BREAK-EVEN ZONES FOR CABLE YARDING BY LOG SIZE

by

Chris B. LeDoux

ABSTRACT

The use of cable logging to extract small pieces of residue wood may result in low rates of production and a high cost per unit of wood produced. However, the logging manager can improve yarding productivity and break-even in cable residue removal operations by using the proper planning techniques. In this study, break-even zones for specific young-growth stands were developed with data from a field study, break-even analysis, and a simulation model called THIN. Results suggest that logging contractors can break even by developing and using residue removal guidelines for various combinations of piece sizes and slope yarding distances. Simulation analysis was used to explore the effect on production rates of slope yarding distances, piece size distributions, and numbers of pieces per acre. For the $76-per-hour machine used, the results of break-even analysis were most affected by piece size. Slope distance also had a strong impact. The number of pieces per acre had the least effect on production rates and costs.

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Chris B. LeDoux[1]

Harvesting young, unmanaged stands creates large quantities of wood residue that could be used for energy (LeDoux and Adams 1983). Generally, this logging residue--tops and limbs, broken logs, old cull logs left behind from previous harvests, and standing and down unmerchantable species--has been left on the site and not used.

Recently there has been increased interest in using logging residue for energy to help diminish projected shortages of wood (USDA Forest Service 1981). To balance this desire against logging cost, product values, and landowner clean-up objectives requires a rigorous financial evaluation. The logging analyst must be familiar with the effects of site-specific variables on the cost of a particular logging operation and with the productivity of any proposed residue-removal venture.

Handling small pieces of residue or logs is a problem for the logging manager. Removing small pieces at long external yarding distances generally results in low productivity and high cost, much of which can be attributed to the use of expensive cable systems to extract the residue. One method for improving productivity is to use external yarding distance as a criterion for the removal of residue and to remove only larger pieces of residue if the yarding distance is long. However, decision-makers must know which variables affect cost and production and understand how those variables interact if they are to determine whether residue removal is economically feasible for a particular harvesting operation. Decision-makers must also be able to determine the total amount and minimum size of residue pieces that can be removed without sustaining a loss. In this article, the effect on production costs of slope yarding distances and piece size distributions is evaluated with a simulation model called THIN (LeDoux and Butler 1981) and a break-even contour is developed.

Although the specific example used here is a medium-sized cable yarder with a four-person crew operating in a corridor 1,000 feet long and 200 feet wide in Pacific Northwest Douglas-fir thinnings, the method could be used for any cable harvester removing residue from thinnings or clearcut harvests.

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USING THIN TO DEVELOP PRODUCTIVITY RATES

For skyline residue yarding, the THIN algorithm simulates the location and hooking of the first piece of residue and then the process of adding pieces to the turn. The simulation continues to add pieces to the turn as long as the skyline payload capacity is not exceeded, adequate chokers exist, and added pieces are not more than a specified distance from the first hooked piece (Fig. 1). The user can specify alternate external slope yarding distances and residue piece sizes as inputs to the model. The algorithm can then build turns and estimate hourly productivity rates for different slope yarding distances and statistical distributions of residue piece sizes.

The user should choose carefully the value used as the maximum distance from the first residue piece hooked to additional pieces; this value is an input to THIN. It is common practice for the hooking crew to pull line laterally from the carriage, hook one or more pieces of residue, pull line to additional pieces and hook them, yard the turn toward the skyline road, then stop and add pieces to complete the turn. The length of chokers flown can be one measure of the maximum distance the hooking line is pulled where choker length is increased slightly to reduce line pulling and effort by the hooking crew when building a turn.

In this simulation, we used a value of 43 feet for the maximum distance that the hooking line could be pulled from the first hooked log. This distance should not be confused with the maximum lateral distance allowed from the skyline; it is simply the maximum distance allowed from the first hooked log (LeDoux and Butler 1981). This distance was selected after detailed examination of turn distributions from field studies of residue yarding (LeDoux 1983, LeDoux and Adams 1983). The user can explore the costs and benefits of other distances simply by running additional simulations.

Data from a field test (LeDoux and Adams 1983) conducted in a young stand were used in this study to illustrate the effects of alternate slope yarding distances and piece size distributions on hourly production rates and costs. The simulation model was then employed to evaluate the effects of each variable on yarding productivity, by allowing that variable to change in value while holding the remaining variables constant.

Slope yarding distance

Generally, the farther out on the slope one goes to hook turns of residue, the lower the hourly productivity rate and the higher the cost per unit. Table 1 shows the effects of changes in slope yarding distance and average piece size on hourly production rates. In all cases, hourly productivity drops significantly as one goes farther out on the slope. For example, if piece size averages 6.0 cubic feet and slope yarding distance is 350 feet, the productivity rate is 273.82 cubic feet per hour.

