = \frac{\text{FDC}}{\text{NVYPD}}
\]

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.

<table>
<thead>
<tr>
<th>Skidding Machine</th>
<th>Net flywheel Horsepower</th>
<th>Efficiency</th>
<th>Cost Hourly ($) Daily ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small tractor</td>
<td>78</td>
<td>.79</td>
<td>38.51</td>
</tr>
<tr>
<td>Large tractor</td>
<td>140</td>
<td>.78</td>
<td>54.56</td>
</tr>
<tr>
<td>Small skidder</td>
<td>70</td>
<td>.74</td>
<td>34.84</td>
</tr>
<tr>
<td>Large skidder</td>
<td>120</td>
<td>.74</td>
<td>40.18</td>
</tr>
</tbody>
</table>

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...
FLOWCHART OF LATERAL YARDING SIMULATION FOR SKYLINE SYSTEMS

Start

Input cut tree variables computed in the cut tree parameter subroutine, the maximum payload and effective choker length for the yarder selected.

Generate random location (x and y coordinates) of 100 logs.

Sort logs by their y coord., closest to the landing, first.

Locate the carriage one choker length (down the skyline corridor) below the log closest (measured in the x direction) to the landing. Locate the butthook at the same x coordinate as the carriage and the same y coordinate as the first log (one choker length directly below the log).

Identify candidate logs within a radius of twice the choker length from the butthook. Sort candidate logs by distance (closest first) from butthook.

Build the turn by hooking logs one at a time, closest first.

Before each log is hooked, assign it a random weight from the exponential distribution of log weights.

YES

NO

Figure 17. Flowchart of lateral yarding simulation for skyline systems.
Figure 17 (continued)

End the turn, store the cumulative values for number of turns and number of logs hooked

Have all logs been yanked?

YES

Compute simulation statistics

NO

End the turn, store the cumulative values for number of turns and number of logs hooked

Have all candidate logs been yanked?

YES

Output the average number of logs per turn

NO
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 foot volume times the pound to board foot 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.

\[ RLOGWT = -WTPLxLOG(1-RNU) \]
TYPICAL SKYLINE SYSTEM CUT BLOCK

Landing

Carriage location

Width = 125 ft

Skyline Corridor

Randomly assigned location of bucked log

Note: $R = 2$ times the effective choker length
$R = 2 \times 18 = 36$ ft for the small yarder, and
$2 \times 22 = 44$ 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
          -0.01009xABS(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:

\[\text{CYCLETIME} = 1.838+.003403xAYD+.0236xALYD+.1903xLOGSPT\]

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.

<table>
<thead>
<tr>
<th>Skyline Yarder Size</th>
<th>Volume/Acre Cut (mbf)</th>
<th>Effective hour (decimal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>5</td>
<td>.68</td>
</tr>
<tr>
<td>Small</td>
<td>10</td>
<td>.73</td>
</tr>
<tr>
<td>Medium</td>
<td>5</td>
<td>.66</td>
</tr>
<tr>
<td>Medium</td>
<td>10</td>
<td>.74</td>
</tr>
</tbody>
</table>

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:

\[ NVYPH = (EFHRSY \times 60 / CYCLETIME) \times (LOGSPT \times PCSZ \times (1 - SCDEF) / 1000) \]

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:

\[ \text{YCPM} = \frac{\text{FHCSY}}{\text{NVYPH}} \]

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.

<table>
<thead>
<tr>
<th>Skyline Yarder Size</th>
<th>Crew Size</th>
<th>Hourly Cost</th>
<th>Daily Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>small</td>
<td>4</td>
<td>94.99</td>
<td>760.00</td>
</tr>
<tr>
<td>medium</td>
<td>6</td>
<td>222.45</td>
<td>1,780.00</td>
</tr>
</tbody>
</table>
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:

\[
\frac{1}{1 - \text{scaling defect}}
\]

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:

\[
\frac{1}{1 - \text{scaling defect of the stand}} \div \frac{1}{1 - \text{zone average scaling defect}}
\]

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/ft³ versus 39 lb/ft³ (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:
Net volume/truckload = \( \frac{52,000 \text{ pounds}}{(\text{pound/board feet})} \) \( \frac{1000 \text{ board feet}}{\text{mbf}} \)

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>
<thead>
<tr>
<th>Species or Species Group</th>
<th>Standby time/trip Regression Equation</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>ponderosa pine</td>
<td>44.00+1.155xlogs/mbf</td>
<td>0.98</td>
</tr>
<tr>
<td>Douglas-fir, western larch</td>
<td>47.00+1.086xlogs/mbf</td>
<td>0.99</td>
</tr>
<tr>
<td>lodgepole pine</td>
<td>56.46+0.9893xlogs/mbf</td>
<td>1.00</td>
</tr>
<tr>
<td>grand fir, subalpine fir</td>
<td>45.02+1.099xlogs/mbf</td>
<td>0.99</td>
</tr>
<tr>
<td>Engelmann spruce</td>
<td>48.87+1.324xlogs/mbf</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Table 3 - Estimated Truck Standby Time. This time includes a 20-minute waiting time, an 11-minute unload time, and variable load time.

<table>
<thead>
<tr>
<th>Gross</th>
<th>15' Long/H</th>
<th>FF</th>
<th>UF-AP</th>
<th>UP-VG</th>
<th>WR</th>
<th>LP</th>
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<tbody>
<tr>
<td>2</td>
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</table>
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).
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:

\[
V_{CPDH} = (2\times MIP \times V_{CPMIP} + 2\times MIUP \times V_{CPMIUP}) \times NTLPD
\]

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 one-way paved mile of travel, \$0.3909,
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.

\[
\text{Adjusted Cost/Acre} = \frac{\text{acres treated} \times \text{per acre cost}}{\text{total stand acres}} = \frac{15 \text{ Acres} \times \$300/\text{Acre}}{40 \text{ acres}} = \$112.50/\text{acre}
\]
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.

\[
\text{Move Cost} = 1240 + 12.55 \times \text{Roundtrip miles}
\]

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:

\[
\frac{(1240 + 12.55 \times 60)}{250} = \frac{1,533}{250} = \$7.73
\]

the move cost per mbf is:

\[
\frac{7.73}{10} = \$0.77.
\]
APPENDIX G

Model Validation - Comparison
APPENDIX C

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 LOCCOST compared favorably with production reported by two studies. Siefert (1983) estimated daily production for three different machines that can be modeled by LOCCOST, based on average study conditions and cycletime equations. Using similar stand conditions, LOCCOST 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. LOCCOST 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). LOCCOST matched time study production reported by Hochrein within 13 percent.

