The Contribution of an Increase in Log Size as a Result of Forest Fertilization to the Value of Standing Timber

by

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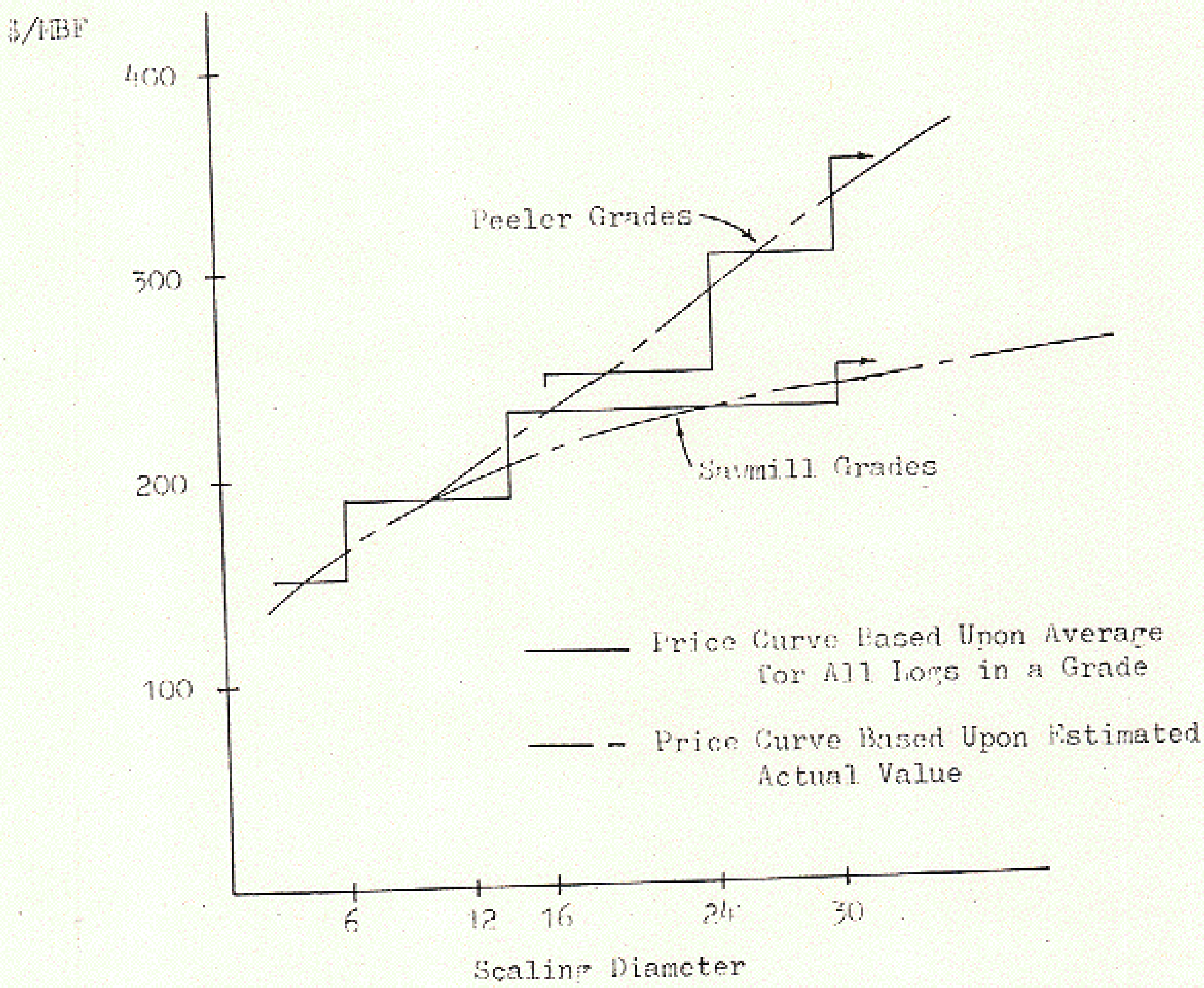
CHAPTER 1. BACKGROUND AND INTRODUCTION

An increase in log size has long been recognized as contributing to the value of standing timber. Past studies have indirectly considered this through a higher stumpage rate. A literature search, however, revealed no studies which directly quantified the contribution of an increase in log size, as a result of fertilizing Douglas-fir, to the value of timber.

Other factors remaining equal, as log size increases product recovery per unit increases and production costs per unit decline. Fahey (1974) and Dobie, Casper, and Wright (1973) state that the overall trend is for product recovery value to increase with log size. This is due to an increase in product recovery and product recovery grade. Mill production costs per unit decline because the capacity of the machinery is fixed, and therefore insensitive to small changes in log size.

Increasing recovery values and declining production costs per unit result in higher mill prices for logs as they increase in size. This is particularly true for small logs where recovery values and production rates are inherently lower. Figure 1 illustrates the increase in mill price with an increase in log size. A positive relationship between mill price and log size is evident. In addition, for peeler and sawlog size logs (which are suitable for peeling), the increase in price occurs over a larger diameter range than for logs that are not suitable for peeling.

Figure 1: Change in Mill Price with an Increase in Log Size.



Based upon data from the State of Washington Department of Natural Resources, Monthly Invoice of Log Prices, January, 1980.

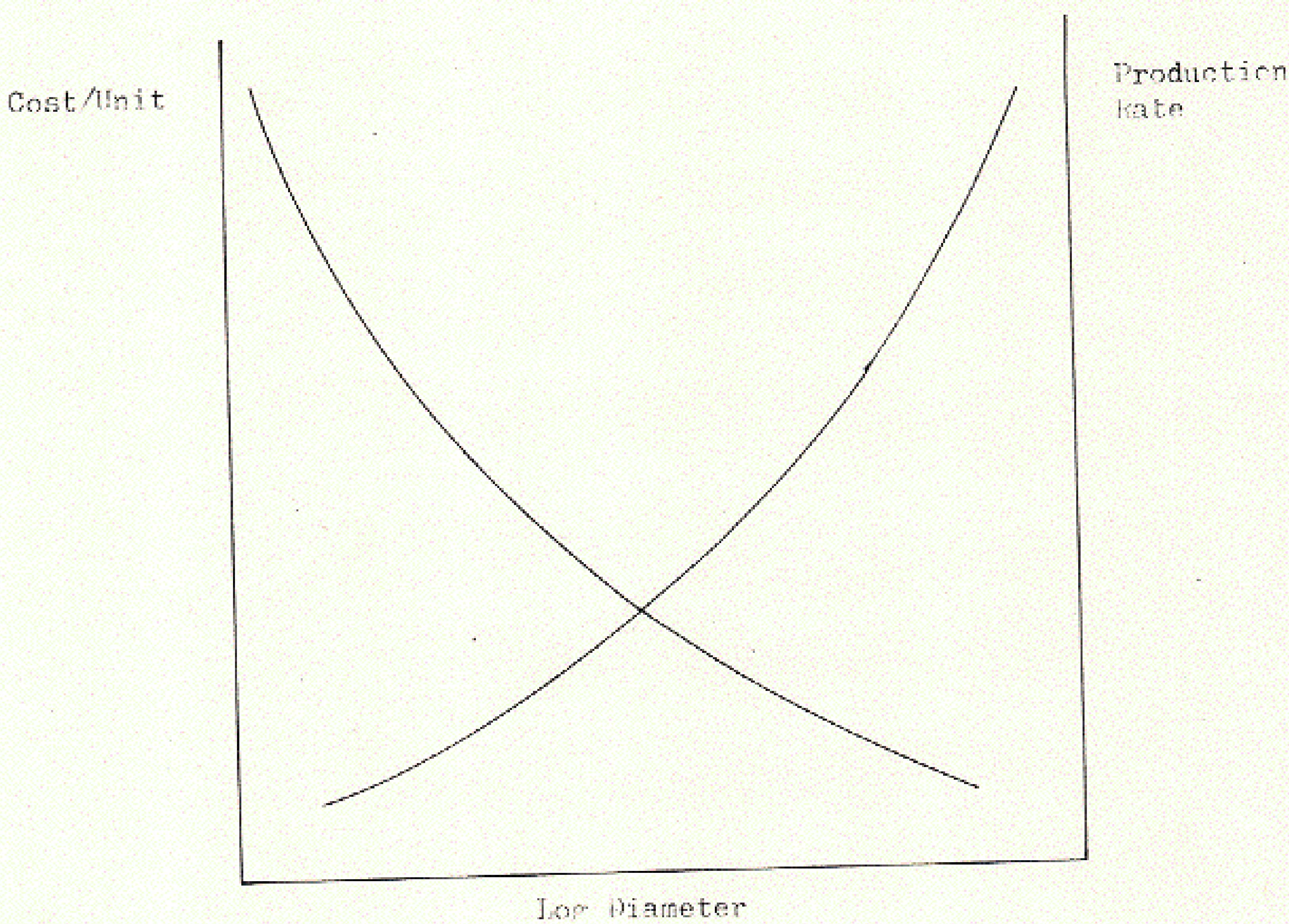
To the timber owner, the increase in mill price is only one side of the coin. Harvesting costs are of equal importance. Branstrom (1933) observed that the most significant variable affecting production rates and yarding costs per unit is log size (Figure 2). Numerous researchers have arrived at the same conclusion. Declining costs per unit are also evident in falling, bucking, loading, and hauling (Conway 1976). Thus, for the timber owner, an increase in log size results in a higher mill price and lower logging costs per unit.

As the previous discussion indicates, log values per unit vary with log size. Due to the wide variation in the size and quality of logs being bought and sold, log grades were developed. The purpose of log grades is to provide an estimation of the quantity and quality of lumber, veneer, and/or usable chips a log will yield. Prior to 1910, lumber was the primary use for commercially harvested Douglas-fir. At this time there were three sawmill grades (Dilworth 1977). Development of the plywood industry brought a further separation of log grades based upon the ability of the logs to produce veneer stock (Dilworth 1977). Currently, the Puget Sound Log Scaling and Grading Bureau classifies Douglas-fir logs into one of eleven grades[1]. In addition, individual log buyers may have their own grade requirements, and separate logs into "sorts" which are not directly correlated to "Bureau" grading standards. This is especially true when selling logs to the Japanese[2].

[1] As specified in the Puget Sound Log Scaling and Grading Handbook, for Douglas-fir there are 4 peeler (veneer) grades, 4 sawmill (lumber) grades, one utility (pulp) grade, and a Special Cull grade. In addition there are 3 fast growth grades.

[2] Jack Wolff. Weyerhaeuser Company. Presentation to Distinguished Visitors Seminar Series. November 5, 1979.

Figure 2: Effect of Log Size on Harvesting Cost per Unit and Production Rates.



Though not addressed directly in this study, it is recognized that timber may be utilized as poles, piles, and a number of other specialty products. The grade specifications and scaling procedures for these products are different than those for saw and peeler grade logs. Poles and piles are scaled by the linear foot, rather than board foot or cunit, and generally have stricter grade requirements.

Assessing defect for grade determination, whether for poles, piles, sawlogs, or peeler logs, is difficult and subjective. Defect affects log value in two ways: 1) grade defect (e.g. excessive knot size) results in "down grading" of a log, and a lower value per unit; and 2) deductable defect (e.g. sweep) reduces the net scale of a log, which also reduces log value.

The extent to which defect affects log grade depends upon how the log will be utilized. Grade requirements are more strict for peeler grade logs used for the production of veneer, than for sawlogs which are cut into lumber. This is due to the fact that there are more strict grade requirements for veneer than for lumber[3]. In addition, reductions in scale are more common in peeler than sawmill grade logs, because for a given defect more volume is generally lost in the manufacturing process of veneer[4].

The rate of growth is receiving increasing attention with regard to log grade. This is of particular importance in this study, due to

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[3]Personal communication with Gordon Holbrook, Log Buyer, Seaboard Lumber Company. Seattle, WA.

[4]Personal communication with Chuck Knapp, Log Grader, Puget Sound Log Grading and Scaling Bureau. Renton, WA.

the fact that accelerated growth is the means to achieve a profitable fertilization program. An increase in the growth rate reduces the number of annual rings per inch and can influence the percent of latewood. Both of these factors have an impact on wood properties. Second growth Douglas-fir peeler and sawlog grades require a minimum of six rings per inch. The highest grade for a log not meeting this requirement is Number 2 Fast Growth. The percent of latewood is not a factor in grading logs. It is considered in some grades of lumber, however, and its importance should not be ignored.

A key point to be emphasized when evaluating the importance of a change in log size to timber value is that differences in final product value are being assessed. Therefore, it is essential to analyze as many factors as possible that can have an affect on the value of the final product. These factors are not static, and can be expected to change as the uses for wood products change.

CHAPTER 2. OBJECTIVE OF STUDY

The general objective of this study is to develop an understanding of the importance of an increase in log size to the value of standing timber. It is hoped that by improving the methods for measuring changes in timber value, better management decisions can be made.

The specific objective of this study is to quantify the contribution of an increase in log size, as a result of fertilization, to the value of standing timber, and to compare this to the contribution from an increase in wood yield.

A marginal approach will be followed which attempts to determine the incremental change in the value of standing timber, in particular that due to an increase in log size. This will be accomplished by analyzing incremental changes in total revenue and cost.