Residue piece size and distribution

Generally, removing larger pieces improves productivity and reduces costs. For example, if we are yarding residue to distances of 650 feet and the average piece size is 6.0 cubic feet, the hourly production rate is 215.09 cubic feet. If slope distance remains unchanged but average piece size increases to 12 cubic feet, the hourly production rate increases by 89 percent, from 215.09 to 405.95 cubic feet (Table 1).

Table 2 shows the effect on hourly production rates of changes in the number of pieces of residue per acre in average piece size. Generally, the effect of pieces per acre on yarding production is less than the effect of changes in slope yarding distance or average piece size. For example, consider the hourly production rates when piece size averages 6.0 cubic feet and there are 100 pieces per acre and 400 pieces per acre. The hourly production rates are 247.38 and 266.12 cubic feet, respectively, an 8-percent increase. In contrast, yarding pieces that average 16.0 cubic feet at the same 100 and 400 pieces per acre results in only a 6-percent increase, from 582.41 to 619.72 cubic feet per hour.

BREAK-EVEN ANALYSIS

The break-even analysis does not consider move-in and -out or rig-up and -down costs, but focuses only on yarding costs and productivity. The analysis is based on the assumption that the hourly operating cost of the medium-size yarding machine and four-person crew is $76 and that the residue is sold for $35 per cord at the roadside as stacked firewood. The data in Table 1 are rearranged and shown in Figure 2. The objective is to find the maximum slope yarding distance for removal of residue of a given size at which market value and extraction costs offset each other and the operation breaks even.

The horizontal line that indicates the $35-per-cord market value shows these combinations of average piece size and slope yarding distance. For example, at production costs of $0.27 per cubic foot a logger could afford to yard 6.0-cubic-foot pieces no farther than 285 feet, and 8.0 cubic-foot pieces no farther than 571 feet. Although firewood products and prices are used in this example, similar analyses could be conducted for any product or price.

The data shown in Figure 2 can be rearranged to show the range of average piece sizes and slope yarding distances that would result in a break-even operation at each slope yarding distance shown (Fig. 3). The cross-hatched area shows the zone of economic profitability, while the unshaded area below the break-even line shows the area of economic loss.

The field manager and logging crew may find it difficult to analyze figures such as those developed above in the field; therefore, the next section describes how the data and results can be further rearranged for practical applications.

For a logging operation in a typical rectangular skyline corridor whose slope distance is 1,000 feet and lateral distance is 200 feet, the conditions we simulated, and a market price of $35 per stacked cord, the crew would be instructed to hook pieces 5.2 cubic feet and larger if the slope yarding distance is 0 to 200 feet, 6.2 cubic feet and larger in the 200- to 600-foot range, and only pieces 9.0 cubic feet or larger from 600 feet on. This policy would result in the operation breaking even, and hooking pieces larger than the minimums specified by zone would clearly result in profit.

Note that Figure 3 suggests that one should hook, for example, 8.0-cubic-foot pieces at a slope yarding distance of 600 feet; this holds true if slope yarding distance is broken down into the 100-foot-long short hauls shown on the x-axis of Figure 3. However, remember that our practical application assumes that the logger will deal with a slope yarding range of 600+ feet when he is matching piece size to slope yarding distance. Thus the size of the piece to be hooked should allow the operation to break even throughout the entire 600+-foot range, rather than within each of the shorter hauls that make up the total slope yarding distance.

Admittedly, it may be difficult for hooking crew members to determine rapidly whether a given piece contains 5.2 cubic feet, 6.2 cubic feet, or whatever the desired size might be for a given slope yarding range. However, given the desired volume of a piece, one can easily develop a matrix of mid-diameters and lengths that would yield the desired size (Fig. 4). A piece whose mid-diameter and length falls on or below the stairstep line (that is, in the shaded area) would be of the desired size and should be hooked. Similar matrices could be developed for alternate desired piece sizes. Ideally, the break-even analysis would be done before the actual logging operation. Clearly the method would not work very efficiently if the crew had to develop the break-even contours while logging.

CONSIDERATIONS FOR MANAGERS

Regional planners or forest managers may wish to develop break-even residue removal policies on a larger scale for wider application. Accordingly, the example data developed above could be arranged to develop contours, such as those shown in Figure 5, of zones where residue removal operations should break even. Such contours could be used by loggers, silviculturists, wildlife and fisheries biologists, and others involved in forest management who wish to visualize and evaluate the impact of alternate residue removal policies. The contours shown in Figure 5 consider only logging costs and firewood market values, but other concerns could easily be integrated into such an approach. Similar analyses could be developed for other yarders, crew sizes, or log size distributions. Break-even contours should be developed site by site or case by case to be most accurate and effective.