Felling, bucking and yarding costs computed by LOCCOST 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. Skylize 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:
   \[ \$9.90/\text{hour} \times 1.5 \times 1 \text{ hour/day} = \$14.85/\text{hour} \]
3. Total Direct Labor Cost, based on an eight hour field day:
   \[ \left( \$9.90/\text{hour} \times 8 \text{ hours} + \$14.85 \times 1 \text{ hour} \right)/8 \text{ hours} = \$11.76/\text{hour}, \text{ charged eight hours per day.} \]
4. Supervision = 25\% of Direct Labor Cost
   \[ = .25 \times \$11.76/\text{hour} \]
   \[ = \$2.94/\text{hour} \]
5. Total Labor Cost = \( \$11.76 + \$2.94 \)/hour
   \[ = \$14.70/\text{hour} \]
6. Saw Rental = $2.69/hour
7. Transportation Cost:
   \[ (25 \text{ miles one-way} \times 2) \times (\$0.30/\text{mile}) \]
   \[ = \$7.50 \text{ per person, per day} \]
   Hourly transportation cost per person
   \[ = (\$7.50/\text{person})/(8 \text{ hours/person}) \]
   \[ = \$0.94/\text{hour} \]
8. Total Cost Per Hour = \( \$14.70 + \$2.69 + \$0.94 \)/hour
   \[ = \$18.33 \]
### Hourly and Daily Costs of Ground-Based Systems

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>$5.44</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$9.88</td>
</tr>
<tr>
<td>Labor</td>
<td>$23.19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$38.51</strong></td>
</tr>
</tbody>
</table>

**Total Daily Cost = $308**

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>$13.12</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$18.12</td>
</tr>
<tr>
<td>Labor</td>
<td>$23.19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$54.56</strong></td>
</tr>
</tbody>
</table>

**Total Daily Cost = $436**

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation</td>
<td>$4.13</td>
</tr>
<tr>
<td>Operating Costs</td>
<td>$7.52</td>
</tr>
<tr>
<td>Labor</td>
<td>$23.19</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$34.84</strong></td>
</tr>
</tbody>
</table>

**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.

<table>
<thead>
<tr>
<th></th>
<th>Yarder ($/hour)</th>
<th>Loader ($/hour)</th>
<th>Yarder and Loader ($/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depreciation</td>
<td>5.08</td>
<td>4.14</td>
<td>9.22</td>
</tr>
<tr>
<td>2. Maintenance, Repair, Fuel and Lube</td>
<td>4.51</td>
<td>6.80</td>
<td>11.31</td>
</tr>
<tr>
<td>3. Lines &amp; Chokers</td>
<td>.51</td>
<td>-</td>
<td>.51</td>
</tr>
<tr>
<td>4. Labor</td>
<td>54.23</td>
<td>19.72</td>
<td>73.95</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>64.33</strong></td>
<td><strong>30.66</strong></td>
<td><strong>94.99</strong></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Yarder ($/hour)</th>
<th>Loader ($/hour)</th>
<th>Yarder and Loader ($/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Depreciation</td>
<td>28.34</td>
<td>12.50</td>
<td>40.84</td>
</tr>
<tr>
<td>2. Maintenance, Repair, Fuel and Lube</td>
<td>33.06</td>
<td>16.66</td>
<td>49.72</td>
</tr>
<tr>
<td>3. Lines &amp; Chokers</td>
<td>4.24</td>
<td>-</td>
<td>4.24</td>
</tr>
<tr>
<td>4. Labor</td>
<td>107.93</td>
<td>19.72</td>
<td>127.65</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>173.57</strong></td>
<td><strong>48.86</strong></td>
<td><strong>222.45</strong></td>
</tr>
</tbody>
</table>
APPENDIX I
LOGCOST Program List
DIMENSION ARRAYS

110 REM
120 DIM X(101), Y(101), A(101), B(101), STACK(12)
130 DIM KNOT(101), Xl(101), Yl(101), Dl(101)
140 REM
150 CLS KEY OFF
160 PRINT
170 PRINT
180 PRINT "LOCCOST"
180 PRINT
200 PRINT "A TIMBER HARVEST ECONOMIC MODEL WHICH ESTIMATES"
210 PRINT "LOGGING COSTS, STUMPAGE AND NET PRESENT VALUE"
220 PRINT "LOCCOST WAS DEVELOPED FOR USE IN EVEN-AGED STANDS"
230 PRINT "IN SOUTHWESTERN IDAHO"
240 PRINT
260 PRINT "BY ROBERT S. CILES"
280 PRINT
290 PRINT "USFS ADVANCED LOGGING SYSTEMS"
300 PRINT "TECHNICAL TRAINING PROGRAM"
310 PRINT "CORVALLIS, OREGON"
320 PRINT
330 PRINT "MARCH, 1986"
340 PRINT
350 PRINT "MAKE SURE THE CAPS LOCK KEY IS ON!"
360 JX=5 : TXY=6 : LTX=23
370 GOSUB 11400
380 LOCATE 23,6 : INPUT "PRESS RETURN TO CONTINUE ->", RKEY
390 CLS
400 PRINT (1) STAND DATA AND CUT TREE CHARACTERISTICS
410 PRINT (2) LOGGING AND ROAD CONSTRUCTION DATA
420 PRINT (3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA
430 PRINT "FOR EXAMPLE, 1986,1995"
440 PRINT "*ANYYEAR,HARVYEAR"
450 PRINT "*ACRES"
530 INPUT "ENTER THE STAND AVERAGE SCALING DEFECT (IN PERCENT) >", PSCDEF
540 INPUT "ENTER SPECIES CODE (PP,DF,LPGF,AF,ES,WL) - (TYPE END TO QUIT) >", SPECIES$
550 IF SPECIES$="END" THEN 690
560 PRINT "ENTER THE FOLLOWING DATA FOR THE TREE SPECIES HARVESTED:
570 INPUT "ENTER CUT TRS/AC, CROSS VOL/AC (BF) (ZTPA, ZCVPA)"
580 INPUT "ENTER QUAD MEAN DBH, AVE TOTAL HEIGHT (_._,_,__) ZQMD, ZTH"
590 INPUT "ENTER THE POND VALUE CLOG PRICE FOB , ML$ (ZPV)"
600 IF SPECIES$="PP" THEN WAPP=ZPA:CPAPP=ZCVPA:QMDPP=ZQMD:THPP=ZTH:PVPP=ZPV
610 IF SPECIES$="DF" THEN WAPP=ZPA:GVPDF=ZCVPA:QMDDF=ZQMD:TFDF=ZTHDF:PVDF=ZPV
620 IF SPECIES$="LP" THEN WAPP=ZTPA:CPALP=ZCVPA:QMDLP=ZQMD:TFLP=ZTHL:PVLP=ZPV
630 IF SPECIES$="CF" THEN WAPP=ZTPA:CPALP=ZCVPA:QMDLP=ZQMD:TFLP=ZTHL:PVLP=ZPV
640 IF SPECIES$="ES" THEN WAPP=ZTPA:CPALP=ZCVPA:QMDLP=ZQMD:TFLP=ZTHL:PVLP=ZPV
650 IF SPECIES$="WL" THEN WAPP=ZTPA:CPALP=ZCVPA:QMDLP=ZQMD:TFLP=ZTHL:PVLP=ZPV
660 GOTO 690
670 GOTO 990
680 CLOSE
690 PRINT "(1) LOGGING SYSTEM AND TERRAIN INPUTS"
700 PRINT "(1) LOGGING SYSTEM AND TERRAIN INPUTS"
710 PRINT "VARIABLES"
720 IF YARDSYS$="SKY" THEN 690
730 INPUT "ENTER THE YARDING TYPE 'BS' = CARDBASED SYSTEM, SKY = SKYLINE SYSTEM"
740 INPUT "ENTER THE AVERAGE SLOPE IN THE DIRECTION OF LOADED SKIDDER (CHOOSE 30, -25, -20, -15, -10, -5, 0, +5, +10) >", SLOPE
750 INPUT "ENTER THE AVERAGE SKIDDER LOADING DISTANCE IN FEET >", DLS
760 GOTO 890
770 INPUT "ENTER THE AVERAGE SLOPE IN THE DIRECTION OF LOADED CRAWLER TRACTOR (CHOOSE -45, -40, -35, -30, -25, -20, -15, -10, -5, 0, +5, +10) >", SLOPE
780 INPUT "ENTER THE AVERAGE CRAWLER TRACTOR LOADING DISTANCE IN FEET >", DLS
790 GOTO 990
800 INPUT "ENTER YOUR ESTIMATE OF MAXIMUM SKYLINE PAYLOAD >", MPLSMSY
810 INPUT "ENTER THE AVERAGE SLOPE (ABSOLUTE VALUE OF SLOPE) (CHOOSE 10, 20, 30, 40, 50, 60, 70, 80, 90) >", SLOPE
820 GOTO 990
830 INPUT "ENTER YOUR ESTIMATE OF MAXIMUM SKYLINE PAYLOAD >", MPLSMSY
840 IF SKYSYS$="MED" THEN 690
850 GOTO 990
860 INPUT "ENTER THE AVERAGE SLOPE (ABSOLUTE VALUE OF SLOPE) (CHOOSE 10, 20, 30, 40, 50, 60, 70, 80, 90) >", SLOPE
870 GOTO 990
880 INPUT "ENTER THE AVERAGE SLOPE IN THE DIRECTION OF LOADED SKIDDER TRACTOR (CHOOSE 30, -25, -20, -15, -10, -5, 0, +5, +10) >", SLOPE
890 INPUT "ENTER THE AVERAGE EIGHT IN THE DIRECTION OF LOADED CRAWLER TRACTOR (CHOOSE -45, -40, -35, -30, -25, -20, -15, -10, -5, 0, +5, +10) >", SLOPE
900 GOTO 990
910 GOTO 990
920 GOTO 990
930 GOTO 990
940 GOTO 990
950 GOTO 990
960 GOTO 990
970 GOTO 990
980 GOTO 990
990 GOTO 990
*AVD
900 PRINT
900 INPUT "ENTER THE ONE-WAY MILES OF PAVED HAUL ROAD"