The study can be broken into five phases:

1) Review of the relationship between log size and grade, and product recovery;

2) Review of the relationship between log size and logging costs;

3) Establishment of a price-size gradient through the relationship between mill price and log size;

4) Quantification of the value added from fertilization due to increase in log size, and the value added due to an increase in wood yield;

5) Comparison of the relative importance of: (a) an increase in log size, and (b) an increase in wood yield to the value of standing timber.

CHAPTER 3. LITERATURE REVIEW

3.1 Product Recovery and Log Size

Numerous recovery studies have developed a relationship between the scaling diameter of a log and its product recovery. Dobie, Kasper, and Wright (1975) found that Douglas-fir lumber recovery increased as the scaling diameter increased. In addition, a higher grade of lumber was recovered. Fahey and Martin (1974) found results similar to Dobie, Kasper, and Wright. Figure 3 illustrates the relationship between log diameter and the percent of lumber recovered for logs of all grades. As expected, the percent of lumber recovered increased as the log diameter increased.

Figure 4 illustrates the relationship between log diameter, and the percent of lumber recovered by grade for Number 2, and Number 3 sawlogs. It can be speculated that the higher percent of Select Structural grade lumber recovered from the Number 2 sawlogs was due to fewer defects, particularly large knots[5].

The product recovery value of a log is a function of the volume recovered, its grade, and the value associated with each grade. Fahey (1974) developed a regression equation for the value per MBF, net log scale, for Number 2 and 3 sawlogs (Figure 5). It was noted by Fahey and Hunt (1972), however, that variations in product recovery, and the corresponding value per MFB, is in part a function of sawing techniques, trimming decisions, and the item being produced.

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[5] Personal communication with Chuck Morey, Affiliate Professor of Forest Resources, University of Washington, Seattle, WA.

Figure 3: Relationship Between Log Diameter and Percent Lumber Recovery for Logs of All Grades.

(Fahey and Martin, 1974)

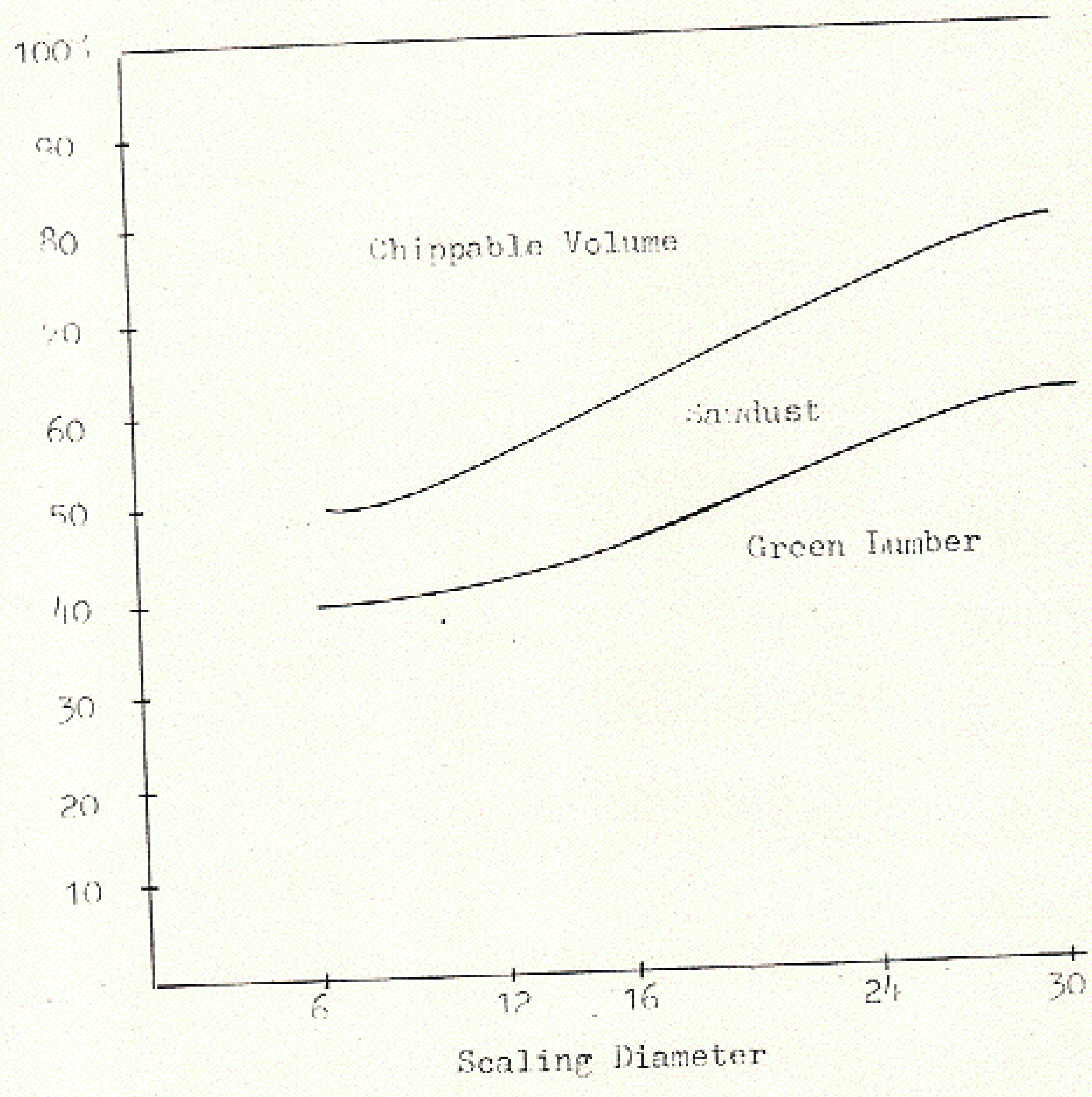


Figure 4: Relationship Between Log Diameter and Percent Lumber Recovery for Number 2 and Number 3 Sawlogs.

(Fahey and Martin, 1974)

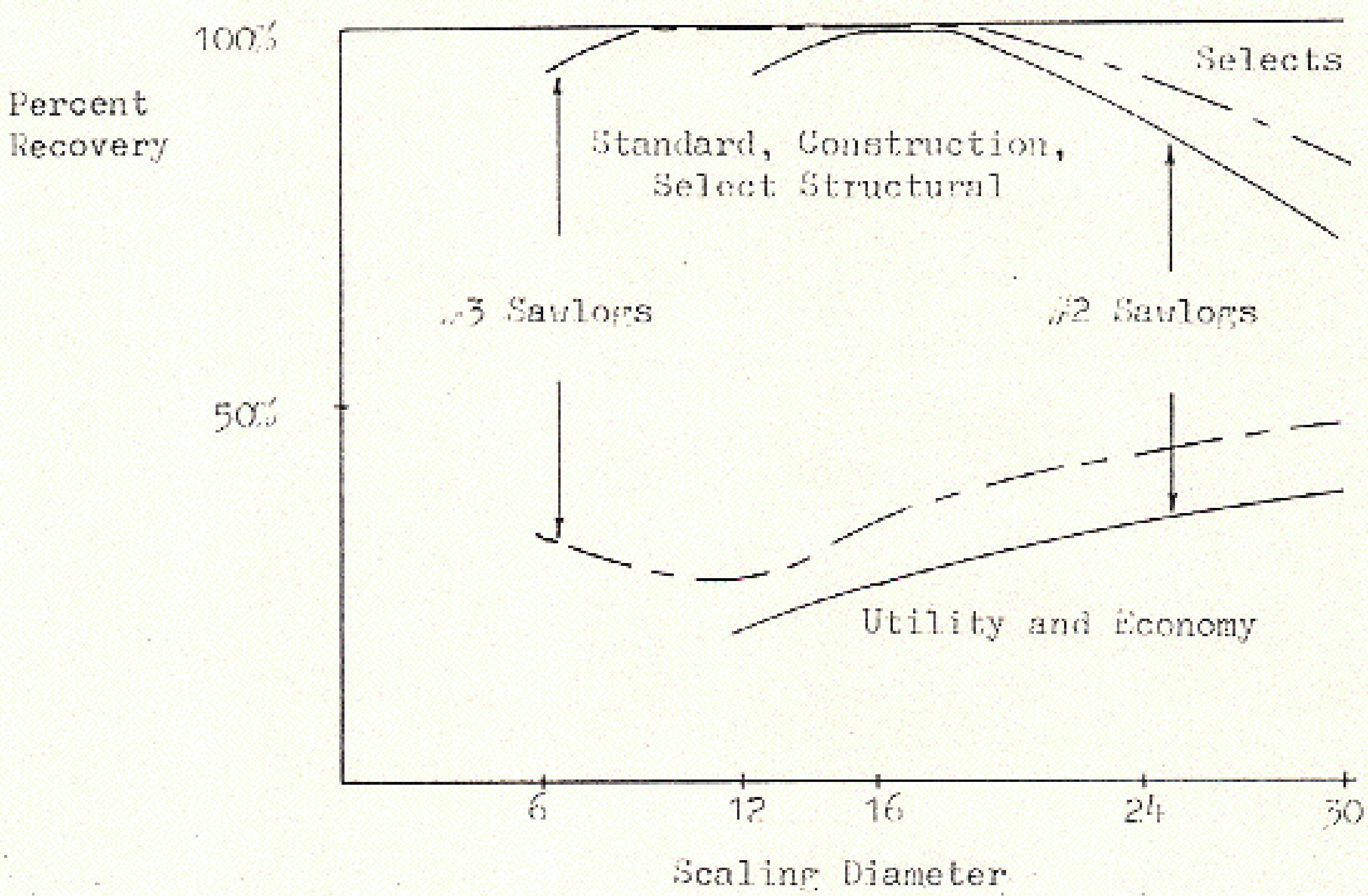
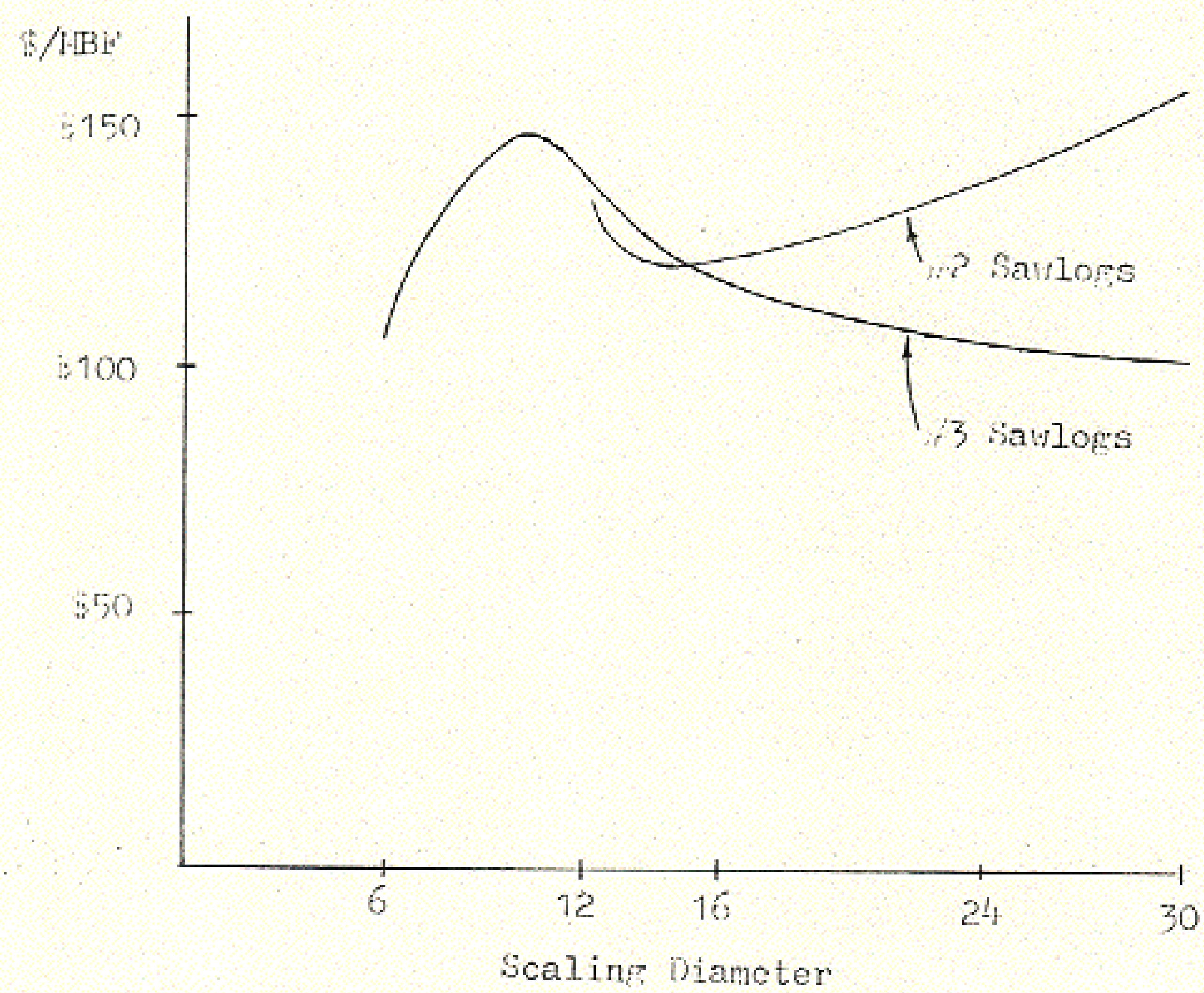


Figure 5: Regression Equation for Value per MBF for Number 2 and Number 3 Sawlogs.

