# Production rates and costs of cable yarding wood residue from clearcut units

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### Abstract

Wood residue is a little used source of fiber, chips, and fuel because harvest costs are largely unknown. This study calculates incremental production rates and costs for yarding and loading logging residue in clearcut old-growth Douglas-fir/western hemlock forests. Harvest operations were observed for two timber sales in western Oregon. Three different cable yarding machines were used in various configurations: highlead, shotgun skyline ("Flyer"), running skyline, and skyline with haulback.

Regression equations were developed for productive yarding time as a function of slope yarding distance, number of merchantable logs per turn, number of residue pieces per turn, merchantable volume per turn, and residue volume per turn. The average yarding production rate for turns containing both merchantable logs and residue pieces was 1,832 ft.$^3$/hr. at a cost of \$0.18/ft.$^3$. Results show that residue is most efficiently yarded and approximates costs of merchantable logs when a turn contains one to three residue pieces totaling at least 15 to 20 cubic feet.

Clearcut logging of old-growth Douglas-fir/western hemlock forests creates significant quantities of wood residue (3, 4, 5, 6, 8, 10). In this study, "residue" is defined as wood pieces below minimum size and soundness specifications for lumber, veneer, pulpwood chips, or other products, and is generated by regular logging operations. These residues form a renewable resource representing a potential source of valuable byproducts: chips for pulp and fuel for heating. In many forest areas they are little used because prospective supplies are not dependable over the long term, and transportation costs are largely unknown.

A 1976 logging study conducted on the Wind River Experimental Forest, Gifford Pinchot National Forest, found highlead residue yarding costs in old-growth Douglas-fir/hemlock forests to average \$14.50/ovendry ton, but incremental yarding costs per acre were as high as \$97.90 ovendry ton (1). Another study (9) estimates 1978 residue logging costs ranging from \$23 to \$51 per ovendry ton, depending on piece size and hauling distance. An administrative study conducted in 1979 on the Twin Timber sales, Willamette National Forest, estimated logging costs for residue ranging from \$37 to \$44 per ovendry ton (11).

The studies reported above used different techniques to develop cost and production rates. This report summarizes results of more comprehensive, detailed time studies used to calculate incremental production rates and costs per volume for yarding residue from clearcut old-growth stands. The results can be used to plan guidelines for efficient residue removal.

## Logging sites

Two timber sales were chosen for study sites with typical old-growth Douglas-fir/western hemlock stands. The Joule timber sale was 51 acres located on the Lowell Ranger District of the Willamette National Forest. This sale consisted of approximately 5.8 million board feet of timber (966,666 ft.$^3$ at 6 board feet per cubic foot) in one single and two side-by-side clearcut units. The Blackeye timber sale was 116 acres located on the Clackamas Ranger District of the Mount Hood National Forest. This sale consisted of approximately 6.7 million board feet of timber (1,116,666 ft.$^3$) in four clearcut units.

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All units were clearcut and yarded separately to uphill landings on and below the roadbed. Existing roads were used for access and required only a small amount of grading and widening. Logging took place during the summer and fall months. An average of 12,499 ft.$^3$/acre of merchantable log volume and 1,764 ft.$^3$/acre of residue material was removed. The average volume of each merchantable log and residue piece was 78.27 ft.$^3$ and 8.23 ft.$^3$, respectively.