*AVG
910 INPUT "ENTER THE ONE-WAY MILES OF UNPAVED HAUL ROAD"

*MAX
920 INPUT "ENTER THE MILES OF ROAD CONSTRUCTION OR RECONSTR CHARGED TO THIS STAND (INCLUDE BOTH SPECIFIED AND TEMPORARY ROADS)"

*MAXI
940 IF RCMI>0 THEN 980
950 INPUT "ENTER THE COST PER MILE FOR ROAD CONSTRUCTION/RECONSTR ($/MILE)"

*AVG
960 INPUT "ENTER THE MILES OF ROAD TO BE MAINTAINED"

*MAXI
970 IF RCMI=0 THEN 980
980 INPUT "ENTER THE AVE VARIABLE COST FOR ROAD MAINTENANCE ($/MBF-MILE)"

CLS
1000 PRINT "(3) ENVIRONMENTAL AND ADMINISTRATIVE COST DATA"

1010 PRINT

1020 PRINT

1030 INPUT "ENTER THE SALE AREA UVROVENT COST/AC ($)"

1040 INPUT "ENTER THE EROSION CONTROL COST/AC ($)"

1050 INPUT "ENTER THE SLASH DISPOSAL COST/AC ($)"

1060 INPUT "ENTER THE SALE PR AND ADMIN COST/AC ($)"

1070 REM

1080 REM

1090 REM

1100 REM

1110 REM

1120 REM

1130 REM

1140 DELAYTV=.25 "DELAY AS FRACTION OF TOTAL TIME"

1150 CPHTV=18.23 "HOURLY COST ($)"

1160 REM

1170 REM

1180 REM

1190 REM

1200 AVGSYS=250 "AVERAGE GROUND BASED SYSTEM OR SKYLINE SYSTEM ACRES"

1210 REM

1220 REM

1230 REM

1240 REM

1250 WEAVE=.2 "WEAVE FACTOR"

1260 EFFLTRAC=.78 "EFFICIENCY, LARGE CRAWLER TRACTOR"

1270 EFFSTTRAC=.79 "EFFICIENCY, SMALL CRAWLER TRACTOR"

1280 EFFRTS=.74 "EFFICIENCY, RUBBER TIRE SKIDDER"

1290 FDCILTRAC=.26 "FIXED DAILY COST, LARGE TRACTOR ($)"
1300 FoCSTRA=300
1310 FDCLRT= 301
1320 FDCST= 279
1330 REM
1340 REM ***** SKYLINE YARDING SYSTEM VARIABLES *****
1350 REM
1360 MPLSSY=2000
1370 ALYD50
1380 FHCSSY=94.99
1390 FHCMSY=222.45
1400 REM
1410 REM ***** LOADING VARIABLES *****
1420 REM
1430 SWZAVG7.05
1440 SWZAVG8=13.2
1450 SWZALC=10.53
1460 REM
1470 RBA ***** HAULING VARIABLES *****
1480 REM
1490 NLHWY=52000
1500 SWZWINP=2,52
1510 SWZWINP=9.38
1520 FDCLOT=9,888.147
1530 FDCLOT=19,10
1540 VCPMIP=9,40
1550 VCPMIP=17,728
1560 REM
1570 REM ***** HAULING *****
1580 REM
1590 NLHWY=52000
1600 NLHWY=3.92
1610 RTMPMI=5.38
1620 FDCLT: 1588/147
1630 YDCLTD= 198.25
1640 VCPMIUP=1.1728
1650 REM
1660 REM **** GENERAL LOGGING OVERHEAD ****
1670 REM
1680 GLOHCFM=8.42
1690 REM
1700 REM COMPUTE CUT TREE PARAMETERS FOR MERCHANTABLE TREES
1710 REM
1720 REM COMPUTE VARIABLE LOGGING COSTS IN $/MBF, STUMP TO MILL
1730 REM
1740 REM PRINT "PROGRAM IS COMPUTING LOGGING COSTS"
1750 REM
1760 REM **** EXPENSES -------
1770 REM
1780 REM "GROUNDBASED SYSTEM SELECTED"
1790 REM
1800 REM
1860 GOSUB 5580
1870 REM
1880 REM ***** COMPUTE LOADING COST PER MBF *****
1890 REM
1900 REM ***** COMPUTE HAULING COST PER MBF *****
1910 REM
1920 REM ***** COMPUTE MOVE IN MOVE OUT COST, YARDING AND LOADING *****
1930 REM
1940 IF YARDSYS$="SKY" THEN MOVECOST=1240+12.55*(2*DISTMILL)
1950 IF YARDSYS$="GBS" THEN MOVECOST=.5*(1240+12.55*(2*DISTMILL))
1960 MOVECPA=MOVECOST/AVSYSAC
1970 MOVECPM=MOVECPA/NVOLPA
1980 IF YARDSYS$="GBS" THEN YLPPD=NVYPD ELSE: YLPPD=NVYPH*8
1990 YLCPM=MOVECPM+YCPM+LCPM+LOCPM
2000 REM
2010 REM
2020 REM
2030 REM)
2040 REM
2050 REM COMPUTE COST OF ROAD CONSTRUCTION, RECONSTRUCTION AND
2060 REM MAINTENANCE, INCLUDING TEMPORARY ROADS, IN $/MBF
2070 RCCPM=RCCPMt/NVOL
2080 MTCCPM=MTCMt*VMTCC
2090 RCPM=RCCPM+MTCCPM
2100 REM
2110 REM COMPUTE ENVIRONMENTAL AND ADMINISTRATIVE COSTS PER MBF
2120 REM
2130 SAICPM=SAtCPA*ACRES/NVOL
2140 ECCPM=ECCPA*ACRES/NVOL
2150 BDCPM=BDCPA*ACRES/NVOL
2160 ENVICPM=SAtCPM+ECCPM+BDCPM
2170 REM
2180 REM
2190 REM COMPUTE ADMINISTRATIVE COST PER MBF *****
2200 ADMINCPM=ADMINCPA*ACRES/NVOL
2210 REM
2220 REM
2230 REM COMPUTE TOTAL HARVEST COST, CROSS STUMPAGE AND NET PRESENT VALUE
2240 THCPM=LQCPM+RCPM+ENVICPM
2250 PRRI=PDVALZ*THCPM+PRRI