(Fahey and Martin, 1974)



In a study related to Fahey and Martin's lumber recovery studies, Fahey (1974) found that second growth Douglas-fir could be used for the production of veneer, praticularly in structural grades. Veneer recovery in grades D and better, for all log grades combined, increased with diameter until approximately 20 inches, then declined (Figure 6). This contrasts lumber recovery studies in which lumber recovery continued to increase as diameter increased. The decline in veneer recovery is most likely a result of the high level of defect characteristically found in the larger diameter classes of Number 3 sawlogs.

The relationship between log grade, scaling diameter, and veneer recovery in grades A through C is shown in Figure 7. Special Mill and Number 2 sawlogs produced a constant percent of veneer (of the total product recovered), regardless of diameter. The percent of veneer recovered decreased with diameter for Number 3 sawlogs. As stated earlier, this is probably due to the high level of defect found in large diameter Number 3 sawlogs.

In summary, for the scaling diameters commonly associated with second growth Douglas-fir, product recovery and product recovery value increases with diameter for both lumber and veneer. In addition, product recovery value increases with log grade. The data for which these studies were based, however, included few logs less than 10 inches in diameter. Therefore, it is difficult to determine the effects of an increase in log size on product recovery for logs less than 10 inches in diameter.

Figure 6: Relationship Between Log Diameter and Veneer Recovery for All Log Grades.

(Fahey, 1974)

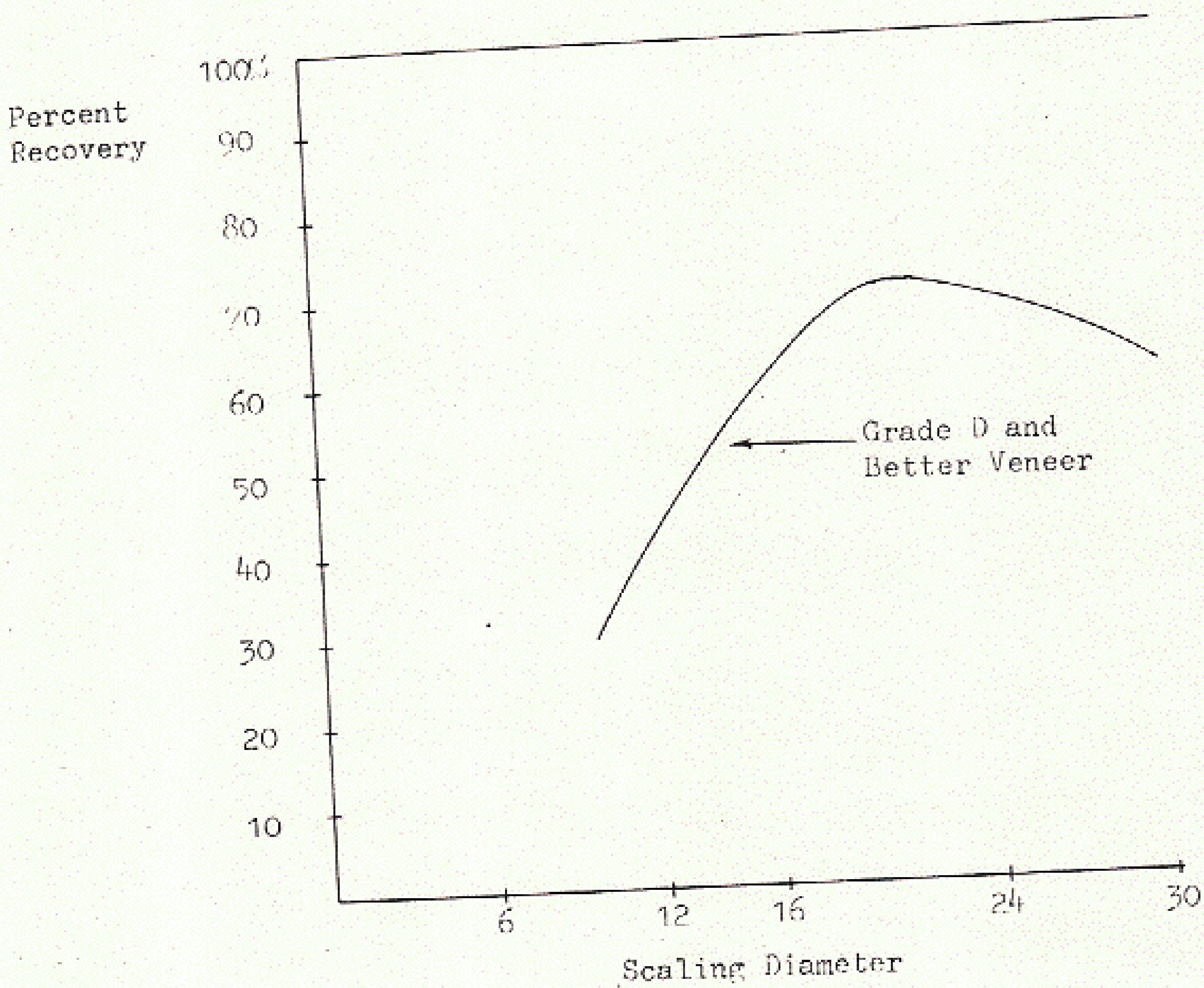
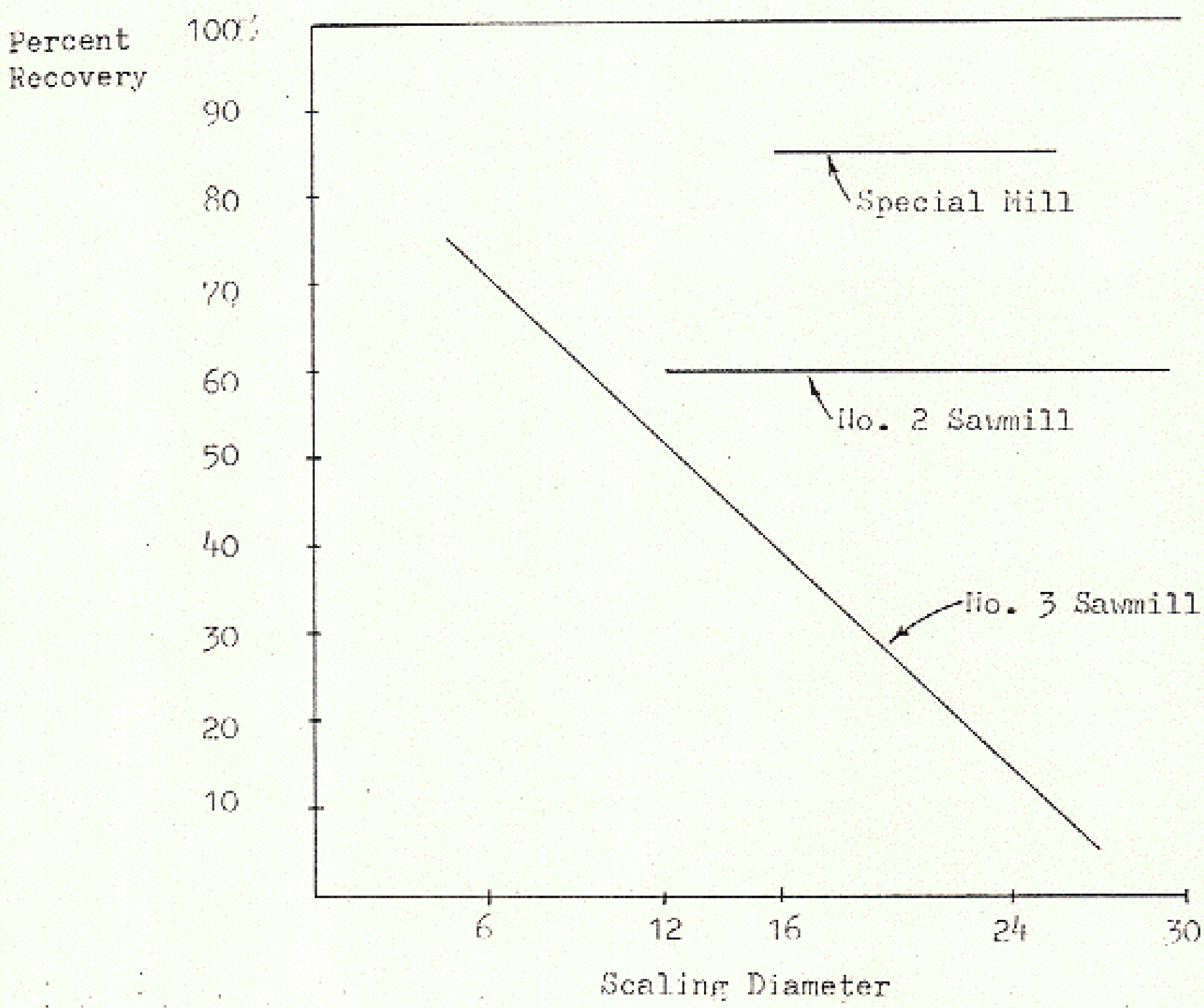


Figure 7: Relationship Between Log Grade, Log Diameter, and Veneer Recovery in Grades A through C.

(Fahey, 1974)



3.2 Effects of Accelerated Growth on Wood Properties

The effect of accelerated growth on wood properties is as potentially important to the value added from fertilization as an increase in wood yield. Fiber structure and chemical make-up are among the most important determinates of "end-use" wood properties such as wood strength, machinability, attractiveness, and paper quality.

Changes in the individual fiber structure have a direct effect on wood specific gravity, an important determinate of wood strength and pulp yield and quality. Studies by McGraw and Nearn (1972) found that with Douglas-fir, accelerated growth as a result of nitrogen fertilization seemed to prolong the production of lower density juvenile wood. They also found significant changes in the within ring wood density; the density of the spring wood increased, while the density of the summer wood decreased. Siddiqui, Gradstone, and Morton (1972) found that accelerated growth resulted in a decrease in specific gravity, a small decrease in the percent latewood, and an increase in the pulp yield per unit weight of wood. Gooding and Smith (1972) found that accelerated growth in Slash pine reduced the specific gravity of wood, although the changes were not significant.

As stated earlier, specific gravity is an important determinate of wood strength. Generally, the greater the specific gravity of the wood fiber, the greater the strength. A method to estimate specific gravity is by ring width and percent of latewood (Western Wood Products Association, 1974). Koch (1972) stated that the percent of latewood and the number of rings per inch are important factors in determining the strength of Southern pine when used for poles, piles, timbers, lumber, plywood, and laminated wood. These factors are of critical importance when there are fewer than three rings per inch and the percent of latewood is less than 50%. Koch further stated that "fast growth" Southern pine has the following characteristics:

1) Low paint retention and poor glueing ability.

2) Reduced machinability and attractiveness for clear-finished lumber.

3) Inadequate strength if harvested early for small poles or small squared timber.

4) Adequate strength for large members.

5) Good steam bending.

He concluded that growth rate objectives are "debatable in forests managed for solid wood properties." Palka (1972) found that in Douglas-fir, wide rings and a low percent of latewood resulting from accelerated growth are associated with rough veneer, which is more susceptible to breakage. In addition, wide rings also make veneer sheets more difficult to glue[6]. It should be noted that while the relative changes in wood properties due to accelerated growth are basically the same between Douglas-fir and Southern Pine (Echoles 1972), the end results may not be. For example, although accelerated growth of Douglas-fir and Southern Pine may reduce wood strength, Douglas-fir may still have adequate strength for its customary uses. Therefore, the reduced strength resulting from accelerated growth may not be of major importance.

[6]Personal communication with Ramsay Smith, Assistant Professor of Wood Utilization and Technology. University of Washington, Seattle, WA.

The yield for non-solid wood products does not appear to be significantly affected by accelerated growth from fertilization. Koch stated that "manufacturers would find no serious problems in producing particleboard from fast grown Southern pine." Horn et al. (1972), and Siddiqui, Gradstone and Morton (1972), state that pulp yield per unit weight of wood increased as a result of the lower wood density associated with fast growth Douglas-fir[7]. The increased pulp yield per unit weight of wood is most likely a result of the lower lignin content in fast growth wood[8]. In addition, McGraw and Nearn (1972) state that the more "intermediate-density" wood, resulting from increased springwood density and decreased summerwood density, should "contribute favorably to pulp characteristics."

Changes in the chemical make-up of wood as a result of fertilization do not seem to significantly affect solid wood properties. Researchers have found that the amount of lignin decreased and that the amount of holocellulose increases, but the differences are not enough to significantly alter the wood properties of solid wood products.

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[7] Pulp yield per unit volume of wood was found to decline, but it was not considered to be of great importance. This is because operating costs in the pulping process are usually figured per ton, not per unit volume. The yield per unit volume is probably of importance to foresters, however, because volume measurements are frequently the base from which the forester's costs and revenues are determined.