The method of break-even analysis presented in this paper will not answer all questions about residue removal, but it can aid decision makers in the financial evaluation of ways to remove residue from harvested stands.

LITERATURE CITED

LeDoux, C.B. 1984. Production rates and costs of cable yarding wood residue from clearcut units. Forest Products Journal (in press).

LeDoux, C.B., and T.C. Adams. 1983. Harvesting residue from thinnings for use as an energy source. Final report to U.S. Department of Energy. Interagency Agreement No. DE-AI51-81R000699. 23 p.

LeDoux, C.B., and D.A. Butler. 1981. Simulating cable thinning in young-growth stands. Forest Science 27(4):745-757.

USDA Forest Service. 1981. Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains. Symposium proceedings, 28-30 Nov. 1979, Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, Utah.

Table 1. -- Hourly production rate (in ft^3) as affected by changes in average piece size and slope yarding distance.

Slope distance[a] (ft.)	Average piece size (ft^3)						
	2.0	4.0	6.0	8.0	10.0	12.0	16.0
50	111.84	234.47	348.01	453.45	551.61	643.00	792.52
150	108.95	220.75	324.98	422.39	513.62	599.25	737.38
250	104.89	212.17	312.48	406.48	494.74	577.78	711.76
350	90.23	184.72	273.82	357.96	437.55	512.94	636.71
450	80.93	169.38	253.10	332.46	407.79	479.39	598.72
550	74.47	156.02	233.55	307.35	377.68	444.78	556.46
650	73.22	145.75	215.09	281.45	345.01	405.95	504.07
750	67.49	140.22	209.76	276.29	340.03	401.13	502.84
850	64.63	134.63	201.66	265.92	327.56	386.75	486.09
950	61.06	125.96	188.32	248.27	305.96	361.50	454.57

[a]Skyline corridor is 1,000 feet long and 200 feet wide.

Table 2.--Hourly production rate (in ft^3) as affected by changes in average piece size and number of pieces per acre.

Pieces per acre[a]	Average piece size (ft^3)						
	2.0	4.0	6.0	8.0	10.0	12.0	16.0
100	80.67	166.24	247.38	324.43	397.68	467.42	582.41
150	84.24	172.88	256.77	336.28	411.74	483.46	601.10
200	86.52	176.13	260.87	341.14	417.27	489.59	607.52
250	88.31	179.99	266.58	348.50	426.11	499.74	619.78
300	88.95	181.85	269.53	352.41	430.87	505.27	626.77
350	88.26	180.54	267.66	350.04	428.07	502.08	623.03
400	87.78	179.50	266.12	348.07	425.70	499.36	619.72

[a]Skyline corridor is 1,000 feet long and 200 feet wide.