2260 RETURN=GETUMPAGA-ADMINCPM+NVOLPA
2270 DTIME=HARVYEAR-ANYEAR
2280 NPVPA=NPRETURZ*(1/1.04^DTIME)
2290 REM
2300 REM PRINT OUT THE SUMMARY OF RESULTS
2310 REM
2410 CLS
2420 PRINT TAB(1);"TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
2430 PRINT TAB(16);""
2440 PRINT TAB(16);""
2450 PRINT
2460 PRINT
2470 F1$="STAND AREA" ;="#### ACRES"
2480 F2$="NET VOLUME" ;="#### MCF"
2490 F3$="NET VOLUME PER ACRE" ;="#### MCF"
2500 F4$="TREES PER ACRE" ;="#### TPA"
2510 F5$="QUADRATIC MEAN DIAMETER" ;="#### INCHES"
2520 F6$="AVERAGE TOTAL HEIGHT" ;="#### FEET"
2530 F7$="AVERAGE GROSS LOG VOLUME" ;="#### SF"
2540 F8$="AVERAGE STEM LENGTH" ;="#### FEET"
2550 F9$="YARDING SYSTEM" ;="""""
2560 F10$="AVERAGE SLOPE YARDING DISTANCE" ;="#### FEET"
2570 F11$="AVERAGE SLOPE" ;="#### PERCENT"
2580 F12$="YARDING AND LOADING PRODUCTION" ;="#### MCF/DAY"
2590 F13$="DISTANCE TO THE MILL" ;="#### MILES"
2600 F14$="FELLING AND BUCKING COST" ;="####$/FD"/Acre"
2610 F15$="YARDING AND LOADING COST" ;="####$/FD"
2620 F16$="HAULING COST" ;="####$/MCF"
2630 F17$="GENERAL LOGGING OVERHEAD COST" ;="####$/MCF"
2640 F18$="STUMP TO MILL LOGGING COST" ;="####$/MCF"
2650 F19$="SPEC AND TEMP ROAD COST" ;="####$/MCF"
2660 F20$="SALE AND RD COST" ;="####$/MCF"
2670 F21$="TOTAL HARVEST COST" ;="####$/MCF"
2680 F22$="PROFIT AND RISK (12 PERCENT)" ;="####$/MCF"
2690 F23$="AVERAGE POND VALUE" ;="####$/MCF"
2700 F24$="ESTIMATED STUMPAGE" ;="####$/ACCRE"
2710 F25$="SALE PREP AND ADMIN COST" ;="####$/ACCRE"
2720 F26$="NET REVENUE (NOT DISCOUNTED)" ;="####$/ACCRE"
2730 F27$="NET PRESENT VALUE (i = 4%)" ;="####$/ACCRE"
2740 PRINT USING F1$;ACRES
2750 PRINT USING F2$;NVOL
2760 PRINT USING F3$;NVOLPA
2770 PRINT USING F4$;TPA
2780 PRINT USING F5$;QMD
2790 PRINT USING F6$;AVT
2800 IF YARDSYS$="YARDSYS" THEN PRINT USING F7$;AVPT : GOTO 2820
2810 PRINT USING F7$;PCSZ
2820 PRINT USING F8$;AVEML
2830 PRINT "YARDSYS" ;="YARDSYS"
2840 PRINT USING F9$;SLOPE
2850 PRINT USING F10$;YARDSYS
2860 PRINT USING F11$;DISTMILL
2870 PRINT "PRESS RETURN TO CONTINUE >>",KEY2$
2880 CLS
2890 PRINT TAB(1);"TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
2900 PRINT TAB(16);""
2910 PRINT TAB(16);""
2920 INPUT"PRESS RETURN TO CONTINUE >>",KEY2$
2930 CLS
2940 PRINT TAB(16);"TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
2950 PRINT TAB(16);""
PRINT TAB(35) "CONTINUED"

PRINT USING H1$, FBCPM
PRINT USING H2$, YLCPM
PRINT USING H3$, HCPM
PRINT USING H4$, LHCPM
PRINT USING H5$, LOGCPM
PRINT USING H6$, ENVICPM
PRINT USING H7$, THCPM
PRINT USING H8$, PRRI
PRINT USING I1$, PDVALTFJE
PRINT USING I2$, GSTUMPACE
PRINT
PRINT USING H9$, ADMINCPA
PRINT USING I3$, NRETVRN
PRINT USING I4$, NPVPA
PRINT
PRINT "PRESS H AND RETURN FOR HARD COPY OF SUMMARY. PRESS RETURN TO CONTINUE >", HCOPY$

IF HCOPY$ = " H THEN 3190
OTO 3200
OSUB 1180
CLS
INPUT "DO YOU WANT TO TRY ANOTHER LOGGING SYSTEM (YES, NO) >" ; ANOTHER$

IF ANOTHER$ & YES" THEN 680
INPUT "DO YOU WANT TO START OVER OR QUIT (START, QUIT) ->" ; QUIT$

IF QUIT$ = " START THEN 3250 ELSE 320
RUN 10
END

REM
REM
REM SUBROUTINE TO COMPUTE CUT TREE PARAMETERS
REM
***** TEST TO SEE IF PONDEROSA PINE TREES WERE CUT *****

IF TPAPP = 0 THEN 3710

REM THIS SUBROUTINE COMPUTES CUT TREE PARAMETERS FOR THE FALLING
REM AND BUCKING, YARDING, LOADING, AND HAULING SUBROUTINES.
REM
REM ***** COMPUTE TOTAL NET VOLUME MBF ***

NVPP = (GVPAPP * (1 - SCDEFL * ACRES / 1000)

AVPTPP = VOLUMEAPP / TPAPP

CUT TREES LENGTH IN FEET

REM *** COMPUTE TOTAL NET VOLUME IN MBF ****

NVPAPP = 0.5 * (1.5 * SCDEFL * ACRES / 1000)