[8] Personal communication with Ramsay Smith, Assistant Professor of Wood Utilization and Technology. University of Washington, Seattle, WA.

Chemical make-up can affect pulp yield[9]. Smith, Wahlgren, and Bengtson (1971) state that fertilization increased the amount of alcohol-benzene extractive (which can reduce pulp yield) in the butt log. However, it was not sufficient enough to affect pulp yield or quality. On the other hand (as stated earlier), an increase in pulp yield per unit weight of wood may result from a lower lignin content. The importance of chemical make-up in determining end use pulp properties should not be overlooked. As Barefoot et al. (1972) reported, "because of the nature of the pulping process, chemical properties might be expected to predominate in yield relationships rather than morphological characteristics."

Branching characteristics can be important when determining product yield and quality in second growth Douglas-fir utilized as veneer. Knots which form from branches result in wood which is hard and brittle. Wood of this type reduces wood strength, machinability, attractiveness and pulp yield. Although fertilization improves the efficiency of the foliage in the crown, no studies were found that suggested branching characteristics were altered. However, in a study by Smith, Wahlgren, and Bengtston (1972) it was concluded that fertilization of Slash pine did not "affect the average number of terminal growth flushes, the average number of branches per whorl, or the average branch diameter."

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[9]Personal communication with Ramsay Smith, Assistant Professor of Wood Utilization and Technology. University of Washington, Seattle, WA.

3.3 Effects of Log Size on Logging Costs

3.3.1. Overview

As stated earlier, when attempting to determine the value gain from fertilization, both changes in mill revenue, and logging costs need to be analyzed. This paper attempts to determine incremental changes in total revenue and cost. Therefore, the change in the cost per work cycle is of greater importance than the cost per unit. For example, the total cost per tree for felling and bucking is of more concern than the cost per MBF, because the marginal approach used in this study requires that charge in total cost, not average unit cost, be assessed.

To understand how log size affects harvesting costs, it is important to analyze how log size affects the individual work elements involved with harvesting. Of particular importance is how a change in log size affects these elements.

3.3.2. Felling and Bucking

When logging in clear cuts, felling and bucking time is dependent upon the conditions at the work site (e.g. brush density), the number of logs per tree (Bureau of Land Management, 1972), as well as many other factors (e.g. tree lean). Felling and bucking time is relatively insensitive to small changes in tree or log diameter. For a small change in diameter (e.g. from 18 to 19 inches in diameter), the relationship between total felling and bucking time, and log size may be thought of as constant.[10] Conway (1976) states "that the time required to fell a 24 inch tree is not much more than that of a 12 inch tree, however, the volume of a 24 inch tree is much greater." Further, Conway states that the tree volume/cost relationships are applicable to mechanical felling. He reported that shears cut through wood at a rate of 3 to 5 inches per second. The larger the tree (up to the maximum size that can be handled), the fewer slices that need to be made per unit of wood.

3.3.3. Yarding

Yarding (or skidding) is the most critical component in most logging systems. Furthermore, it requires the most capital investment. To fully understand yarding it is necessary to separate the work cycle into outhaul, hook, inhaul, and unhook. A conceptual example of the relationship between these cycle elements, and slope distance and log size is shown in Figure 8. Note that hooking and unhooking are fixed with respect to both slope distance and log size, while inhaul and outhaul are variable with respect to slope distance. In addition, inhaul time may vary slightly with log size.

The outhaul involves the transportation of chokers to the log hook site. The variable having the greatest impact on outhaul time is slope distance for cable yarding, and slope distance and terrain for ground skidding. Hooking is the attaching of a log to the mainline or skidder with a choker. Dykstra (1976) found that hook time for a running skyline was influenced by the number of riggers, the conditions at the

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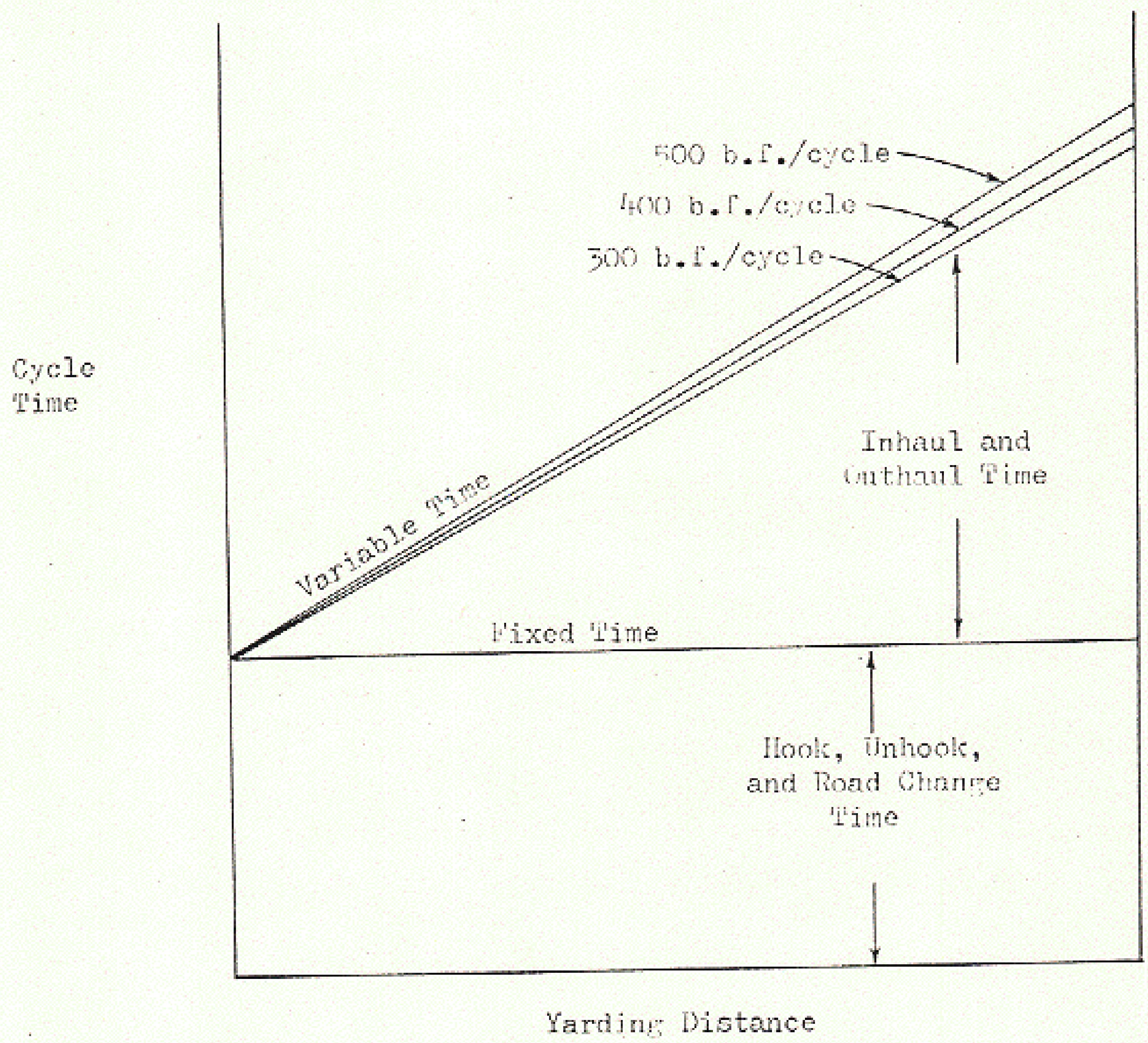
[10] Personal communication with Doyle Burke, Associate Professor of Forest Engineering. University of Washington, Seattle, WA.

Figure 8: Relationship Between Yarding Cycle Elements, Slope Distance, and Log Size.



hook site, and the number of logs per turn. The volume per log was not a significant factor within the size range analyzed in Dykstra's study.

Inhaul involves the hauling of the logs from the logging area to the landing. Similar to felling and bucking, Conway (1976) states that the time required to inhaul small logs is approximately the same as large logs. From this it is assumed that the effects of a small change in log size on inhaul time is insignificant.

Unhooking (including decking) is the disconnecting of a log from the mainline or skidder at the landing. The determinates of unhooking time are similar to those for hooking; the number of chasers, conditions at the landing, and the number of logs per turn. The importance of hooking and unhooking to the yarding cycle should not be underestimated. Dykstra (1976) stated that hooking and unhooking account for 65% of the productive yarding time for a cable system. Other authors (Conway 1976, Adams 1965) have made similar comments.

For the yarding cycle as a whole, it appears that slope distance is the most important variable in determining yarding time. Dykstra (1976) stated that slope distance was the most "influential single variable" of cycle time for the logging systems he studied. Conditions at the hooking site (although difficult to measure) were also important variables. As with felling and bucking, for a small change in diameter, the relationship between log size and total cycle time may be thought of as constant.[11] Figure 9 and Table 1 illustrate the effect of log size

[11] Personal Communication with Frank Greulich, Assistant Professor of Forest Resources. University of Washington, Seattle, WA.

TABLE 1. Effect of Log Size on Time and Costs Per Turn.*

Machine Rate = $138.00/hr.
Yarding Distance = 500'

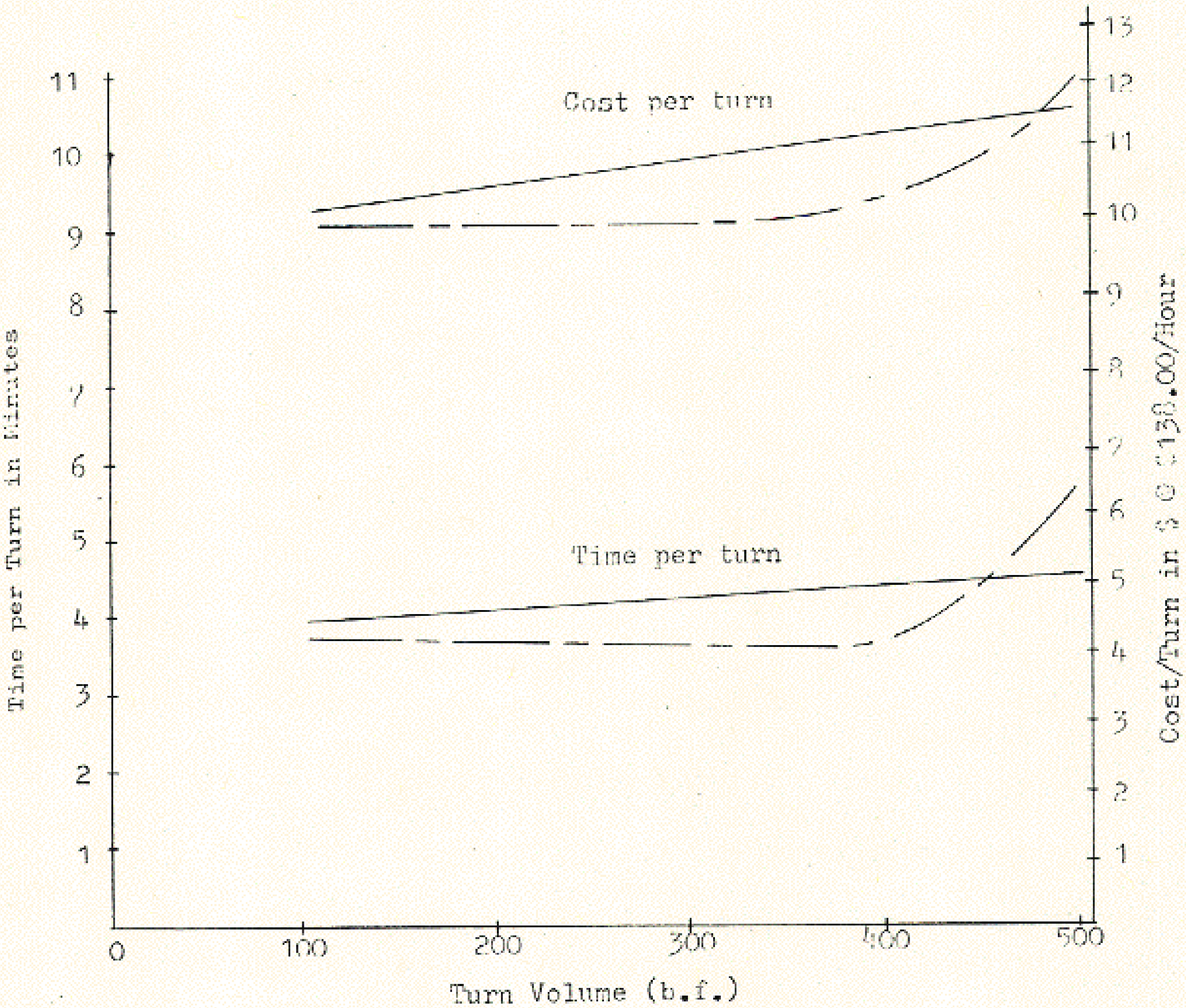
Volume Per Log	Time per Turn	Cost per Turn
50 b.f.	3.97 minutes	$ 9.16
75	4.00	9.23
100	4.04	9.33
125	4.07	9.39
150	4.10	9.46
175	4.14	9.56
200	4.17	9.63
250	4.25	9.81
300	4.30	9.93
350	4.37	10.09
400	4.44	10.25
500	4.56	10.53

*Based upon regression equation developed by Dennis Dykstra, 1976. Production Rates and Costs for Yarding by Cable, Balloon, and Helicopter Compared for Clearcutting and Partial Cutting. Oregon St. Univ., Corvallis, OR. For. Res. Lab. Bull. 22.