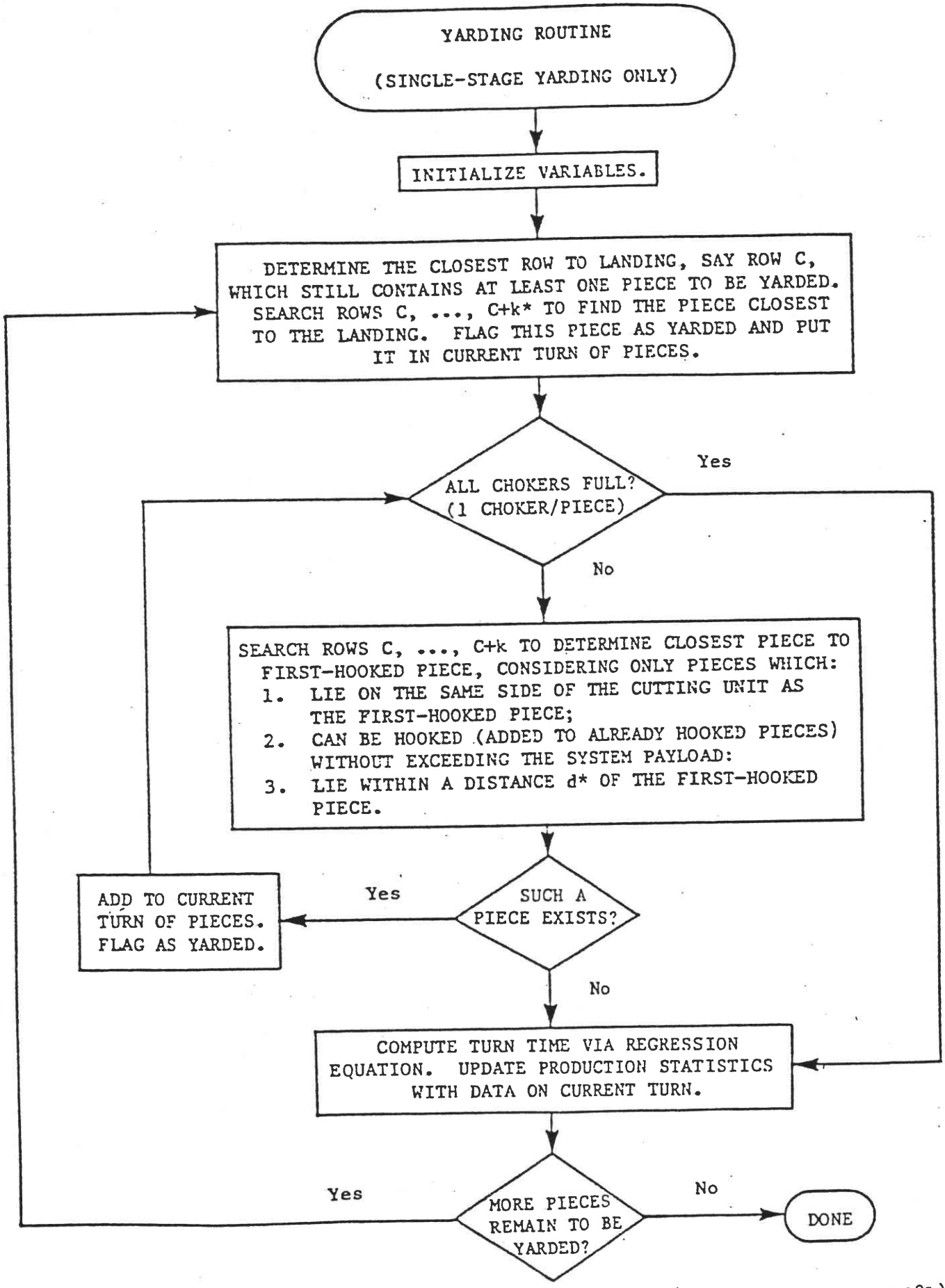


Figure 1.--Flowchart of THIN's simulated yarding routine (LeDoux and Butler 1981).