AVPP = VOLUMEAPP / TPAPP

REM *** COMPUTE MERCHANTABLE LENGTH IN FEET ****

REM **END OF SUBROUTINE TO COMPUTE CUT TREE PARAMETERS ****

REM
REM
REM
REM
REM
REM
3520 MLPP=.3537*THPP+7.389*QMDP/1000=41.14
3530 REM
3540 REM ***** COMPUTE CROSS 16 FT LOG/GMF *****
3550 REM
3560 LPMPP=MLPP/1000
3570 REM
3580 REM ***** COMPUTE AVERAGE NUMBER OF PIECES/TREE *****
3590 REM
3600 PCPTPP=1.468+0.01864*THPP+0.0002468*QMDPP+0.0217/GMDP
3610 IF PCPTPP<1 THEN PCPTPP=1
3620 REM
3630 REM ***** COMPUTE AVERAGE PIECE SIZE IN SF *****
3640 REM
3650 LPMPP=(MLPP/16)/(AVPTPP/1000)
3660 REM
3670 REM ***** COMPUTE AVERAGE NUMBER OF PIECES/TREE *****
3680 REM
3690 LPMPP=12.09-.01397*PCSZPP+8.809999E-06*PCSZPP^2+187.1/PCSZPP
3700 REM
3710 REM ***** TEST TO SEE IF DOUGLAS-FIR TREES WERE CUT *****
3720 REM
3730 REM ***************************************************
3740 REM
3750 REM COMPtYTE DOUGLAS-FIR TREE PARAMETERS
3760 REM
3770 REM
3780 NVDF=(VADF*(1-SCDEF)*ACRES)/1000
3790 AVPTDF=CVPADF/TPADF
3800 MLDF=.6919*THDF+5.658*SQR(QMDDF=35.6
3810 LPMDF=(MLDF/16)/(AVPTDF/1000)
3820 REM
3830 REM ***** TEST TO SEE IF LODGEPOLE PINE TREES WERE CUT *****
3840 REM
3850 REM ***************************************************
3860 REM
3870 REM COMPtYTE LODGEPOLE PINE CUT TREE PARAMETERS
3880 REM
3890 REM
3900 NVLP=(CVPALP*(1-SCDEF)*ACRES)/1000
3910 AVPThF=CVPALP/TPALP
3920 MLLP=.6481*THLP+16.54*5QR(QMDLP)_0.41
3930 LFMDF=(MLLP/16)/(AVPTDF/1000)
3940 REM
3950 REM ***** TEST TO SEE IF GRAND FIR TREES WERE CUT *****
3960 REM
3970 REM
3980 REM COMPtYTE GRAND FIR CUT TREE PARAMETERS
3990 REM
4000 REM
4010 REM
4020 REM
4030 REM
4040 REM
4050 REM
4060 REM
```plaintext
REM *****************************************************************
REM COMPUTE TOTAL OR WEIGHTED AVERAGE CUT TREE PARAMETERS
REM *****************************************************************

REM ***** COMPUTE GROSS VOLUME/AC IN SF AND NET VOLUME/AC IN MBF

NVOLPA = GVPA * (1.5CDEF) * 1000

REM COMPUTE TOTAL TREES PER ACRE

TPA = TPAPP + TPADF + TPALP + TPAF + TPAAF + TFAES + TPAWL

REM ***** COMPUTE TOTAL NET VOLUME IN BF *****

NVOL = NVPP + NVDF + NVLP + NVF + NVAF + NVES + NVWL

REM ***** COMPUTE QUADRATIC MEAN DIAMETER IN INCHES *****

BAPTREE = (CTPAPP * .7854 * QMDPp + TPADF * .7854 * QMDDF + TPALP * .7854 * QMDLP + TPAF * .7854 * QMDAF + TPAAF * .7854 * QMDAF + TFAES * .7854 * QMDDES + TPAWL * .7854 * QMDWL) / TPA

QMD = SQR(BAPTR / .7854)

REM ***** COMPUTE AVERAGE GROSS VOLUME/TR IN SF *****

AVPTGVPA / TPA

REM ***** COMPUTE AVERAGE 16 FT LOGS/F *****

LPM = (VpAE5 + LpJL * CVpAWL) / CVpA

REM ***** COMPUTE AVERAGE PCE SIZE IN BF *****

PCSZ = (PCSZP * GVPAPP + PCSZDF * CVPADF + PCSZLP * GVPALP + PCSZCFCVF + PCSZAF * GVPAAF + PCZAF * GVPAAF + PCZAF * GVPAAF + PCZAF * GVPAAF + PCZAF * GVPAAF + PCZAF * GVPAAF + PCZAF * GVPAAF)

REM ***** COMPUTE AVERAGE MERCHANTABLE LENGTH AND TOTAL HEIGHT *****

AVE = (WL * TPAWL) / TPA

AVETH = (THPP * TPAFP + THDF * TPAFD + THLP * TPAFL + THCF * TPAFAF + THAF * TPAF + THES * TPAES + THWL * TPAWL) / TPA

REM ***** COMPUTE AVERAGE NUMBER OF BUCKET LOGS PER ACRE *****

NLOCSPA = GVFS / PCS:

REM ***** COMPUTE AVERAGE POUND/BOARD FOOT RATIO *****
```