Figure 9: Effect of Log Size on Time and Cost per Turn.

(Based on Data from Table 9)

Yarding Distance = 500'



on yarding time and costs. The solid line represents the estimated change in yarding time and costs, based upon a regression formula developed by Dykstra (1976). The broken line is an approximation of the actual time and costs[12]. In both cases the insensitivity of yarding costs to small changes in log size should be noted.

3.3.4. Loading and Hauling

Similar to felling, bucking, and yarding, loading and hauling costs are not significantly affected by small changes in log size. Loading time is fixed with respect to log size for logs which weigh less than the capacity of the loader[13]. Hauling time is dependent upon travel distance, road class, and the efficiency of the yarding and loading system (Conway 1976, Pearce and Stenzel 1972). It is reasonable to assume that for most harvesting systems the influence of a change in log size on loading and hauling time occurs primarily through its affect on the other components of the harvesting system.

3.3.5. The Logging System as a Whole

From the previous discussion it is clear that small changes in log size do not significantly affect logging time (or the corresponding costs) until the weight or size capacity of the equipment is approached. For a small increase in log size (e.g. from 20 to 21 inches in diameter),

[12]Personal communication with Doyle Burke, Associate Professor of Forest Engineering. University of Washington, Seattle, WA.

[13]Ibid.

the time (and cost) required to complete a work cycle increase only slightly. It is recognized that the effect of an increase in log size on logging costs depends in large part upon the design of the logging system. However, for each logging system there is a range in which a change in log size has an insignificant impact on costs. Within this range there will not be a significant increase in logging costs as the average log size increases[14].

It is important to note that most logging equipment in use today in the Pacific Northwest is designed so that it can handle old growth timber. When using this type of equipment, second growth logs are rarely large enough to present a problem with overloading. It is more likely that the limit of the number of logs that can be handled in one cycle will be reached before the load capacity of the equipment is a factor. This may not be true in the future. Changes in harvesting systems, equipment design, and increased whole tree logging may result in second growth trees approaching the maximum load capacity of the equipment. Whether the incremental growth response from fertilization will ever affect logging costs, however, remains to be seen.

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[14] Personal communication with Doyle Burke, Associate Professor of Forest Engineering. University of Washington, Seattle, WA.

CHAPTER 4. METHODOLOGY

4.1 Overview

The data used in this study were collected from two installations established for the Regional Forest Nutrition Research Project (RFNRP). The installations were established during 1969 in natural Douglas-fir stands in the vicinity of Cedar Falls, Washington. Each installation consisted of six 3/20 acre plots. Two of the plots were not treated with fertilizer, two recieved 200 lb N/acre, and two 400 lb N/acre, both in the form of urea. The breast height age of the plots ranged from 29 to 36 years in 1969. 50-year site index varied from 94 to 121. Stocking on the plots ranged from 85 to 120%[15]. A grouping of the plots is shown in Table 2. Within each group the untreated plots will be compared with the treated plots to determine the change as a result of fertilization.

It should be remembered that the analysis used to determine the change in value due to an increase in log size involves very small increments of change, both in terms of volume response and price differentials. What seems to be needless detail, however, can have a significant impact when projected to a per acre basis. As stated earlier, the following procedure is directed toward isolating those increments of revenues and costs which are altered by fertilization, in particular those resulting from an increase in log size. This marginal approach was considered to be the best method available to assess the change

[15]Personal communication with Charlie Peterson, Project Mensurationist, Regional Forest Nutrition Research Project. University of Washington, Seattle, WA.

TABLE 2. Grouping of Plots.

Plot #	Age (1969)	Site Index (1969)	Volume/Acre (1969)	Stem/Acre (1969)	lb N/Acre
1004	33	117	24,133	340	0
1001	35	121	29,000	347	200
1002	37	108	25,133	360	400
1006	35	108	19,067	333	0
1003	36	115	24,400	320	200
1005	36	110	22,260	393	400
1025	29	106	10,200	293	0
1026	31	107	14,467	360	200
1029	30	99	11,800	380	400
1027	32	94	12,600	340	0
1028	29	103	9,000	293	200
1030	30	97	8,333	293	400

in timber value due to fertilization. The methods used to determine the average mill price and total merchantable stand volumes in 1969 and 1977 were those considered to give the best information regarding the response to fertilization.

4.2 The Relationship Between Mill Price and Log Size

Data from the Washington State Department of Natural Resources Monthly Invoice of Log Prices were used for determining mill price differentials. The mills surveyed by the DNR included both water and inland sales. Water sales are those in market areas on towable waters, but not identified for export. Inland sales are those in areas not on towable waters, and not identified for export. Data on sales outside the United States are not included.

The average price for Douglas-fir in each log grade was determined monthly from January 1974 through July 1979. Using #3 sawlogs as a base, price differentials and proportional (percent) price differences between grades were determined (See Appendix, Tables 1 - 5). The objective was to get a general picture of the long term price trends and the price relationships between grades, not to determine absolute prices for logs of a particular grade.

Prices for each log grade were established using relative price differences. Number 3 sawlogs were valued at $200/MBF, and this price was used as a base to develop the relative prices for Number 4 sawlogs, Number 2 sawlogs, special mill grade logs, and chip logs. In general, mill prices for Number 4 sawlogs typically were 18% lower than for Number 3 sawlogs, and the proportional value was $164/MBF. Mill prices for Number 2 sawlogs were 26% higher, with a value of $245/MBF. Special mill grade log prices were 37% higher, and were valued at $275/MBF. Prices for chip logs were assumed to be 60% lower, and were valued at $80/MBF. It is felt that relative prices are more accurate than absolute prices in measuring price differentials, because they seem to stay more constant over time.

4.3 Quantifying the Value Added per Acre Due to an Increase in Log Size

4.3.1. Breakdown of Mensurational Data.

Figure 10 illustrates the stages involved with determining the revenue added at the mill due to a change in log size. Stages two through four (determination of the weighted average mill price) are the most critical. Stage two involves breaking the plots down by scaling diameter and log position. This was done by a computer program which calculated the number of 32-foot logs in a tree and the corresponding log diameters using tree height, DBH, and average stand tariff as the data inputs. If the log diameter was less than 4" at 32', but greater than 4" at 16', it was tallied as a half log, and the scaling diameter was calculated at 16'. Log position in the tree was used to separate the logs into defect classes[16]. It was assumed that log position has a

[16] As it turned out, this step was not necessary in this study due to the relatively narrow diameter distribution. In general, there is little benefit to this step when dealing with second growth.

Figure 10. Stages Involved in Determining the Value Added From Fertilization Due to an Increase in Log Size.

STAGE 1 — RFNRP DATA

↓

STAGE 2 — Breakdown of the Data and Grouping Logs by Log Position and Scaling Diameter

↓

STAGE 3 — Determination of the Volume in Each Log Class

↓

STAGE 4 — Determination of the Average Mill Price for Each Plot

↓

STAGE 5 — Determination of the Revenue Added per Acre Due to an Increase in Log Size, and Due to an Increase in Wood Yield

↓

STAGE 6 — Comparison of the Value Added from an Increase in Log Size Between Unfertilized and Fertilized Plots

↓

STAGE 7 — Comparison of the Value Added Due to an Increase in Log Size And The Value Added Due to an Increase in Wood Yield direct influence on the type of grade defect found in a log. Figure 11 illustrates how log position varied with the number of logs per tree. It should be noted that log position was determined by working down from the top of the tree to the butt. The implicated assumption is that log defect within a tree is more closely correlated to its distance from the top than from its distance to the butt. For example, in a one log tree, the log can be thought of as a butt log or a top log. It is assumed the defect characteristics more closely resemble those of a top log, rather than a butt log.

In stage 3, the total volume per plot, for the logs in each diameter and position class, was calculated by multiplying the number of logs in each diameter class by the corresponding volume in Table 3. The volume per acre was found by multiplying the plot volume by 6.67.

4.3.2. Determination of Average Mill Price for 1969 and 1977

Determination of the weighted average mill price for each plot (Figure 10, stage 4) involves three steps:

1) The weighted average mill price for each diameter and position class was determined. This was done by multiplying the mill price for each log class by the proportion of that particular grade in the log class, and adding the products. For example, using the relative prices developed in section 4.2, if 30% of the 17" butt logs are special mill grade, 65% were #2 sawlogs, and 5% were cull (chips), the average weighted mill price would be:

Figure 11: Number of Logs per Tree and Log Position.

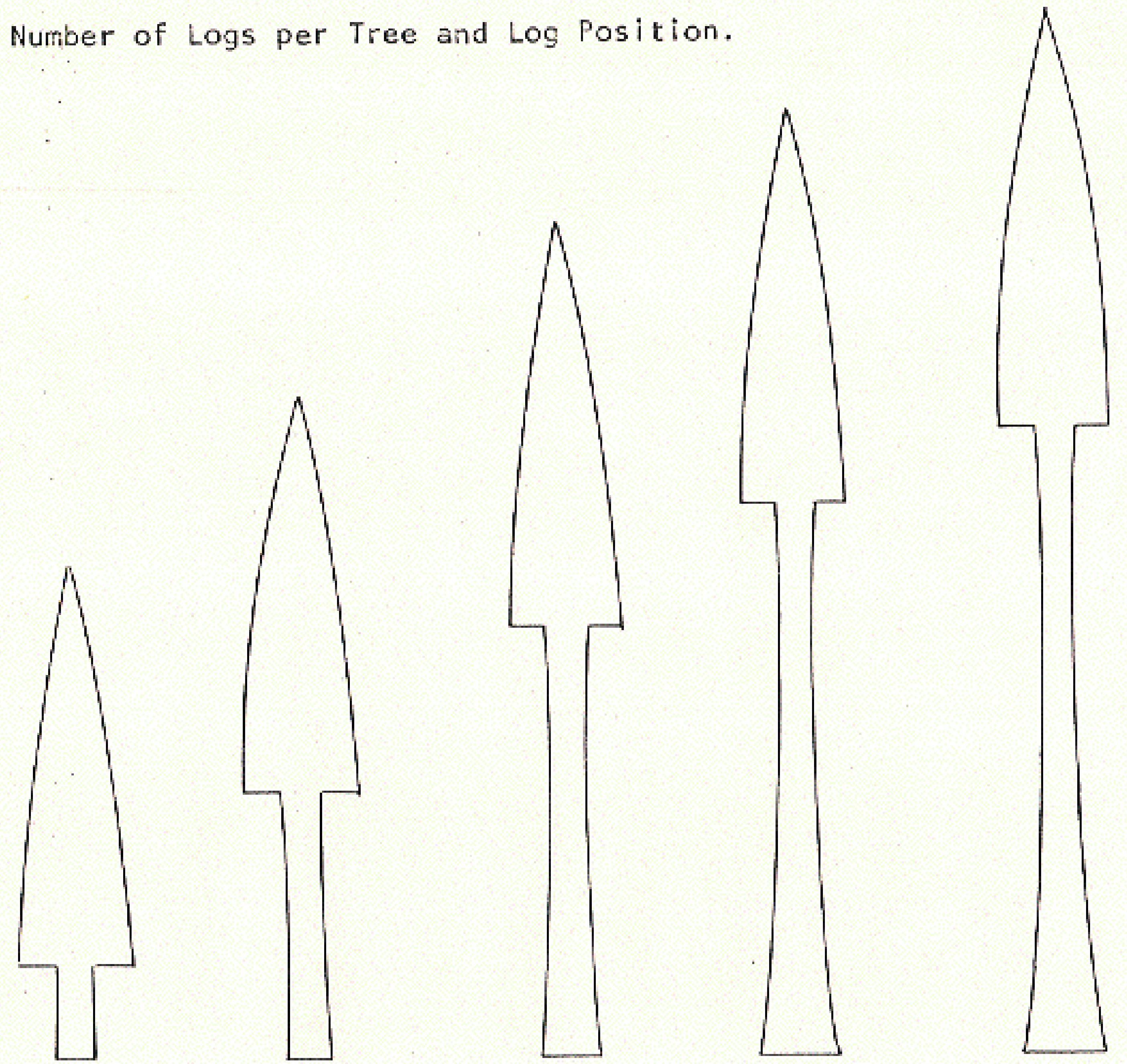


TABLE 3. Volume per Log (b.f. Scribner)*

Diameter	Length	
	16'	32'
4	10 b.f.	20 b.f.
5	20	30
6	20	50
7	30	60
8	30	70
9	40	90
10	60	120
11	70	140
12	80	160
13	100	190
14	110	230
15	140	280

*Obtained through RFNRP data

.3 (\$275/MBF) + .65 (\$245/MBF) + .05 (\$80/MBF) = \$246.00/MBF.

2) The proportion of volume in each log class to total volume on the plot was determined by dividing the volume in each log class by the total volume on the plot.