## Logging equipment and crews

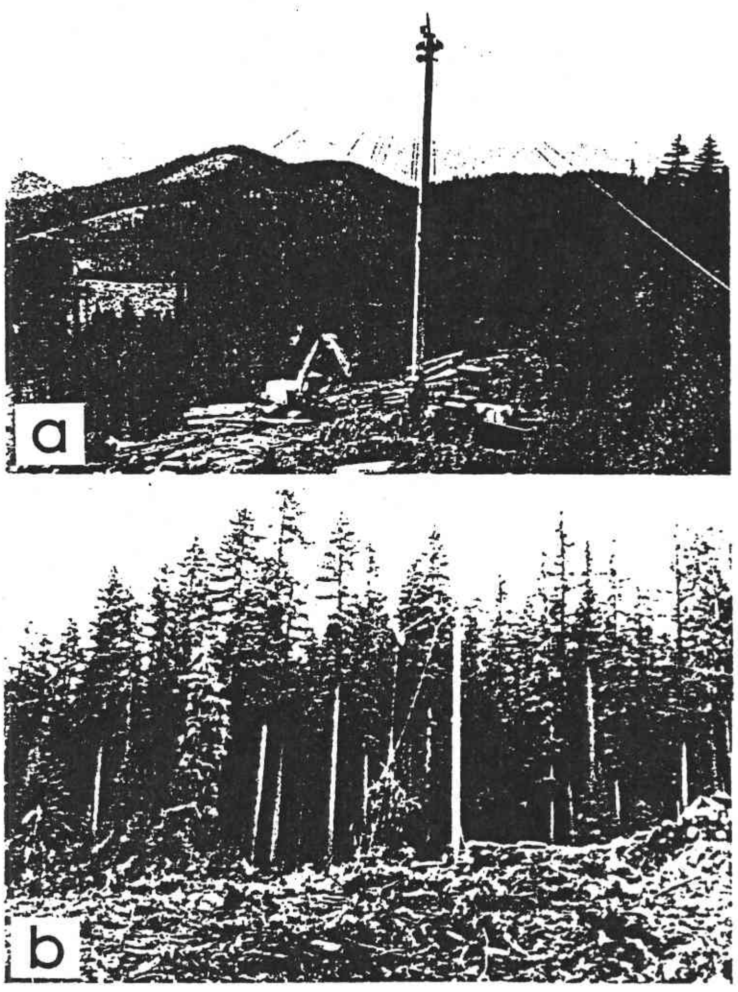
Three separate yarder, crew, and rigging configurations were studied. Calculations included the time and cost of the loader machine and operator. Proficient contractors logged each sale.

The Joule timber sale was logged by McDougal Brothers using a Skagit BU-94 trailer-mounted yarder with a 100-foot tower (Fig. 1a). Production rates were taken when the Skagit BU-94 was rigged in a conventional highlead setup and also in a shotgun (Flyer) configuration with a Danebo Mini-G carriage. Operations were performed by a crew of eight people: one yarder engineer, one loader operator, two chasers, one rigging slinger, two chokersetters, and one hooktender. An FMC Link-belt 5600 hydraulic log-loader mounted on a crawler-tractor base decked the logs, loaded trucks, and kept the landing free of debris.

The Blackeye timber sale was logged by Graves Logging Company using two separate yarding systems rigged differently. One system used a large Washington 208E self-propelled yarder with a 110-foot tower rigged in a slack skyline configuration and equipped with a Young-Stannes radio-controlled slack-pulling carriage (Fig. 1b). The other yarding system used a Thunderbird TMY-45 yarder mounted on a crawler-tractor base with a 45-foot tower (Fig. 1c) rigged in a running skyline configuration and equipped with a mechanical slack-pulling Danebo MSP carriage. Both yarding systems used a crew of nine people: one yarder engineer, one loader operator, two chasers, one rigging slinger, three chokersetters, and one hooktender. Also used was a Lorain 60-C hydraulic log-loader mounted on a crawler-type base.

## Yarding production rates

Table 1 summarizes cycle production data for the three yarders operated during the 3-month time study. This data was recorded by one person located at the landing or at the hooking point, depending on the visi-



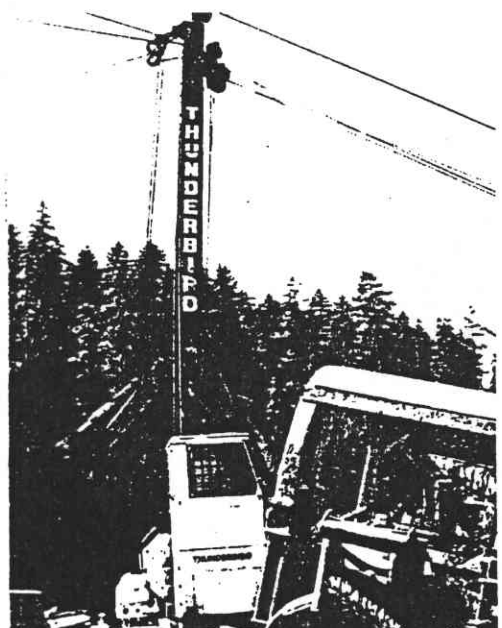




Figure 1. — a) Skagit BU-94 trailer-mounted yarder with a 100-foot tower; b) Washington 208-E self-propelled yarder with a 110-foot tower; c) Thunderbird crawler tractor base yarder with a 45-foot tower.