**5140 REM**
**5150 LBBF=LBBFPP*GVPAPP+LBBFDF*GVPADF+LBBFLP*GVPALP+LBBFGF*VPALF+LFBF*.VP**
**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+PVCF*LPVF+PVAF*LVAF+PVESAVES*VPLN)**
**5280 REM**
**5290 REM**
**5300 REM**
**5310 REM ***** SUBROUTINE TO COMPUTE FALLING AND BUCKING COST PER MBF *******
**5320 REM**
**5330 IF CBSYS$='LTRAC' THEN MAXPL=20000**
**5340 IF CBSYS$='STRAC' THEN MAXPL=13000**
**5350 IF CBSYS$='CTRAC' THEN MAXPL=50000**
**5360 IF CBSYS$='STRAC' THEN MAXPL=12000**
5670 IF CGBYS$="LRTS" THEN MAXFL=10000
5680 IF CGBYS$="SRTS" THEN MAXPL=7000
5690 REM
5700 REM ***** GO TO LATERAL YARDING SUBROUTINE *****
5710 REM
5720 COSUB 7530
5730 REM
5740 REM ***** GO TO THE GROUND BASED SYSTEM SELECTED *****
5750 REM
5760 IF CGBYS$="LTRAC" THEN 5820
5770 IF (ThSYS$ "STRAC THEN S0S0
5780 IF CGBYS$="LRTS" THEN 6290
5790 IF GSYS$="SRTS" THEN S00
5800 REM
5810 REM **********************
5820 REM LARGE CRAWLER TRACTOR
5830 REM "**************************
5840 REM ***** COMPUTE CYCLE TIME *****
5850 REM
5860 DIDIST= (2*AYD*(1+WVE))IMtFT
5870 NWEIGHT=WTPT*1_SCDEF*LOGSPT
5880 TRAVEL=,03+.002705*OIDIST+.00010*NWEIGHT
5890 POSITION=.3878
5900 WINCH=.13+.02693*TWDPT
5910 HOOK=.1+1.041*LOSPT+.01933*TWDFT
5920 IMTRAVEL=.Q1+.0L48*IMDPT+.8*(HKSJSpT_1)
5930 LANDIN=1.26+.7426*LOCSPT
5940 PSLASH=.1558
5950 CYCLETIME=TRAVEL+POSITION+WINCH+HOOK+IMTRAVEL+PSLASH
5960 RETURN
5970 REM
5980 REM ****************************
5990 REM SMALL CRAWLER TRACTOR
6000 REM ******.************************
6010 REM ***** COMPUTE CYCLE TIME ****
6020 REM
6030 DIDIST=(2*AYD*(1+WEAVED]*IMDFT
6040 NWEIGHT=WTPT*(1_SCDEF)*LOGSPT
6050 IF SLOPE<0 THEN OUTSLOPE=ABS(SLOPE) ELSE OUTSLOPE=0
6060 TRAVEL=,35+.00309*OIDIST+.000147*NWEIGHT+.000147*AYD+1.9315*OUTSLOPE
6070 POSITION=.4519
6080 WINCH=.31+.0335*TWDFT
6090 HOOK=.12+.9315*LOGSFT+.0119*TWDFT+.2251*HK55pT
6100 IMTRAVEL= .0+,0023*IMDPT+.2463*(HKSJSpT_u
6110 LANDIN=,8485+.575*LOCSFT+.0Oo14*NwEIHT
6120 PSLASH.149
6130 CYCLETIME=TRAVEL+POSITION+WINCH+HOOK+IMTRAVEL+PSLASH
6140 RETURN
6150 REM
6160 REM ****************************
6230 REM
6240 YCPM=400*EFFSTRACLOGST+1.250*AVPT/1000*AVPT/CYCLETIME
6250 YCPM=YCPM+YCPFRAC/NVYPD
6260 RETURN
570 REM
6380 REM
6390 REM
6400 OUTSLOPE=-1*SLOPE
6410 IF OUTSLOPE<15 THEN VELOUT=7.95*5280/60
6420 IF OUTSLOPE=15 THEN VELOUT=6.43*5280/60
6430 IF OUTSLOPE=20 THEN VELOUT=5.45*5280/60
6440 IF OUTSLOPE=25 THEN VELOUT=4.68*5280/60
6450 IF OUTSLOPE=30 THEN VELOUT=4.13*5280/60
6460 REM
6470 REM
6480 REM
6490 REM
6500 REM
6510 REM
6520 REM
6530 REM
6540 REM
6550 REM
6560 VEICHT=WTPT*L0CSPT
6570 IF SLOPE<-5 THEN VMPH=3.036*5.58*LOGWEIGHT
6580 IF SLOPE=-5 THEN VMPH=5.673.58*LOGWEIGHT
6590 IF SLOPE=0 THEN VMPH=3.93*LOGWEIGHT
6600 IF SLOPE=5 THEN VMPH=2.76*LOGWEIGHT
6610 IF SLOPE=10 THEN VMPH=2.05*LOGWEIGHT
6620 REM
6630 REM
6640 REM
6650 REM
6660 REM
6670 REM
6680 REM
6690 REM
6700 REM
6710 REM
6720 REM
6730 REM
6740 VEL5=VMPH*5280/60
6750 IF SLOPE<5 THEN VMPH=6
6760 IF VMPH>6 THEN VMPH=6
6770 IF VMPH>6 THEN VMPH=6
6780 IF VMPH>6 THEN VMPH=6
6790 IF VMPH>6 THEN VMPH=6
6800 IF VMPH>6 THEN VMPH=6
6810 IF VMPH>6 THEN VMPH=6
6790 IF SLOPE<10 THEN VMPH=20.38*LOGWEIGHT
6800 REM
6810 REM **** IF PREDICTED VEL > 6 MPH THEN SET IT = 6 MPH ****
6820 REM
6830 IF VMMPH>6 THEN VMMPH=6
6840 REM
6850 REM ***** COMPUTE INHAUL VELOCITY IN FEET PER MINUTE *****
6860 REM
6870 VIN=VMMPH*5280/60
6880 REM
6890 REM *************************************************
6910 REM SMALL AND LARGE RUBBER TIRED SKIDDERS
6920 REM *************************************************
6930 REM ***** COMPUTE CYCLE TIME *****
6940 REM
6950 OUTHAUL=ODIST*VMMPH; INHAUL=ODIST/VELIN
6960 TRAVEL=OUTHAUL+INHAUL
6970 POSITION=TRAVEL
6980 WINCH=.25+1.02432*TWDPT
6990 HOOK=.24+.592*LOSPT+.107*TWDPT+.35*HKSITESPT
7000 IMMTR=.07+.00316*IMDPT+.13*(HKITESPT-1)
7010 LANDIN=.025+.3205*LOSPT+.00008*WEIGHT
7020 FSLASH=.1558
7030 CYCLETIME=TRAVEL+POSITION+WINCH+IMTRAV+LANDIN+FSLASH
7040 RETURN
7050 REM
7060 REM *** COMPUTE DAILY PRODUCTION AND YARDING COST PER MBF ****
7070 REM