3) The weighted average mill price for each *plot* was determined by multiplying the weighted average mill price for each *log class* (as determined in step #1) by the proportion of that log *class* to total volume in the *plot* (as determined in step #2) and adding the products. For example, if a plot has 12 diameter classes represented in the butt logs, 8 classes in the middle logs, and 4 in the top logs, there would be 24 (i.e., 12 + 8 + 4) log classes represented on the plot. Each log class has a corresponding average mill price (Pm) and is proportional (A) to the total volume on the plot. The weighted average mill price for the plot (Pa) is:

$$Pa = A_{(1)}Pm_{(1)} + A_{(2)}Pm_{(2)} + \ldots\ldots.A_{(24)}Pm_{(24)}.$$

4.3.3. Recognition of Ingrowth Logs in 1969 and 1977

To allow for more accurate measurement in the change of the weighted average mill price from 1969 to 1977, all logs used to calculate the 1977 mill price should also be used in calculating the 1969 mill price. Survival logs are present in both 1969 and 1977. Ingrowth logs are present in 1977, but not 1969. Ingrowth logs originate from ingrowth trees, or survival trees in which height and diameter growth results in the addition of a log. Because ingrowth logs are typically in the smaller diameter classes (and of lower value), the change in weighted average mill price between 1969 and 1977 will be underestimated if they are included in the mill price for 1977, but not in 1969.

The value of the ingrowth logs in 1977 is known and therefore no corrections are necessary. However, because ingrowth logs were not present in 1969, their value must be estimated. To include ingrowth in the 1969 average mill price two assumptions were made. 1) although ingrowth logs were not of merchantable sawlog size in 1969, they were assumed to have value as chip logs. 2) the volume of the ingrowth logs in 1969 is the same as in 1977. In reality, the volume in 1969 is less but the assumption is probably as accurate as the next best guess.

4.3.4. Determining the Value Added per Acre Due to an Increase in Log Size

When determining the total value gain from fertilization, the additional revenues need to be compared to the additonal costs. The total increase in mill revenues from 1969 to 1977 can be determined using the following equation:

(Average Mill Price 1977 x Volume/Acre 1977)

-(Average Mill Price 1969 X Volume/Acre 1969) Equation 1

= Total Increase in Mill Revenues/Acre 1969-1977.

This can be broken into the change in revenues due to an increase in log grade and an increase in wood yield. The increase in revenues due to a change in log grade can be found by keeping the volume per acre constant and changing the average mill price. The equation used for this is:

(Average Mill Price 1977 x Volume/Acre 1977)

-(Average Mill Price 1969 x Volume/Acre 1977) Equation 2

= Change in Revenue/acre Due to a Change in Log Grade

The increase in revenue due to an increase in wood yield can be found by keeping the average price the same, and changing the volume per acre. The equation for this is:

(Average Mill Price 1969 x Volume/Acre 1977)

-(Average Mill Price 1969 x Volume/Acre 1969) Equation 3

= Change in Revenue/acre Due to a Change in Yield.

To find the total change in revenue due to fertilization in equations #1, #2, or #3, the following equation was used:

Change in Revenue (Fertilized) - Change in Change in Revenue (Unfertilized) = Change in Revenue/acre due to fertilization Equation 4

To determine the total value gain, the increase in total harvesting costs must be deducted from the change in revenue. It is important not to confuse the change in total costs with the change in costs per MBF. The costs per MBF are an average, and their use can lead to distortions if used in a marginal analysis. The change in total harvest costs due to fertilization can be determined by finding the difference in the change in total costs between the fertilized and unfertilized plots. In this study the change in total harvesting costs was estimated based on data from the literature review.

CHAPTER 5. RESULTS

The average mill price (in constant dollars) for logs increased on all plots between 1969 and 1977 (Tables 4 and 5). In general, the average mill price increased with the level of treatment. The increases ranged from \$4.80/MBF on an untreated plot, to \$16.60/MBF on a plot treated with 400 lb N/acre. On untreated plots, the price per MBF increased from an average of \$188.70 to \$195.00; an increase of \$6.30. The average increase on plots treated with 200 lb N/acre was from \$190.40 to \$199.60; an increase of \$9.20. And on plots treated with 400 lb N/acre, the average increase was \$11.60, from \$184.00 to \$195.60.

A conceptual example of the revenue changes analyzed in this study is shown in Figures 12 and 13. V_t represents the total increase in mill revenue from 1969 to 1977. These changes are also shown in Tables 6 and 7. As expected, V_t is greater on the treated plots (V_{t200} and V_{t400}) than on the untreated plots (V_{t0}). Using Equations 2 and 3 on page 38, V_t can be broken into the revenue added due to an increase in wood yield (V_y) and the revenue added due to a change in log grade (V_g). V_g averaged about 10% of V_t on the untreated plots, and about 15% of V_t on the treated plots. Figure 14 uses the data in Table 7 to illustrate the average change in revenue for the fertilized and unfertilized plots.

Referring again to Figure 13, R_t is the difference in V_t between the unfertilized and fertilized plots. R_t seems to be correlated with the level of treatment. Increases in total revenue averaged \$699.00/acre higher on plots treated with 400 lb N/acre than the untreated plots;

TABLE 4. Changes in Average Mill Price/MBF in Constant Dollars 1969-1977.

0 N lb

Plot #	1969 Price	1977 Price	Price Increase 1969-1977	Percent Price Increase
1004	190.20	196.70	$6.70	3.5%
1006	192.20	197.00	4.80	2.5
1025	183.80	191.90	8.10	4.4
1027	184.10	193.00	8.90	4.8

200 N lb

Plot #	1969 Price	1977 Price	Price Increase 1969-1977	Percent Price Increase
1001	195.20	204.20	$9.00	4.5%
1003	193.50	204.10	10.60	6.0
1026	183.50	193.20	9.6	5.8
1028	181.00	192.80	11.7	7.1

400 N lb

Plot #	1969 Price	1977 Price	Price Increase 1969-1977	Percent Price Increase
1002	188.70	198.40	$9.70	5.1%
1005	187.10	198.20	11.10	5.9
1029	175.40	192.00	16.60	9.5
1030	178.00	191.00	13.10	7.3

TABLE 5. Average Change in Weighted Average Mill Price/MBF in Constant Dollars 1969-1977 for Unfertilized and Fertilized Plots.

	1969 Price	1977 Price	Price Increase 1969-1977	Percent Price Increase
0 lb. N	$188.70	$195.00	$ 6.30	3.4
200 lb. N	190.40	199.60	9.20	4.8
400 lb. N	184.00	196.60	11.60	6.3

Figure 12: Increase in Revenue from 1969 to 1977.

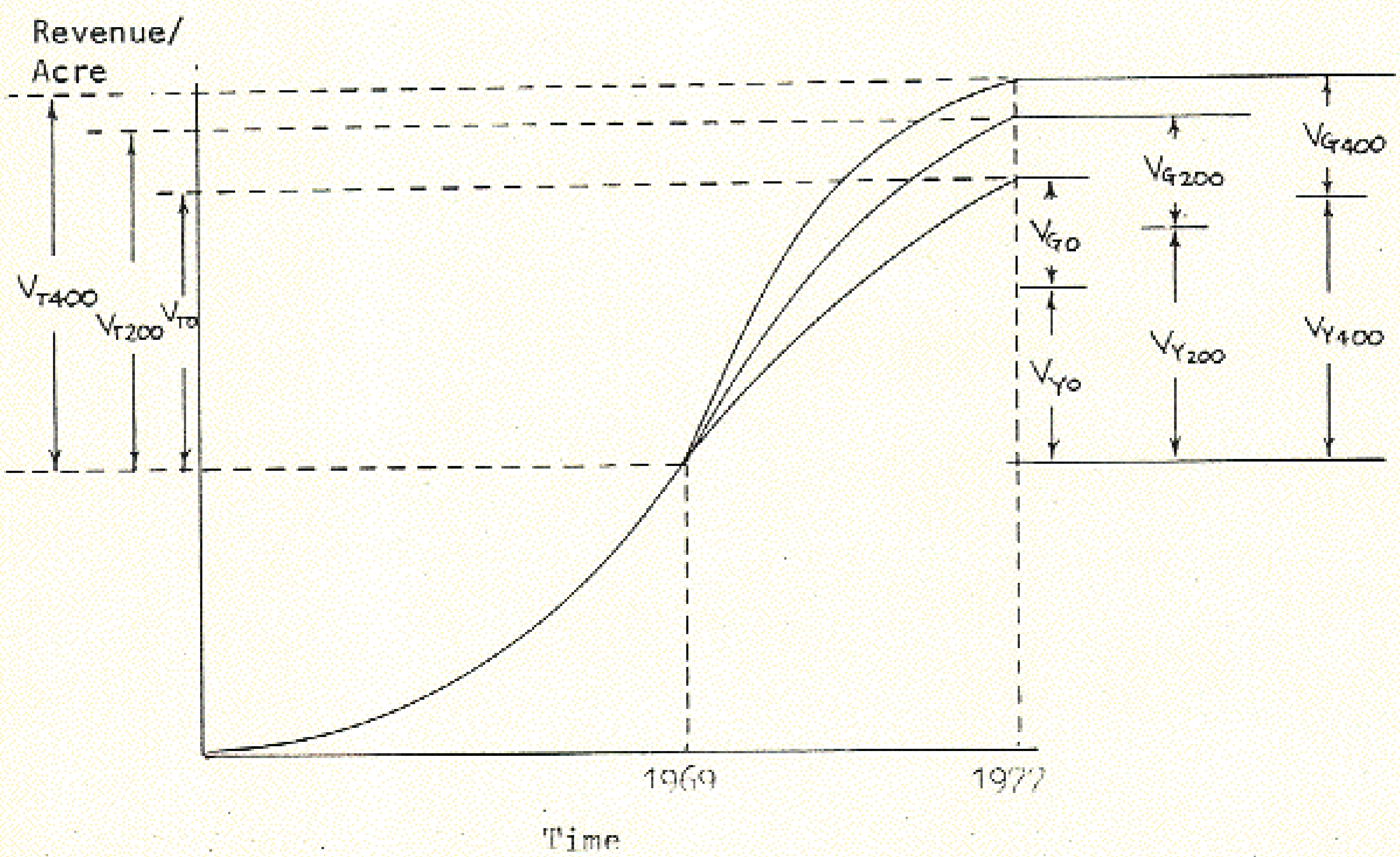


Figure 13: Difference in the Increase in Revenue from 1969 to 1977 Between the Fertilized and Unfertilized Plots.

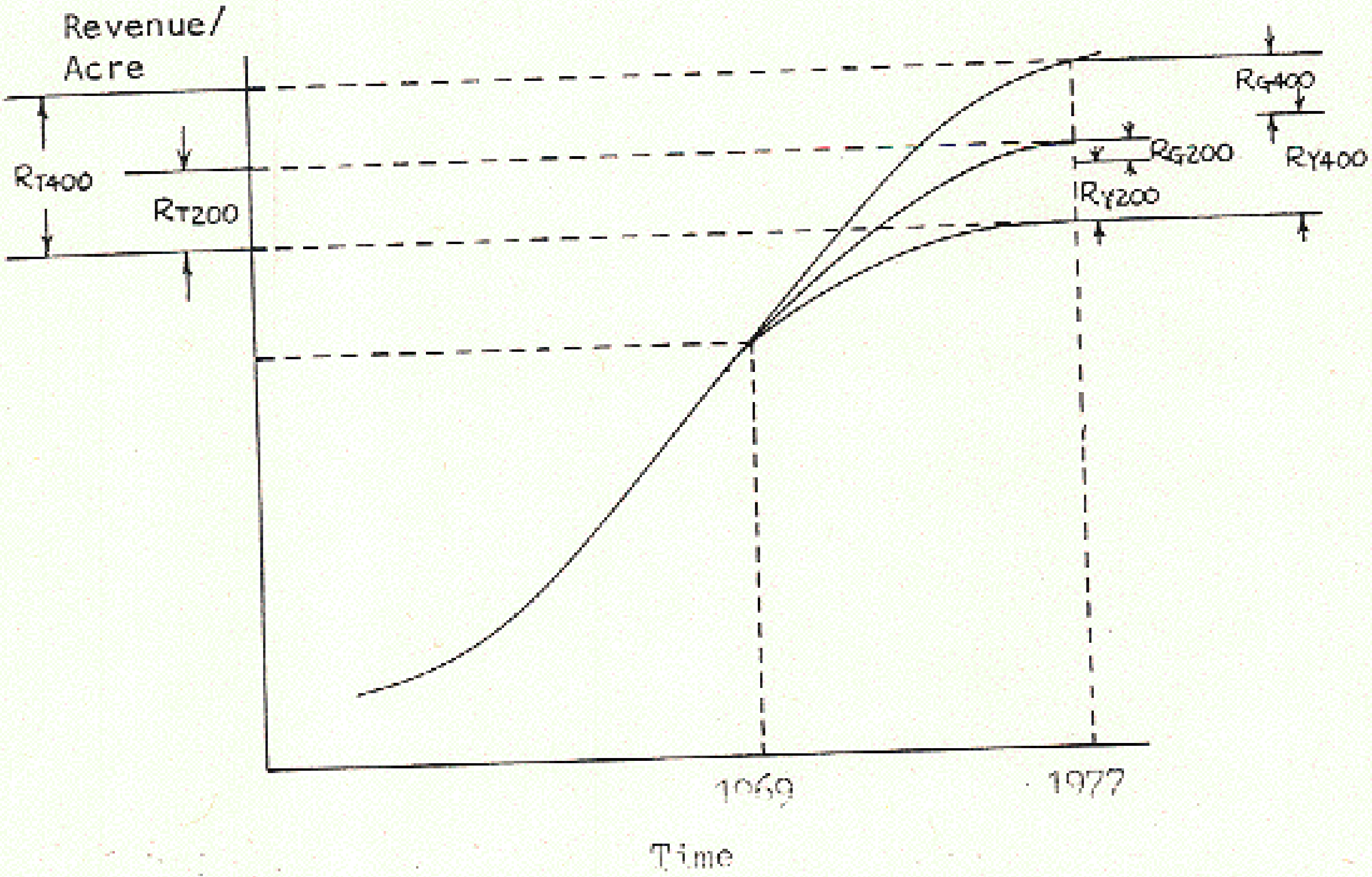


TABLE 6. Revenue Added per Acre at the Mill for Each Plot 1969-1977.