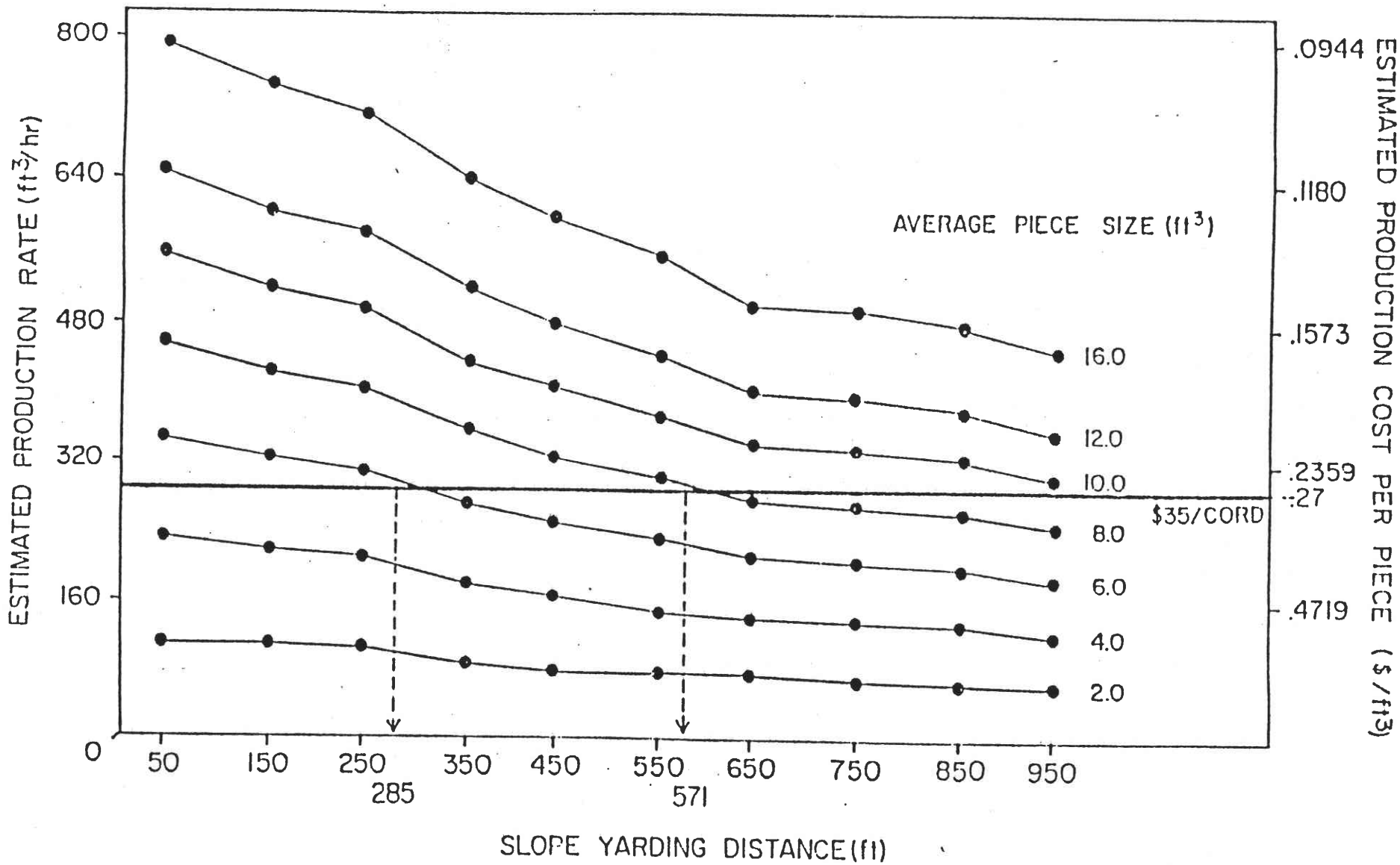


Figure 2.--Simulated production rates and costs of skyline yarding for various combinations of piece size and slope yarding distance. Horizontal line shows size/distance combinations at which operation would break even, assuming residue is sold for $35 per stacked cord and that machine and crew operating cost is $76 per hour.