7080 PD=(480*EFFRTS*LOSPT*(1 SCDEF)*(AVFT/1000)*.975)/CYCLETIME
7090 IF BSYS=TITS THEN FDCRTS=FDCRTS ELSE FDCRTS=FDCRTS
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 0 TO THE LATERAL YARDING SUBROUTINE
7200 REM
7210 IF WTPL>1000 THEN SKYSYS='MED'; GOTO 7220
7220 IF SKYSYS='MED' THEN MAXPL=MPL/MAXPL
7230 IF SKYSYS='MED' THEN MAXPL=MPL/MAXPL
7240 IF MAXPL>0 THEN MAXPL=600
7250 GOSUB 9280
7260 REM
7270 REM ***** Go TO THE SKYLINE SYSTEM SELECTED *****
7280 REM
7290 REM
7300 REM
7310 REM SMALL SKYLINE YARDING SYSTEM
7320 REM
7330 REM
7340 REM
7350 REM ***** COMPUTE CYCLETIME, HOURLY PRODUCTION, AND COST/MBF *****
7360 REM
7370 CYCLETIM3.587+.003672*AyD+.01657*ALyD+.2337*L005pT_.OlO09*ABS(SLOPE)
7380 IF VPA>7500 THEN EFHRSSY=.73 ELSE FHRSSY=.38
7390 NVYPH= (EFHRSSY*60/CYCLErIM)*(Loc5pT*pc5z*(1_5cD),1 000)
7400 YCPM:FHCSSY/NVYPH
7410 RETURN
7420 REM
7430 REM
7440 REM
7450 REM
7460 REM
7470 REM
7480 REM
7490 REM
7500 REM
7510 REM
7520 REM
7530 REM
7540 REM
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7970 REM
7980 REM
7990 REM
8000 REM
8010 REM
8020 REM
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8090 REM
8100 REM
8110 REM
8120 REM
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9860 REM
9870 REM
9880 REM
9890 REM
9900 REM
9910 REM
9920 REM
9930 REM
9940 REM
9950 REM
9960 REM
9970 REM
9980 REM
9990 REM
7810 N1=NI+1
7820 KOUNT(N1)=I
7830 X1(N1)=X(I)
7840 Vi(Ni)V(I)
7850 D1(Ni)=SQR((X(I)Mj) 2+V(I) 2)
7860 NEXT I
7870 GOSUB 8030
7880 REM BEGIN BUILDING TURN *****
7890 IF CI=CI THEN 3100 "CHOKERS ARE FULL, END THE TURN"
7900 IF NEXTPL+PAYLOAD+WT> "LOOK AHEAD TO SEE IF NEXT LOG WILL EXCEED"
7910 IF NEXTPL+MAXPL THEN 8310 "MAX PAYLOAD, IF IT DOES, END THE TURN"
7920 IF NMOVES= THEN 3310 "ONLY THREE HOOKSITES PER TURN ARE ALLOWED"
7930 REM MOVE MACHINE ****
7940 NMOVES=NMOVES+1 : Ni=0
7950 GOSUB 8190
7960 REM ***** COMPUTE INTERMEDIATE TURN STATS, CONTINUE BUILDING TURN *****
7970 IF NLOGS=N THEN 3390 "SET VARIABLES=0, MOVE MACHINE *****"
8470 FOR I=1 TO N
8480 A(I+1)=XW
8490 B(I+1)=YW
8500 NEXT I
8510 M=N
8520 A(1)=0 : B(1)=0
8530 L=2
8540 R=N+1
8550 P=1
8560 I=1
8570 IF A(I)<V THEN 8620
8580 L=2
8590 IF A(I)<V THEN 8640
8600 IF I=1 THEN 8600
8610 SWAP A(I),A(I+1)
8620 SWAP B(I),B(I+1)
8630 IF (R-I)<M THEN 8750
8640 IF A(I)<V THEN 8640
8650 P=P+1
8660 SWAP A(I),A(J)
8670 SWAP B(I),B(J)
8680 IF (R-J)<M THEN 8850
8690 IF A(J)<V THEN 8690
8700 P=P+1
8710 IF A(J)<V THEN 8710
8720 SWAP A(I),A(J)
8730 SWAP B(I),B(J)
8740 IF (R-J)>M THEN 8950
8750 IF (J-L)>=M THEN 8750
8760 L=J+1
8770 GOTO 2560
8780 IF A(I+1)>A(I) THEN 8970
8790 V=A(I+1)
8800 J=I
8810 IF A(J)<V THEN 8810
8820 A(J+1)=A(J)
8830 B(J+1)=B(J)
8840 J=J+1
8850 IF A(J)<V THEN 8850
8860 A(J+1)=V
8870 B(J+1)=V
8880 NEXT I
8890 RETURN
9030 REM
9040 REM ***** SORT CANDIDATE LOGS BY DISTANCE FROM MACHINE *****
9050 REM
9060 N2=N1+1
9070 FOR I=1 TO N1
9080 N1=I+1
9090 FOR J=I+1 TO N1
9100 IF (DI(I)-DI(J))<=0 THEN 9150
9110 SWAP XI(I),XI(J)
9120 SWAP Y1W,Y1W
9130 SWAP DI(I),DI(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 OLD=ML
9220 FOR K=N TO 1 STEP -1
9230 IF X(K)>0 THEN 9250
9240 NEXT K
9250 DL=X(K)-ML-.5 : IF ML<=0 THEN ML=0.001
9260 RETURN
9270 REM
9280 REM
9290 REM ***** SUBROUTINE TO EMULATE LATERAL YARDING OF SKYLINE *****
9300 REM ***** SYSTEMS INCLUDING SMALL AND MEDIUM YARDERS *****
9310 REM
9320 REM
9330 REM ***** INITA LIZE KEY VARIABLES *****
9340 REM
9350 N1=0 : NLOGS=0 : CS=0 : TLYD=0 : N1=0
9360 WI=15 : CN=5 : N=100
9370 REM
9380 REM ***** COMPUTE THE LENGTH OF THE CUT BLOCK *****
9390 REM
9400 LE=4360*N/(WI*NLOGS)
9410 REM
9420 REM ***** GENERATE RANDOM LOCATION OF LOGS *****
9430 REM
9440 FOR I=1 TO N
9450 X(I)=RND*WI
9460 Y(I)=RND*WI
9470 NEXT I
9480 REM
9490 REM ***** SUBROUTINE TO MOVE MACHINE *****
9500 REM
9510 GO TO 8450
9520 REM
9530 REM ***** BEGIN LATERAL YARDING *****
9540 REM
9550 REM ***** LOCATE CARRIAGE AND BUTTOCK, IDENTIFY LOGS WITHIN REACH *****
9560 REM
9570 FOR I=1 TO N
9580 IF Y(I)>0 THEN 9600
CALO+XID=CL : XBR=CALO : YBH=VD= I : GOTO 9110