TABLE 1. — *Average cycle time statistics and hourly production rates for three yarders.*[a]

| Yarder | Cycle statistics[b] | | Hourly production rate[c] | Sample size[d] |
|---|---|---|---|---|
| Skagit BU 94 Shotgun | Mean | 5.16 | 1,683.59 | 904 |
| | Max. | 16.40 | | |
| | Min. | 1.21 | | |
| | St. dev. | 1.73 | | |
| Skagit BU 94 Highlead | Mean | 4.92 | 2,028.91 | 224 |
| | Max. | 12.20 | | |
| | Min. | 2.10 | | |
| | St. dev. | 1.46 | | |
| Washington 208E | Mean | 6.17 | 1,811.65 | 891 |
| | Max. | 18.40 | | |
| | Min. | 1.50 | | |
| | St. dev. | 2.99 | | |
| Thunderbird TMY-45 | Mean | 10.46 | 1,803.86 | 223 |
| | Max. | 19.10 | | |
| | Min. | 3.60 | | |
| | St. dev. | 2.97 | | |

[a]Production rates and costs of logging residue study, Willamette and Mount Hood National Forests.
[b]Time in minutes, delay free.
[c]Cubic feet per hour, delay free.
[d]Number of yarding cycles observed.

bility of the turns being hooked and yarded. Total cycle time in minutes was recorded for each turn. The merchantable and residue logs yarded during the study were scaled at the landing or at the hooking point on a turn-by-turn basis. Residue and merchantable logs were yarded in mixed turns regularly. Other turn attributes, such as slope yarding distance, were similarly recorded. Table 2 summarizes the merchantable log and residue piece size distributions. On the Blackeye timber sale, there were generally more residue pieces per acre, but the average piece size was smaller than on the Joule sale. Figure 2 summarizes the yarding delays observed during the time-study operation as a percentage of total observed time.

Regression analysis was performed on the time-study data of each yarder to develop prediction equations for estimating cycle time, excluding delays. A forward stepwise regression procedure was used to examine the effect of several variables on yarding cycle time. Variables were selected similar to those found useful in predicting production rates in most cable logging time studies (2): slope yarding distance, number of merchantable logs, volume of merchantable logs, number of residue pieces, and volume of residue pieces. Table 3 summarizes the statistical regression analysis

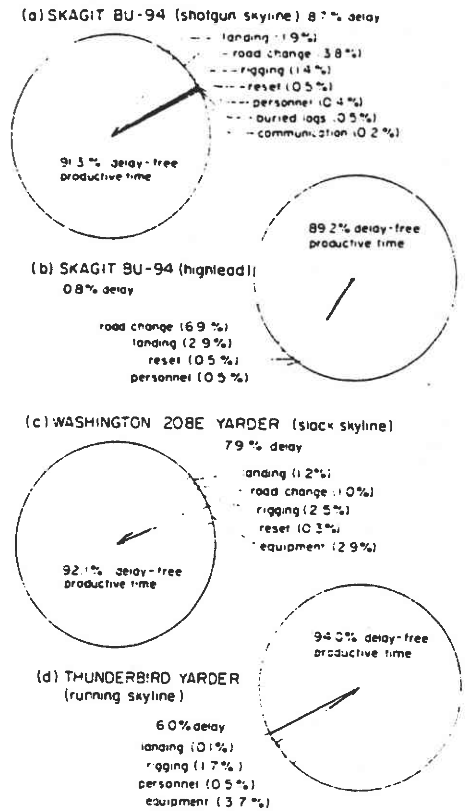



Figure 2. — Delay types and percentages of total observed time for differently rigged yarders: a) Skagit BU-94 rigged in shotgun skyline; b) Skagit BU-94 rigged in highlead; c) Washington 208-E yarder rigged in slack skyline; d) Thunderbird yarder rigged in running skyline.

of the yarding production cycle for each of the three yarders observed. The regression equations were chosen by comparing $R^2$ values (Table 1) and levels of significance of the variables.

## Residue yarding costs

The yarding costs for each system listed in Table 4 are based on the total hours worked and the purchase of all new equipment. The costs do not include an allowance for profit and risk. The study results of the BU-94 yarder in a shotgun configuration will be used in the following examples to illustrate the incremental effect of each variable upon merchantable and residue yarding costs. Similar analysis could be conducted for each of the other yarders with similar conclusions.