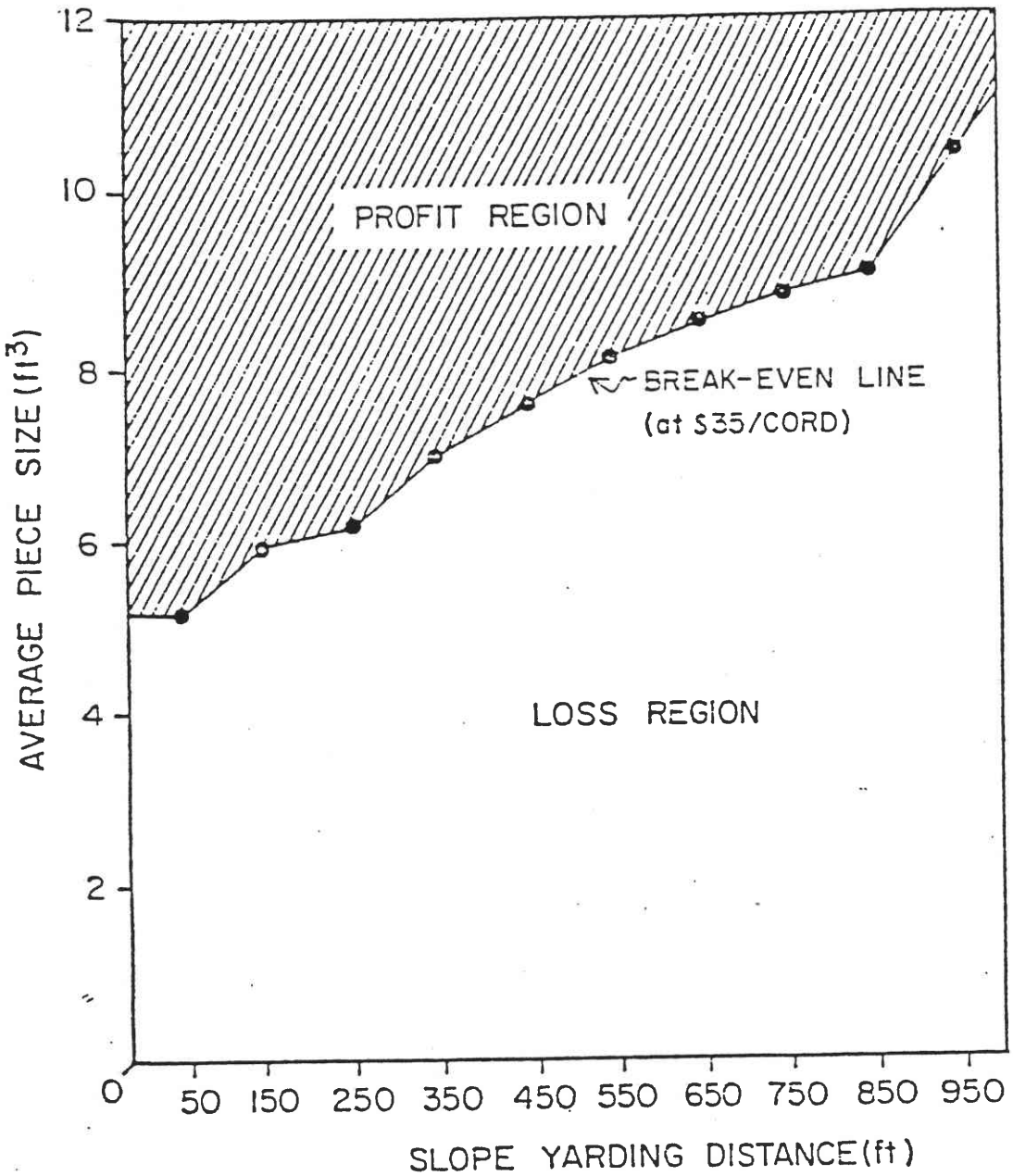


Figure 3.--Simulated economic regions and break-even line for cable yarding of residue that is sold for $35 per stacked cord. Cross-hatched area shows combination of average piece size and slope yarding distance that are economically feasible and yield a profit within each slope yarding distance shown; line shows size/distance combinations that allow break-even operation, and unshaded area (below line) shows size/distance combinations that yield loss. Skyline corridor is 1,000 feet long and 200 feet wide.

Volume of piece = 9.0 ft^3

$$\text{Volume} = C \cdot L$$

WHERE:

C = Basal area at piece's center

$= 0.005454154\ D^2$

D = Diameter at piece's center

$$= \frac{\text{Diameter of piece's large end + diameter of piece's small end}}{2}$$

L = Length of piece (in feet)

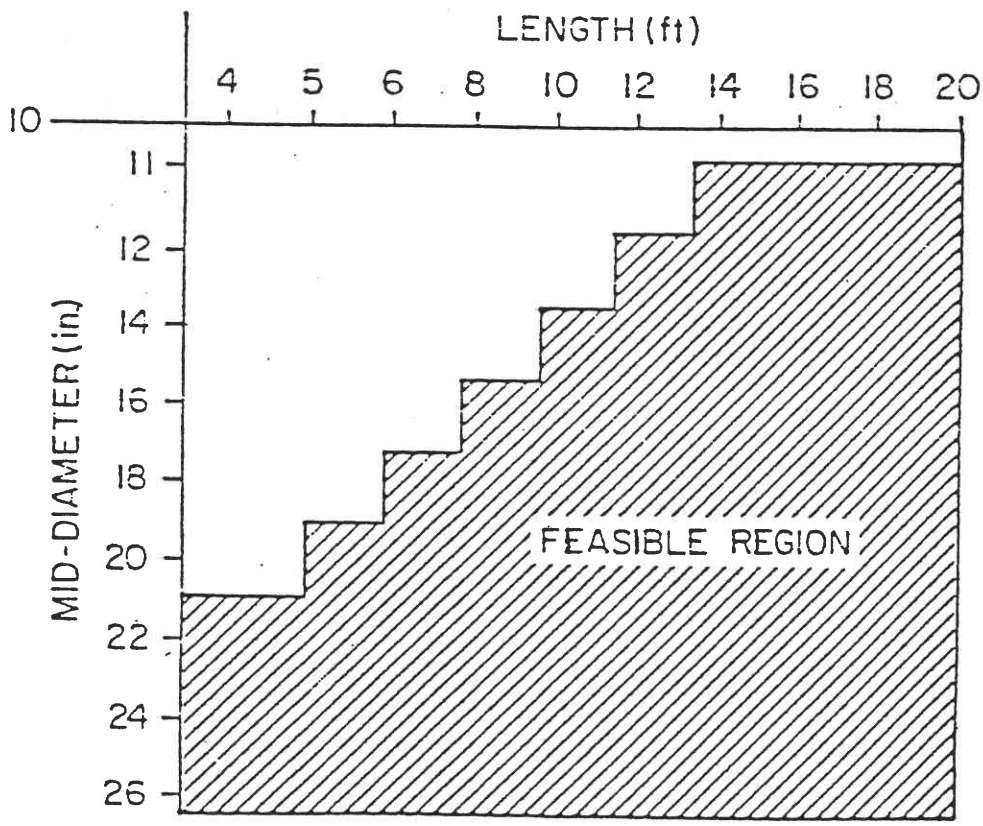


Figure 4.--Matrix of mid-diameters and lengths for residue pieces of at least 9.0 cubic feet. Piece is 9.0 cubic feet or larger if its mid-diameter and length fall on or below the stairstep line.