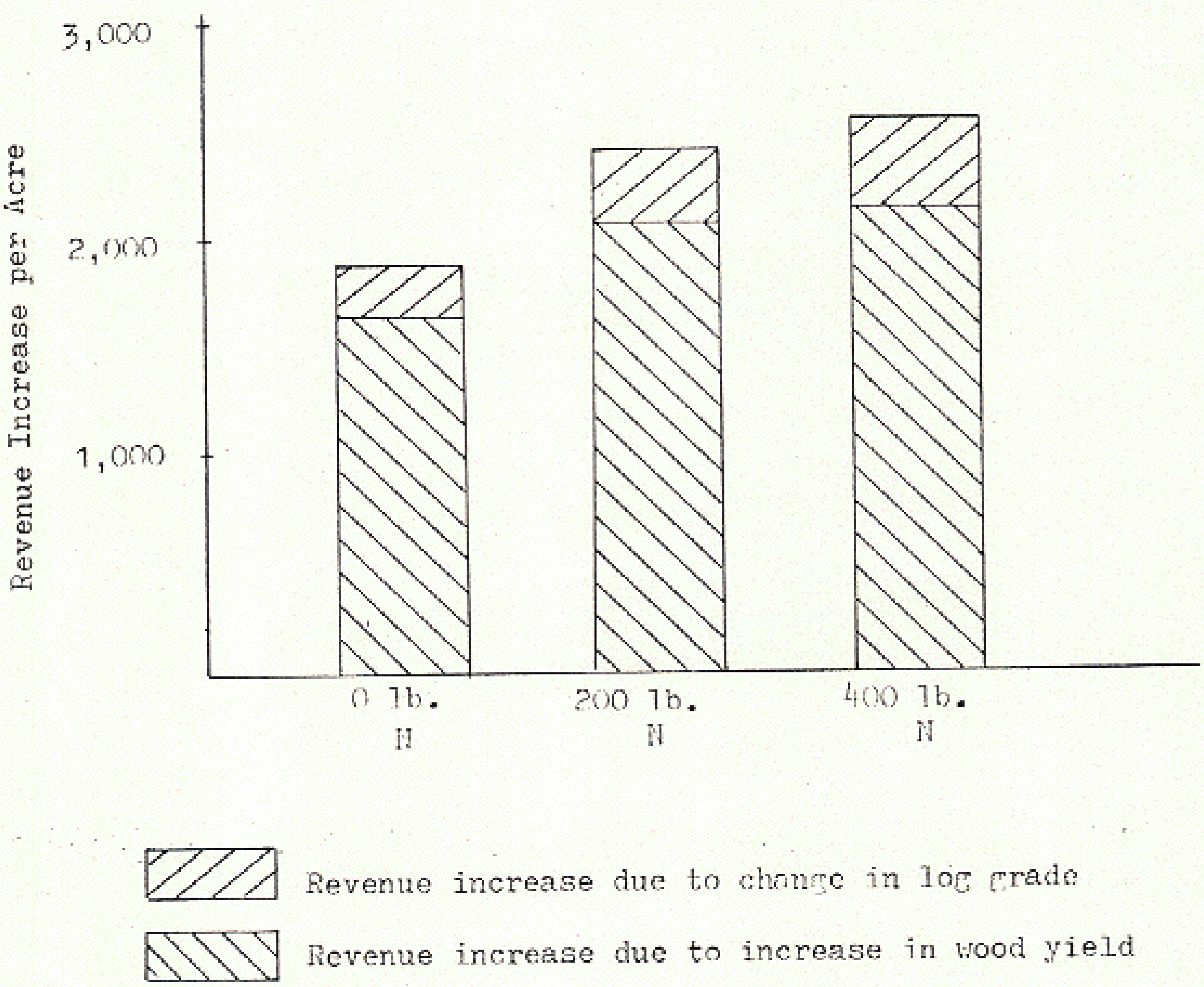
Plot #	Total Increase in Revenue	Increase Due to Increase Yield	Increase Due to Change in Grade	% Increase Due to Change in Grade
0 lb N/Acre				
1004	$1885.00	$1674.00	$211.00	11.2%
1006	1975.00	1822.00	153.00	7.8%
1025	1682.00	1514.00	168.00	10.6%
1027	1975.00	1752.00	223.00	11.3%
200 lb N/Acre				
1001	$2768.00	$2384.00	$384.00	13.8%
1003	2137.00	1757.00	380.00	17.8%
1026	2895.00	2595.00	300.00	10.4%
1028	2009.00	1745.00	253.00	12.6%
400 lb N/Acre				
1002	$2923.00	$2523.00	$400.00	13.7%
1005	2483.00	2069.00	414.00	16.7%
1029	2454.00	1994.00	460.00	18.7%
1030	2455.00	2145.00	310.00	12.6%

TABLE 7. Average Revenue Added per Acre at Mill 1969-1977 for Unfertilized and Fertilized Plots.

	Total Increase in Value	Increase due to Increased Yield	Increase due to Change in Grade	% Increase due to Change in Grade
0 lb. N	$1,880.00	$1,690.00	$190.00	10.0
200 lb. N	2,452.00	2,123.00	320.00	13.4
400 lb. N	2,579.00	2,183.00	396.00	15.4

Figure 14: Average Change in Revenue per Acre for Unfertilized and Fertilized Plots.

(Based upon data in Table 7)



\$492.00 was from a change in wood yield (R_{y400}), \$207.00 was from a change in log grade (R_{g400}). On plots treated with 200 lb N/acre, R_t averaged \$573.00/acre higher than the untreated plots. The increase in wood yield (R_{y200}) accounted for \$432.00 of the increase. A change in log grade (R_{g200}) accounted for \$141.00. The revenue increase due to a change in log grade (R_g) averaged about 25% of R_t on the plots treated with 200 lb N/acre and about 30% of R_t on the plots treated with 400 lb N/acre. The differences in the revenue added between the treated and untreated plots are listed in Tables 8 and 9.

As stated earlier, this paper attempts to determine the incremental change in the value of standing timber as a result of an increase in log size by analyzing incremental changes in revenue and cost. Therefore, the incremental change in mill revenue between the treated and untreated plots (R_g in Figure 13) is considered more relevant than the change in mill revenue over time (V_g in Figure 12).

Total logging costs were only slightly affected by increases in log size. Referring again to Table 1 and Figure 9, it should be noted that yarding costs increased less than \$1.00 per turn when the log size increased from 50 to 350 b.f. Because of this, the increase in total yarding costs was considered to be insignificant. Some increase in total harvesting costs can be expected. The increase due to the growth response from fertilization is so small, however, that it is nearly impossible to measure.

TABLE 8. Differences in the Revenue Added per Acre Between Unfertilized and Fertilized Plots.

Plot #	Total $ Difference from 0-lb N/acre	$ Difference Due to Change in Yield	$ Difference Due to Change in Grade	Change in Grade as a % of Total Change
		200 lb N		
1001	$883.30	$709.40	$173.30	20.6%
1003	161.60	(65.00)*	226.40	140.6%
1026	1212.50	1080.00	146.50	12.0%
1028	33.90	3.00	30.80	90.8%
		400 lb N		
1002	1038.00	848.40	189.40	18.2%
1005	507.60	247.00	260.30	51.2%
1029	771.70	479.80	291.90	37.8%
1030	479.50	392.40	87.30	18.2%

*( ) indicates loss of revenue.

TABLE 9. Average Difference in Revenue Added per Acre Between Unfertilized and Fertilized Plots.

	Total $ Difference from 0 lb. N/Ac	$ Difference due to Change in Yield	$ Difference due to Change in Grade	Change in Grade as % of Total Change
0 lb. N	-	-	-	-
200 lb. N	$573.00	$432.00	$141.00	24.5%
400 lb. N	699.00	492.00	207.00	29.6%

Due to the small increase in total harvesting costs, the total value added from fertilization is approximately equal to the revenue added at the mill. Therefore, the total value gain from fertilization can be approximated from the revenue added at the mill (refer to Tables 8 and 9).

CHAPTER 6. DISCUSSION

6.1 Change in Actual Mill Prices from 1974 to 1979

The average mill price for Douglas-fir logs of all grades increased from 1974 through 1979 (based upon data from the DNR's Monthly Invoice of Log Prices). It is realized that the absolute prices used in this study are somewhat low, but it should be remembered that the DNR survey included all points of sale, including many inland mills which offer relatively low prices for logs. Despite the low absolute price, an average annual price increase of 12 to 15% is evident. There were a few sharp rises and dips in the monthly prices, but the yearly trend is relatively smooth.

When attempting to analyze the value added from an increase in log size, differential log prices between grades were considered more relevant than absolute prices. With one exception, the price differential between the log grades analyzed remained surprisingly constant. The exception is chip log prices, which have been volatile from 1976 through 1979. Future differential mill prices can be expected to change with differences in manufacturing costs and the value of the final output associated with a particular log grade. In addition, the export market, which has not been addressed in this paper, can be expected to play a significant role in determining absolute price levels and relative price differentials.

6.2 Price-Size Gradient

Differential mill prices and log grades were used to develop a price-size gradient because the data provide reasonably accurate information without a large amount of manipulation. However, two main factors need be considered when analyzing this information. First, the mill price for a grade is usually the average price offered for all logs in that grade. Logs just above the minimum size limit or with higher amounts of defect will probably be worth less than the average price for a grade. Similarly, logs at the upper end of the size limit or with lower amounts of defect will probably be worth more than the average. A log buyer will frequently account for these differences within a grade by grouping the lower quality logs in a different "sort" than the high quality logs. A higher price/MBF is then offered for the logs in the high quality sort[17]. Secondly, logs increase in value in relatively small stairstep increments, rather than the relatively wide intervals implicitly assumed when using log grade size requirements[18]. This is particularly true for logs in diameter classes less than eighteen inches. By recognizing changes in log value only at the size intervals established for log grades, the value of small growth increments may not be detected. For example, suppose plot "A" has a high proportion of logs which are in the 10-11 inch diameter class, and plot "B" has a normal distribution of logs across all diameter classes. Plot "A" will probably show a higher increase in log value than plot "B", because more logs will meet the 12 inch diameter requirement for a Number 2 sawlog, increase in grade, and realize a relatively higher increase in value. The difference in the actual value increase between the two plots, however, may be small.

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[17] Personal communication with Chuck Morey, Affiliate Professor of Forest Resources. University of Washington, Seattle, WA.

[18] Personal communication with Gordon Holbrook, Log Buyer, Seaboard Lumber Company. Seattle, WA.

The relative importance between scaling diameter and defect should be considered when determining changes in log value. For second growth sawlogs, scaling diameter is usually the most important determinate of mill price[19]. This lends itself well to a price-size gradient. Problems arise, however, because grading rules cover only a relatively narrow diameter range. Grade changes for sawlogs occur at 6, 12, and 30 inches. Needless to say, 30 inches is beyond the diameter for most second growth logs. In actuality, second growth sawlogs increase in value with size rather continuously. However, an exact determination can not be made using mill prices for the different grades. An approximation (assuming defect requirements are met) of the actual change in price can be obtained through interpolation (refer to the broken line in Figure 1). A similar situation exists when analyzing the effect of log size on peeler log prices, except that defect plays a more important role in determining log grade. Puget Sound Log Scaling and Grading Bureau standards assume that logs are not "suitable for peeling" until they are 16" in diameter. The next change in grade is at 24", and then 30". As with sawlogs, it is assumed the value of the peeler grade logs will increase continuously with size. An approximation (assuming defect requirements are met) can be obtained by examining the corresponding broken line in Figure 1.

Developing a price-size gradient for sawlogs and peeler logs is difficult because of the wide size intervals between grades and the

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[19] Personal communication with Jim Crotts, Land and Timber Supervisor. Weyerhaeuser Company, Snoqualmie Falls, WA.

increasing importance of defect as a log approaches the minimum size for peeling. Using weighted average prices, however, all logs for a given diameter may be grouped together to develop an average price. A price-size gradient may then be developed from this. Obviously the gradient would depend upon the proportion of high grade to low grade logs, but a single gradient based upon weighted average prices for all logs is probably more useful in this study than two separate gradients for saw and peeler grade logs. It should be noted that weighted average prices for each diameter and position were not necessary in this study because the log diameters ranged from only 4 to 15 inches, which by scaling and grading bureau standards includes only sawlogs. Also, no adjustments were made for the chip logs due to a lack of reliable data.