TABLE 2. — *Merchantable log and residue piece size distributions, units in cubic feet.*

| Timber sale | Average | Maximum | Minimum | Standard error of mean | No. of sample |
|---|---|---|---|---|---|
| Joule | | | | | |
| Merchantable log | 93.30 | 498.24 | 2.55 | 3.76 | 536 |
| Residue piece | 5.06 | 257.03 | 0.14 | 0.32 | 1,595 |
| Blackeye | | | | | |
| Merchantable log | 63.25 | 354.66 | 2.78 | 1.98 | 855 |
| Residue piece | 11.41 | 267.17 | 0.27 | 0.86 | 580 |

TABLE 3. — *Prediction equations obtained by regression analysis, excluding delays (estimates of time in minutes), for three yarders.*[a]

| Yarder | Equations | $R^2$ | N[g] |
|---|---|---|---|
| Skagit BU-94 Shotgun | $Y = 2.74983 + 0.00177 (X_1)^b + 0.12664 (X_2)^c + 0.00317 (X_3)^d + 0.20023 (X_4)^e + 0.00930 (X_5)^f$ | 16.4 | 904 |
| Skagit BU-94 Highlead | $Y = 3.08365 + 0.00197 (X_1) + 0.16855 (X_2) + 0.00300 (X_3) + 0.12621 (X_4) + 0.00530 (X_5)$ | 18.9 | 224 |
| Washington 208E | $Y = 3.77856 + 0.00290 (X_1) - 0.11982 (X_2) + 0.00265 (X_3) + 0.48923 (X_4) - 0.00272 (X_5)$ | 58.6 | 891 |
| Thunderbird TMY-45 | $Y = 1.92641 + 0.00423 (X_1) + 0.18713 (X_2) + 0.00674 (X_3) + 0.22898 (X_4) + 0.00482 (X_5)$ | 32.4 | 223 |

[a]All partial regression coefficients significant at 5% level.
[b]$X_1$ = slope yarding distance in feet.
[c]$X_2$ = number of merchantable logs, integer.
[d]$X_3$ = volume of merchantable logs, ft.$^3$.
[e]$X_4$ = number of residue logs, integer.
[f]$X_5$ = volume of residue logs, ft.$^3$.
[g]Number of yarding cycles.

TABLE 4. — *Hourly yarding costs*[a] *for three yarding system combinations.*

| Yarding system | Yarder[b] | Labor[c] | Chain-saws[d] | Carriage[e] | Radio signal[e] | Loader[b] | Total hourly cost |
|---|---|---|---|---|---|---|---|
| | ($) | | | | | | |
| Washington 208E | 140.58 | 141.11 | 2.21 | 10.80 | 0.87 | 61.78 | 357.35 |
| Thunderbird TMY-45 | 54.25 | 141.11 | 2.21 | 0.88 | 0.87 | 69.13 | 268.45 |
| Skagit BU-94 | 112.24 | 126.85 | 2.21 | 0.45[f] | 0.87 | 59.46 | 302.08 |

[a]Hourly costs reflect all new equipment; equipment costs were obtained from equipment dealers.
[b]Includes depreciation, insurance, interest, operating costs (fuel, oil lubricants, maintenance, repair, and taxes) and rigging.
[c]Labor rates were obtained from the cost guide for empirical appraisals, USDA Forest Service, Pacific Northwest Region 6, Revision 10.
[d]Hourly costs for three chainsaws.
[e]Includes radio signal with three transmitters.
[f]The carriage used on the Skagit BU-94 appeared to be homemade; it resembled a Danebo Mini-G and was so appraised.

Data from regression analysis and hourly yarding costs (Tables 3 and 4) were integrated within a computer program. The output was used to develop Figure 3, which shows the incremental effect and sensitivity of each respective variable in the regression equation upon cost per volume produced. The variable of interest was allowed to change value while all other variables within the equation were held constant at their observed mean values. It is important to note that merchantable logs and residue pieces were yarded simultaneously in most turns; thus, the results in Figure 3 reflect hourly production rates and costs for yarding a given quantity of wood, but of varying quality.

Figure 3(a) suggests that as slope yarding distance increases, cost per volume produced rises. For example, a logging analyst contemplating hooking merchantable logs and residue pieces at the average number and volume could expect a cost of \$0.1604/ft.$^3$ with a slope yarding distance of 200 feet. However, a longer distance of 300 feet would increase cost by 3.8 percent to \$0.1665/ft.$^3$. Similarly, going from 900 feet, at a cost of \$0.2034/ft.$^3$, to 1,000 feet would increase cost by 3.0 percent to \$0.2095/ft.$^3$.