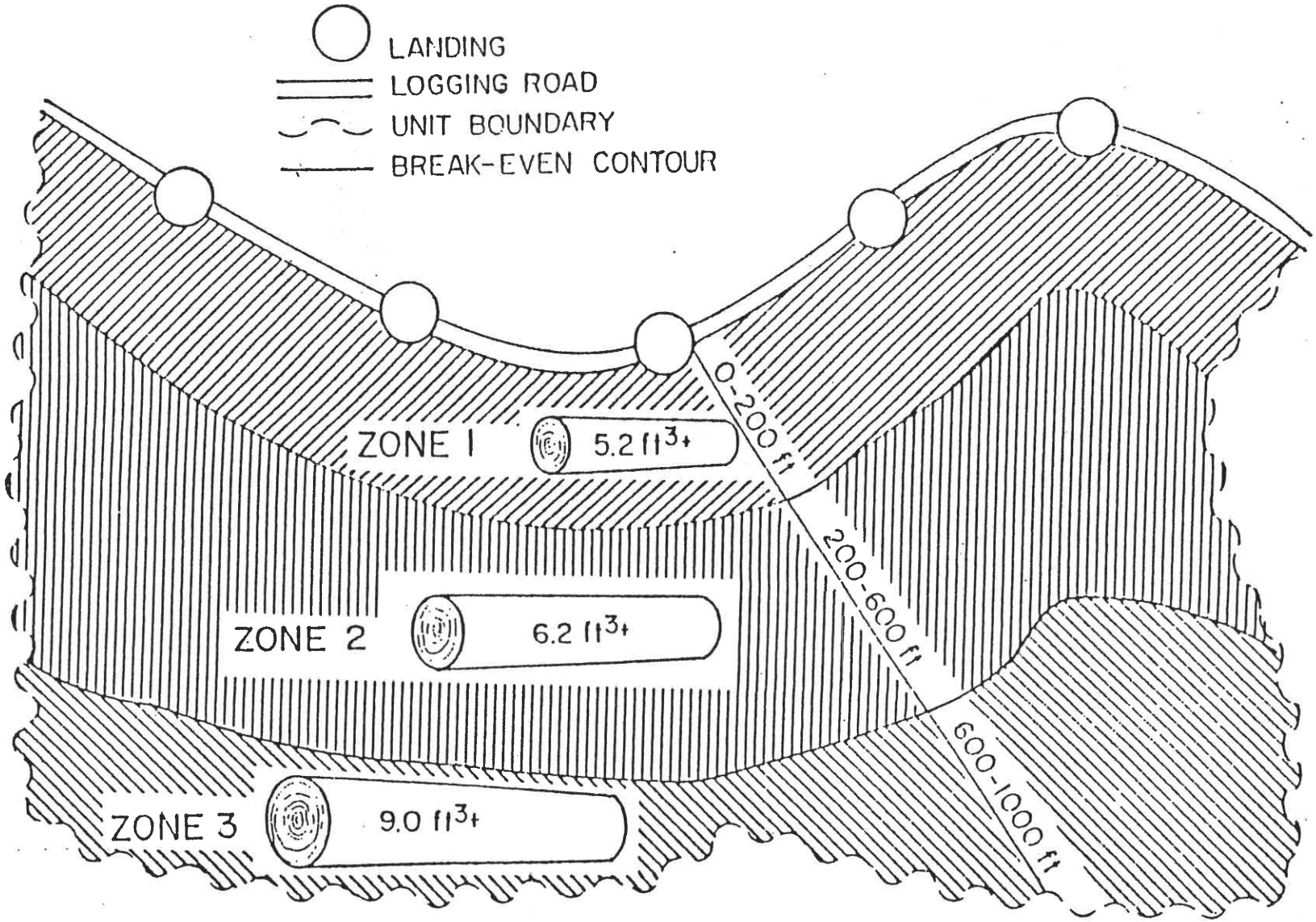
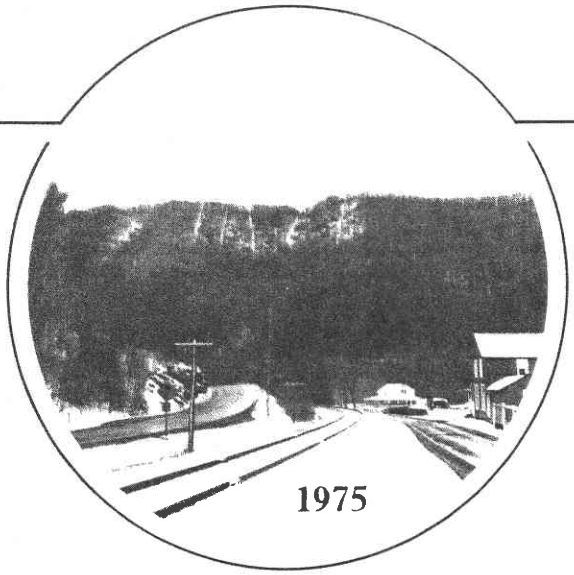
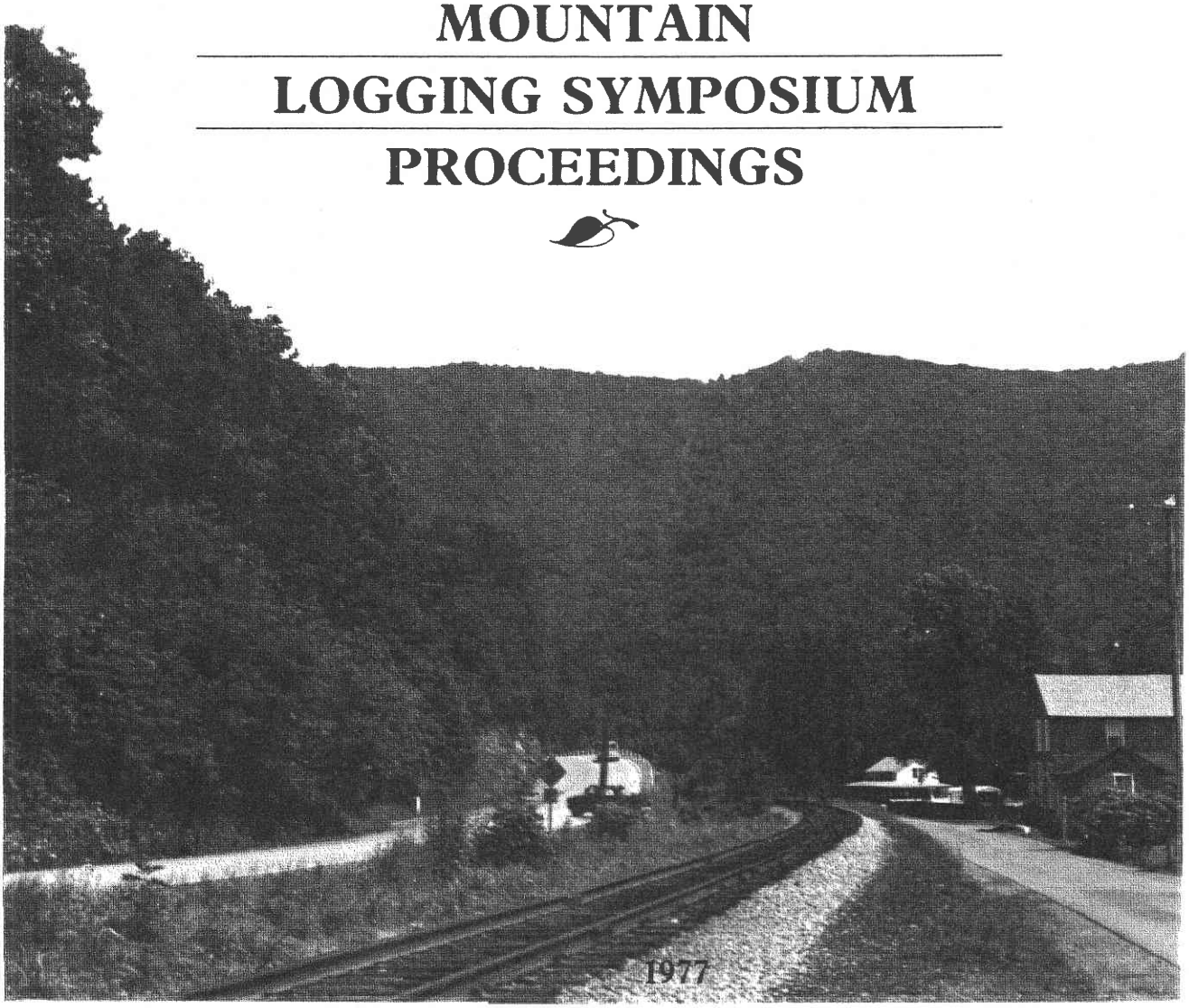


Figure 5.--Simulated contours of break-even residue removal zones for a typical skyline logging unit. Skyline corridor is 200 feet wide. In Zone 1, operator could break even removing residue pieces 5.2 cubic feet; in Zone 2, 6.2 cubic feet; and in Zone 3, 9.0 cubic feet.



MOUNTAIN LOGGING SYMPOSIUM PROCEEDINGS



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