NEXT I

FOR I=1 TO N

IF X(I)=0 THEN 9670

DIST=SQR((X(I)-XBH)^2+(Y(I)-YBH)^2)

IF DIST>2*CL THEN 91370

Ni=Ni+i

KONTJ(Ni)=I

X1(Ni)=X(I)

Y1(Ni)=Y(I)

DuN1=DIST

NEXT I

REM

NEXT I

REM

NEXT I

REM

REM ***** SORT LOGS WITHIN REACH BY DISTANCE FROM BUTTHOOK *****

REM

REM ***** BEGIN HOOKING LOGS *****

REM

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10150 IF ZONAVG<6! THEN TIMAVG=32.262+1.681*tZONAVG
10160 IF LPM>213! THEN TIMF(:12.2I32+1.681*LPM
10170 IF LPM>6! AND LPM<26! THEN TIMPG=37.62+1.681*LPM-LPM
10180 IF LPM<6! THEN TIMP3.262+1.G81*LPM
10190 ZONTIM=TIMAVG/VOLAVG
10200 PTIME=TIMAVG/VQLPG
10210 DIF=PGTIM/ZONTIM
10220 ALLOWLDIF-1!
10230 REM
1040 REM
1050 REM COMPUTE DEFECT ADJUSTMENT FACTOR *****
10260 ZD=1!/(1!DEFAVG)
10270 PDEF=1!/(1SCDEF)
10280 DEFECT= (PDEF/ZDEF)-1
10290 REM
10300 REM ***** COMPUTE TOTAL LOADING ADJUSTMENT FACTOR *****
10310 REM
10320 ADJLAMA=ALLOWL+DEFECT-1!
10330 REM
10340 REM ***** COMPUTE LOADIN' COST PER MBF *****
10350 REM
10360 LCPM SWZALC*ADJLAMA
10370 RTJRN
10380 REM
10390 REM ***** SUBROUTINE TO COMPUTE HAUL COST PER MBF *****
10410 REM
10420 REM ***** COMPUTE AVE WET VOL/TRUCKLOAD, NUMBER OF LOADS *****
10430 REM ***** AND TOTAL STANDBY TIME FOR EACH SPECIES *****
10440 REM
10450 REM
10460 REM
10470 REM PONDEROSA PINE
10480 REM
10500 IF TPAPP=O THEN 10560
10510 GVPLP= (ULHWY/LBBFPP)/1 000 : NVPLPP=VPLPP*(1_SCDEF)
10520 14LOADSPPNVPP/NVPLPP
10530 SBTPP=NLOADSPP*(44! +1.159*LPMPP)
10540 REM
10550 REM
10560 REM
10570 REM DOULASFIR
10580 REM
10590 IF TPADF=O THEN 10650
10600 GVPLDF= (NLHWY/LBBFDF) / 10(0: WVPLDF=VPLDF*( 1 SCDEF)
10610 NLDADSDFNVDF/WVPLDF
10620 SBTFDF=NLOADSDF*(47 +1 .0:36*LPMDF)
10630 REM
10640 REM
10650 REM
10660 REM PONDEROSA PINE
10670 REM
10680 IF TPAPP=O THEN 10740
10690 VPLLP (HLHWY/LFLP)/ 1000 NVPLLF: VPLLP*( 1 SCDEF)
10700 NLOADSLPUVLP/NVPLLP
10710 REM
10720 REM
10730 REM
10740 REM
10750 REM
10760 REM
10770 REM
10780 REM
10790 IF TPADF=O THEN 10850
10800 GVPLDF= (NLHWY/LBBFDF)/1000 : NVPLDF=VPLDF*(1-SCDEF)
10810 NLOADSDF=LOADDEF*(47+1.056*LPMDF)
10820 REM
10830 REM
10840 REM
10850 REM
10860 REM
10870 REM
10880 REM
10890 REM
10900 REM
10910 REM
10920 REM
10930 REM
10940 REM
10950 REM
10960 REM
10970 REM
10980 REM
10990 REM
11000 REM
10710 SBTLP=NLLOADLP*(56.46+.9893*LPMLP)
10720 REM
10730 REM ***************
10740 REM GRAND FR
10750 REM ***************
10760 REM
10770 IF TPACF=0 THEN 10830
10780 cVPLCF=(NLHWY/LBBFCF)/1000 NVPLCF=cVPLCF*(1SCDEP)
10790 NLOADSCF=NVCF/NVPLCF
10800 SBTcF=NLOADSCF*(45.02+1.099*LPMCF)
10810 REM
10820 REM
10830 REM SuBALPINE FIR
10840 REM
10850 IF TPAAF=0 THEN 10920
10860 CVPLAF=(NLHWY/LBBFAF)/1000 NVPLAF=VPLAF*(1 SCDEF)
10870 NLOADSAF=NVAF/NVPLAF
10880 SBTAF=NLOADSAF*(45.02+1.099*LPMAF)
10890 REM
10900 REM ****************************
10910 REM
10920 REM ENELMANN SPRUCE
10930 REM
10940 REM
10950 IF TFAES=0 THEN 11010
10960 cVPLES= (NLHWY/LBBFES)/1000 NVPLES=GVPLES*(1SCDEP)
10970 NLOADSES=NVES/NVPLES
10980 SBTES=NLOADSES*(45.02+1.324*LPMES)
10990 REM
11000 REM
11010 REM WESTERN LARCH
11020 REM
11030 REM
11040 IF TPAWL=0 THEN 11090
11050 CVPLWL=(NLHWY/LBBFWL)/1000 NVPLWL=VPLWL*(1SCDEP)
11060 NLOADSWL=NVWL/NVPLWL
11070 SBTWL=NLOADSWL*(47.6+1.086*LPMWL)
11080 REM
11090 REM ***** COMPUTE AVE NET VOL IN MBF AND STANDBY TIME PER LOAD *****
11100 REM
11110 LOADS=NLOADSPP+NLOADSDF+NLOADSLP+NLOADSGF+NLOADSAF+NLOADSES+NLOADSWL
11120 NVPLOAD=NVOL/NLOADS
11130 SBT=SBTPP+SBTDF+SBTLP+SBTCF+SBTAF+SBTES+SBTWL
11140 SBTPLOAD=SBT/NLOADS
11150 REM
11160 REM COMPUTE TOTAL ROUND TRIP TRAVEL TIME INCLUDING DELAYS *****
11170 REM
11180 R'TTT'P=MIPRTMPMIF: RmUP=MIPMUP*RTMPMUP
11190 TRrrr=Rr!-rp+Rrrrup+SBTPLOAD
11200 REM
11210 REM ***** COMPUTE TOTAL HAUL COST PER DAY *****
11220 REM
11230 HTLPD=720/TR1Tr
11240 NVHPD=HTLPD*NVPLOAD
11250 REM
11260 REM **** COMPUTE TOTAL HAUL COST PER DAY *****
1170 REM
1180 FCPDH=FDCLT+FDCLTD
1190 VCPDH:(2*MIP*VCPMIP+2*MIUP*VCPMIJP)*NTLPD
1200 TCPDH=FCPDH+VCPDH
1210 REM
1220 REM ***** COMPUTE HAUL COST PER MBF *****
1230 REM
1240 HCPM=TCPDH/NVHPD
1250 REM
1260 REM ***** COMPUTE THE DISTANCE TO THE MILL (ONE-WAY) *****
1270 REM
1280 DISTMILL=MIUP+MIUP
1290 RETURN
1300 REM
1310 REM
1320 REM ***** SUBROUTINE TO CREATE GRAPHICS - WINDOWS AROUND PAGES *****
1330 REM
1340 REM
1350 REM ***** SUBROUTINE TO PRINT A HARD COPY OF THE SUMMARY *****
1360 REM
1370 REM
1380 REM
1390 REM
1400 REM
1410 REM
1420 REM
1430 REM
1440 REM
1450 BLX=TLX : BRX=TRX : TLY=BLY : BRY=BLY
1460 LOCATE TLY,TLX: PRINT CHR$(201) : LOCATE TRY,TRX PRINT CHR$(187)
1470 LOCATE BLY,BLX: PRINT CHR$(00) : LOCATE BRY,BRX :PRINT CHR$(188)
1480 FOR I=TLX+1 TO TRX-1
1490 
175
LOCATE TLY,I : PRINT CHR$(05)
1500 
175
LOCATE BLY,I : PRINT CHR$(205)
1510 NEXT I
1520 FOR J=TLY+1 TO PLY-I
1530 
175
LOCATE J,TLX: PRINT CHR$(186)
1540 
175
LOCATE J,TRX: PRINT CHR$(186)
1550 NEXT J
1560 RETURN
1570 REM
1580 REM
1590 REM
1600 REM
1610 REM
1620 LPRINT
1630 LPRINT
1640 LPRINT
1650 LPRINT TAB(16) "TIMBER HARVEST PRODUCTION, COST, AND REVENUE SUMMARY"
1660 LPRINT TAB(16) "--
1670 LPRINT TAB(16) "--
1680 LPRINT
1690 LPRINT
1700 LPRINT USING F1$;ACRES
1710 LPRINT USING F2$;NVOL
1720 LPRINT USING F3$;NVOLPA
1730 LPRINT USING F4$;QMD
1740 LPRINT USING F5$;AVETH
1750 LPRINT USING F6$;AVPT
1760 IF YARDSYS$="GBS" THEN LPRINT USING F7$;AVEGB
1770 LPRINT USING F8$;AVEF
1780 LPRINT USING F9$;AVPD
1790 LPRINT USING GA$;AYD
1800 IF YARDSYS$="GBS" THEN LPRINT USING GA$;GBS
1810 LPRINT USING GB$;GBS
1820 LPRINT USING GC$;GC
1830 LPRINT USING GD$;GD
1840 LPRINT USING GE$;GE
11620 IF YARDSYS$="1" THEN LPRINT USING C3$;SLOPE : GOTO 11850
11640 LPRINT USING C4$;SLOPE
11660 LPRINT USING C4$;DISTMILL
11670 LPRINT
11680 LPRINT
11690 LPRINT
11800 LPRINT USING H1$;ROM
11910 LPRINT USING H2$;ROM
11920 LPRINT USING H3$;ROM
11930 LPRINT USING H4$;ROM
11940 LPRINT USING H5$;ROM
11950 LPRINT USING H6$;ROM
11960 LPRINT USING H7$;ROM
11970 LPRINT USING H8$;ROM
11980 LPRINT USING H9$;ROM
11990 LPRINT USING H10$;ROM
12000 LPRINT USING H11$;ROM
12010 LPRINT
12020 LPRINT USING H12$;ROM
12030 LPRINT USING H13$;ROM
12040 LPRINT USING H14$;ROM
12050 RETURN
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 76 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 (SAl), $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 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, DP, LF, GP, AP, AB, 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
Note: This data only applies
to the species selected above, PP.
Cut trees and volume per acre may be estimated from cruise records,
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

1 Idaho Forest Products Marketing Bulletin; Department of Forest
Idaho Forest Products Marketing Bulletin; Department of Forest
Products, College of Forestry Wildlife and Range Sciences and
Products, College of Forestry Wildlife and Range Sciences and
Cooperative Extension Service, University of Idaho, Moscow,
Cooperative Extension Service, University of Idaho, Moscow,
Idaho, 83843
ENTER SPECIES CODE (PP,DF,LP,GF,AP,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 save to the next screen.

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

(3) LOGGING SYSTEM AND TERRAIN DATA

ENTER THE YARDING TYPE

CBS - GROUND BASED SYSTEM, SKY - SKYLINE SYSTEM

These are the machines available if you choose CBS:

- 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 CBS

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 smaller 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 (SD) 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
CBS - GROUND BASED SYSTEM, SKY - SKYLINE SYSTEM

Enter CBS

ENTER A SKIDDING MACHINE
STRAC = SMALL CRAWLER TRACTOR, LTS = 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.