Figure 3(b, c) also shows the effect of varying the number of merchantable logs or residue pieces yarded per turn while the other variables are at their mean values. If the analyst is considering yarding two merchantable logs per turn, the cost would be \$0.1822/ft.$^3$; if three were yarded, the cost would increase by 2.4 percent to \$0.1866/ft.$^3$. If the crew yarded five pieces of

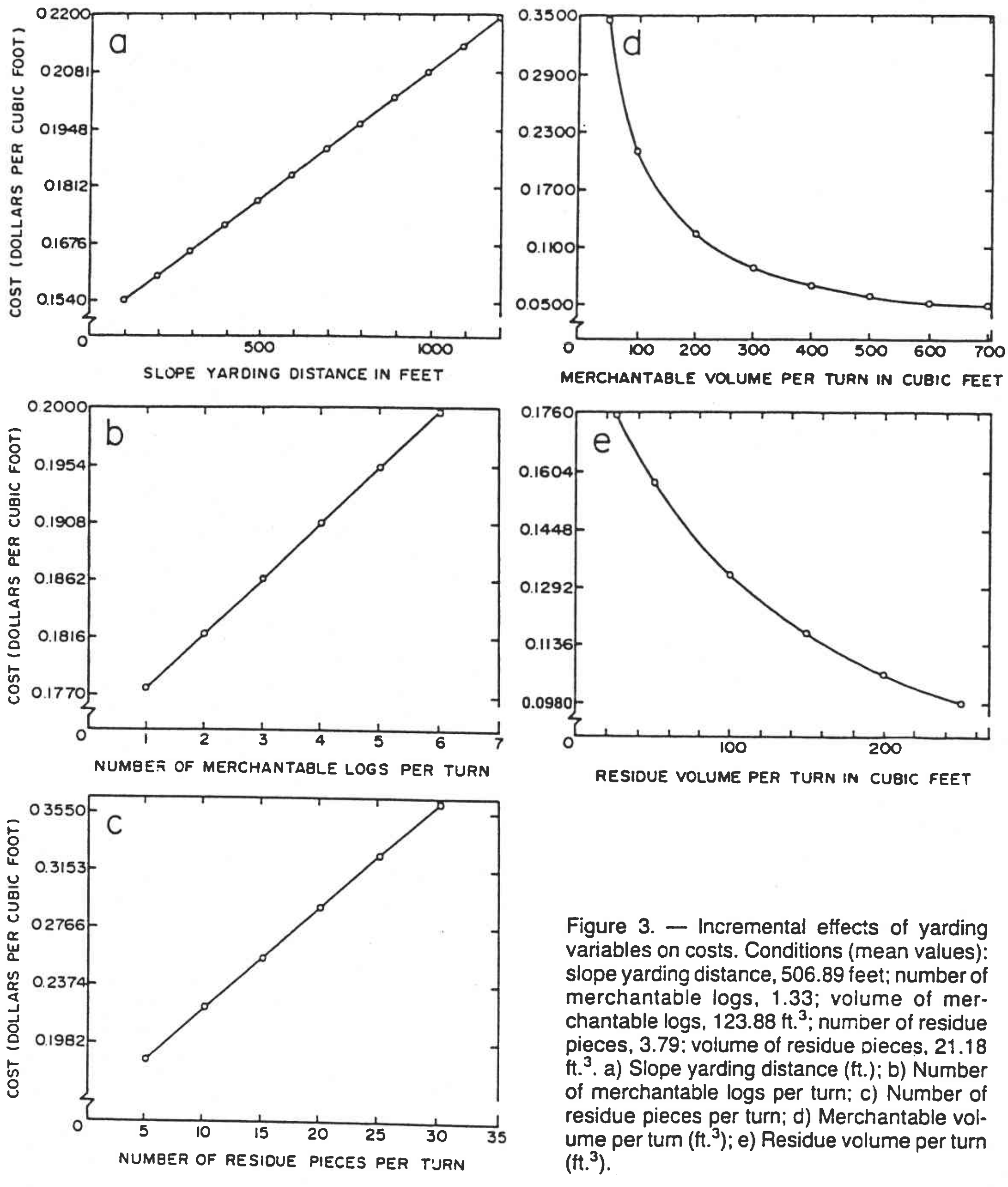



Figure 3. — Incremental effects of yarding variables on costs. Conditions (mean values): slope yarding distance, 506.89 feet; number of merchantable logs, 1.33; volume of merchantable logs, 123.88 ft.$^3$; number of residue pieces, 3.79; volume of residue pieces, 21.18 ft.$^3$. a) Slope yarding distance (ft.); b) Number of merchantable logs per turn; c) Number of residue pieces per turn; d) Merchantable volume per turn (ft.$^3$); e) Residue volume per turn (ft.$^3$).

residue per turn, the cost would be \$0.1876/ft.$^3$; with ten pieces of residue, the cost would increase by 18.6 percent to \$0.2224/ft.$^3$. The relationship illustrated is the result of holding turn volume constant and increasing the number of pieces to make up that volume.

The incremental costs associated with yarding various volumes per turn of merchantable logs or residue pieces are graphed in Figure 3(d, e). The cost to remove merchantable logs in turns of 50 cubic feet would be \$0.3487/ft.$^3$; logs in turns of 200 cubic feet would decrease cost by 64.7 percent to \$0.1230/ft.$^3$. For 25 cubic feet of residue volume per turn, the cost would be \$0.1758/ft.$^3$; while 50 cubic feet would decrease cost by 10.5 percent to \$0.1573/ft.$^3$. Going from a residue turn volume of 100 to 150 cubic feet would decrease cost by 11.7 percent.

In order to determine the marginal cost of yarding residue pieces, additional analysis was conducted. Again, a computer program was written to integrate the cycle time and costs with the results from Figure 3. The output is graphed in Figure 4, which illustrates the marginal costs of yarding residue pieces of different sizes with mean values of merchantable volume and log number. It suggests that cost per residue volume produced increases substantially as piece size gets smaller. Remember that both merchantable logs and residue

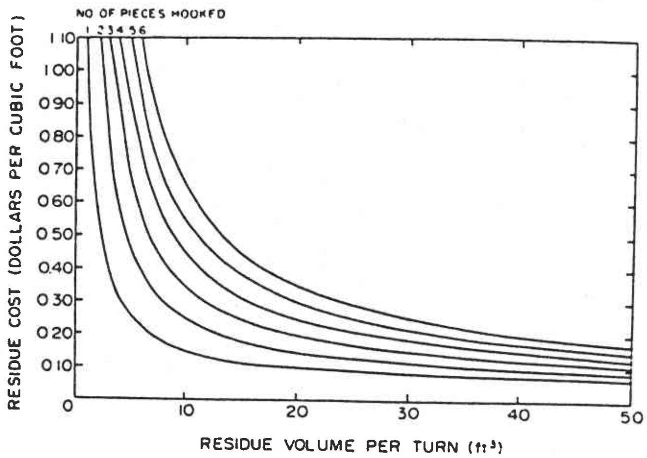



Figure 4. — Marginal yarding costs of residue portion of turn volume. (Skagit BU-94 (shotgun) on Joule sale). Conditions (mean values): slope yarding distance, 100 feet; number of merchantable logs, 1.33; volume of merchantable logs, 123.88 ft.$^3$; number of residue pieces, 1 to 6.

pieces were yarded simultaneously in each turn, so that results will change if other than mean values are used as constants.

Figure 4 also shows the effect on marginal cost of adding a certain number of residue pieces to generate a specified turn volume. For example, hooking one piece of residue of 10 cubic feet results in a cost of about \$0.14/ft.$^3$; however, if six pieces of residue were hooked to total 10 cubic feet, the cost would increase 471 percent to \$0.66/ft.$^3$. The graph indicates that residue is most efficiently yarded and approximates cost of merchantable logs when a turn contains one to three residue pieces totaling at least 15 to 20 cubic feet.

## Discussion

Besides the prospect of increased revenue from the sale of selectively yarded residue, there are other incentives to remove residue: reduction of fuel loadings on the site, facilitation of planting, reduction of slash burning thus reducing the smoke management problem, removal of habitat for forest insect pests and diseases, and visual management improvements. However, it is beyond the scope of this report to fully deal with the silvicultural concerns. Supplemental research could investigate residue utilization standards in a systems theory approach.

This study includes data from yarders that span presently available large and medium size classes and several rigging configurations. The yarding sites and variables used to develop the production data cover the range of situations normally encountered in logging. The prediction equations (Table 3) can be used to develop reliable estimates of production rates. The results can also be used in simulation programs or other cable logging models. There is additional research in progress developing guidelines for efficient residue removal and turn size building. By being able to estimate the effect upon production rates and costs of yarding residue, it is expected that more economical decisions will be made in future logging operations. Perhaps this wood will become more available for fiber, chips, or fuel.

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