6.3 The Revenue Added/Acre Due to an Increase in Log Size

It appears that fertilization does result in an increase in mill revenues. Furthermore when the plots were paired (refer to Table 2), all of the treated plots showed increases above their untreated counterparts. The amount of the increase seems to be related to the level of application. This is consistent with earlier studies which indicated that the level of application has a direct affect on the rate of growth. Using the procedure followed in this study, an increase in the rate of growth translates directly into an increase in log value.

Although it can not be supported by the data, the revenue added from an increase in log size probably depends in part upon the initial (i.e., before treatment) mill value of the timber. The initial mill value depends upon many factors including site index and stand age (which influences tree size) and site environment factors such as stocking density (which influences defects such as knot size and distribution)[20]. In general, the higher the initial quality of the timber, the greater the revenue added from an increase in growth. This is expected because the additional growth will be worth more at the mill. Further, an important factor frequently overlooked is that low quality timber is frequently reduced in scale. Although a log is not downgraded, a reduction in scale is possible. The importance of this is that the value of the growth on the section of log which is lost by a reduction in scale is zero[21]. This loss is probably low, but nevertheless it should be considered.

It is expected that the growth response from fertilization may have its greatest impact on log values as the log approaches the merchantable size for sawlogs, peeler logs, poles, and piles. Stands with the highest potential for increasing in value (expressed as a percent) are probably those just under the merchantable sawlog size. This is due to the approximately 100% increase in price from chippable to sawlog grade logs. The largest absolute increase in log value probably occurs in high quality stands approaching pole and piling size[22]. Assuming

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[20] Personal communication with James King, Weyerhaeuser Company, Centralia, WA.

[21] This is true only if the logs are sold in the open market. If the logs are processed by the timber owner, a reduction in scale is of no importance (other than the correlation between a reduction in log scale and the volume that is lost in the manufacturing process).

[22] Personal communication with Jim Grant, Forester. Wycoff Company, Bainbridge Island, WA.

January, 1980, prices, it is possible for timber in this size range to change from high quality Number 2 or Number 3 sawlogs worth $250 to $400/MBF, to pole and pile grade timber worth $550 to $800/MBF[23].

6.4. Comparison of the Revenue Added per Acre Due to an Increase in Log Size to the Revenue Added per Acre Due to an Increase in Wood Yield

Analysis of the data indicates that an increase in wood yield contributes more to the change in total revenues at the mill than does a change in log grade. It can be speculated that the relatively small contribution from an increase in log size resulted in part because the diameter range studied included only sawlogs, which are relatively low in value compared to peeler logs.

Referring to Tables 6 and 7, the contribution of a change in log grade to the total increase in mill revenues between 1969 and 1977 is greater on fertilized plots than on unfertilized plots. In addition, the contribution seems to increase with the level of application. This same trend is evident when studying the revenue added as a result of fertilization (Tables 8 and 9). An important difference is that the percent contribution of a change in log grade to the revenue added from

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[23]The apparent value added of an increase in size is probably not as great as the price differential indicates. The high quality #2 and #3 sawlogs are probably suitable for peeling or export and, therefore, at the upper end of the average mill price for all #2 and #3 sawlogs. In addition, logs which just meet the minimum size requirements for poles, will be on the low end of the price range for those products. The combined effect is to reduce the price differential between the two products.

fertilization (25 to 30%) was approximately double the percent contribution a change in log grade made to the total increase in mill revenues between 1969 and 1977 (13 to 15%).

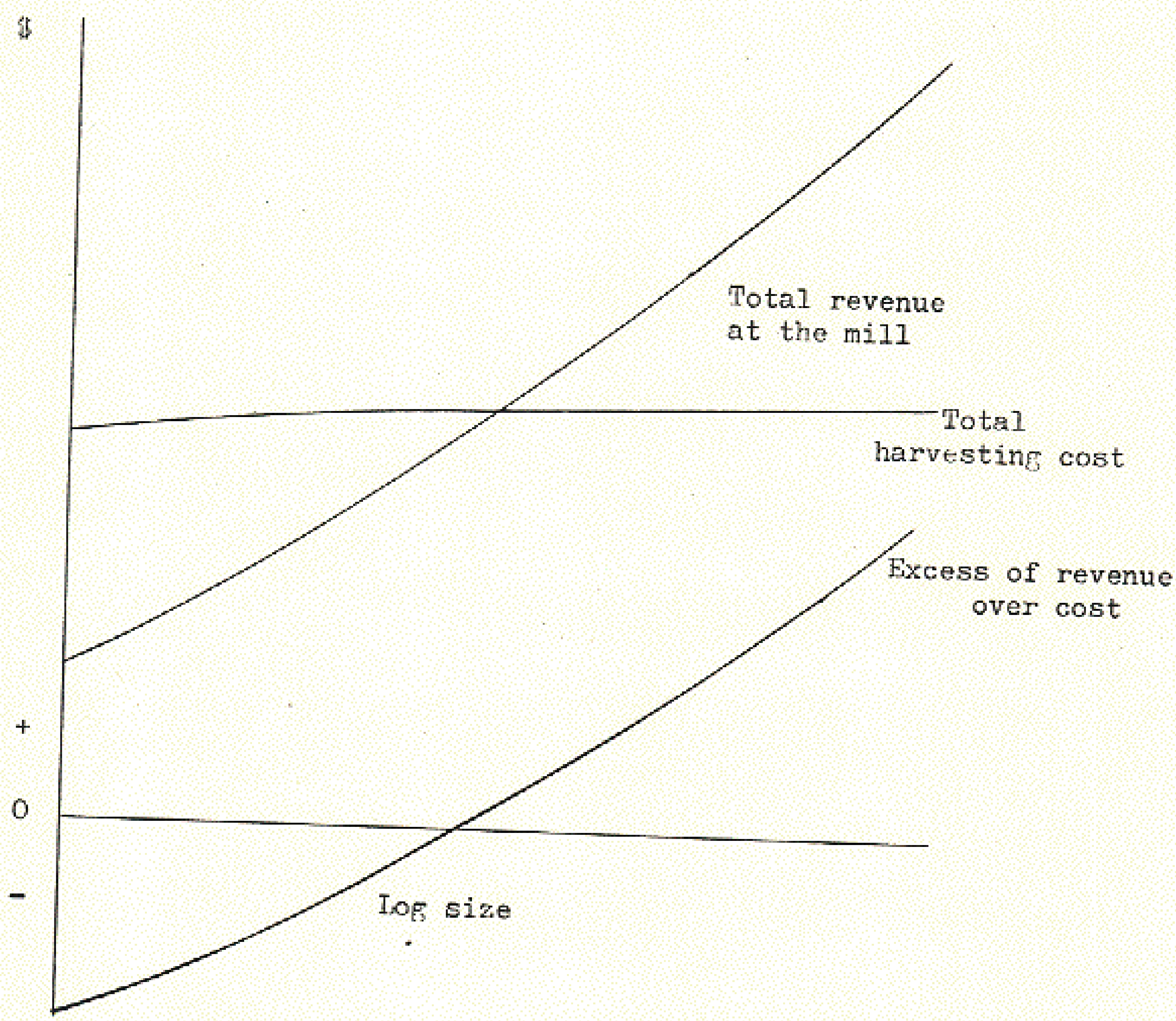
For reasons explained earlier, in this paper the percent contribution of the change in log grade to the revenue added from fertilization is considered more relevant than the percent contribution a change in log grade made to total increase in mill revenues.

6.5 The Value Added per Acre

To determine the total value gain due to an increase in log size, the change in the total harvesting costs need to be deducted from the change in revenue. In Section 3.3 it is stated that for each logging system there is a range in which a change in log size has an insignificant impact on logging costs. For the purposes of this study, it is assumed the logs are within this size range. Therefore, the value added from fertilization is approximately the increase in revenues at the mill. A conceptual example of how fertilization will affect the value of timber is illustrated in Figure 15. Mill revenues increase from both an increase in wood yield and an increase in the price per unit. The increase in total harvesting costs are insignificant, however, and are not considered when calculating the changes in timber value. The result is that the total value added from fertilization is nearly the same as the increase in revenues at the mill.

When first examined, the assumed value gain from fertilization is larger than was determined from earlier studies. There are two possible

Figure 15: Effects of Log Size on Total Revenue and Harvesting Cost.



reasons for this. First, the growth response from fertilization on the plots studied was almost double the average volume response measured on plots of comparable site and age for the RFNRP. Second, harvesting costs were not deducted from the additional revenues received at the mill for reasons explained earlier.

On the other hand, when current timber prices are considered, the assumed value gain from fertilization may have been slightly understated because of the low mill prices used to value the logs. If this occurred, corrections can be made by multiplying all of the calculated values by a factor to raise the Number 3 sawlog to current price levels. This is possible because the differential prices were determined from proportional differences in mill prices. If a proportional change in mill prices takes place, the value calculations would need to be recalculated using the new price differentials.

6.6 Additional Considerations

The general approach used in this study can be applied whenever the value gain depends on both a change in wood yield and log size. However, four important points should be emphasized:

1) Log position needs to be considered when analyzing timber which can vary in quality with position in the tree. It was unnecessary in this study because defect (within a diameter class) does not vary significantly with log position in second growth Douglas-fir. In addition, most second growth logs in the size range studied are utilized for sawlogs, which are rarely down-graded for defect. This is not true

for old growth Douglas-fir. Defect can vary tremendously within the tree. For example, a 30 inch butt log may have different defect characteristics than a 30 inch middle log. Further, these different defect types may have varying effects on the mill value of the log. An example is a butt log which is down-graded due to butt rot from Number 1 Peeler to Number 1 Sawlog. Rot of this type, however, usually occurs only in butt logs, and is of little relevance when adjusting for defect types common in middle logs[24].

2) When calculating the value of a change in log size, the net log scale at the mill, not the gross log scale or response volume, needs to be multiplied by the increase in mill price. This would account for breakage and reductions in scale at the mill. Furthermore, adjustments for operational falldown in response should also be made. These reductions, while not significant when dealing with a small plot, may be important when considered on a per acre basis.

3) The value added may be different for an integrated timber company which grows and processes its own timber, as compared to a landowner who is selling logs on an open market. For the landowner without production facilities, the end point of the manufacturing process is where the timber is purchased by the log buyer. This may be on the stump, at the sorting yard, or at the mill. For the integrated timber company, the end point may be at the distribution yard for the

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[24] Personal communication with Chuck Knapp, Log Grader, Puget Sound Log Scaling and Grading Bureau. Renton, WA.

final product, on the stump, at the sorting yard or at the mill. The methodology in this paper lends itself to selling logs on the open market, where Bureau grading and scaling standards are important (assuming the logs are not sold camprun). Most of the discussion is directed toward factors affecting the integrated manufacturer, where small incremental changes in value are more likely to be captured by the company.

4) Tax effects were not considered. A tax fixed with respect to the value of the timber, would have no effect on the change in value. Taxes which are variable with respect to the value of the timber, would reduce revenues by the factor (1 - tax rate).

CHAPTER 7. SUMMARY AND CONCLUSIONS

An increase in log size appears to make a significant contribution to the value of standing timber. An increase in log size results in a higher mill price per unit, and thus higher mill revenues. Harvesting costs, however, increase only slightly, if at all. Because the increase in harvesting costs are small, the value added can be approximated from the change in revenues at the mill.

The relative importance of the value added from an increase in log size as compared to the value added from an increase in yield is difficult to assess. The value added due to an increase in log size represented 25-30% of the total value difference between the fertilized and unferilized plots. Further, the relative importance of an increase in log size seems to be greater with a higher level of application. It is speculated that this may be due in part to distortions in the data.

The initial quality of the timber is expected to have an important role in determining the value added from fertilization. Assuming that accelerated growth from fertilization does not affect log grade, the value added will be greater the higher the initial quality of the timber. It is hoped that the use of weighted average prices helps adjust for defect and variations in the quality of the timber.

An analysis of how the value added from an increase in log size varies with age and site was not possible because of the narrow data base. Due to the complexities involved in determining the value added from a change in log size, it would be difficult to speculate what variations may exist.

It should be emphasized that statements regarding the value added from fertilization should not be interpreted as an appraisal of the profitability of fertilization. The value added is a measure of the net change in timber value associated with fertilization. Before an assessment of profitability can be made, fertilizer application and administration costs also need to be considered.

While it was not the intent of this paper to analyze the effect of accelerated growth from fertilization on wood properties, these effects should not be ignored. As previously discussed, changes in product value which are being assessed; therefore, as many factors as possible (which have an effect on product value) should be taken into account.

Finally, it is recommended that study of the value added from fertilization due to an increase in log size be continued. The actual value gain from fertilization will be underestimated unless the value increase resulting from an increase in log size is considered. Further sophistication of the techniques for measuring the value added from an increase in log size is needed before this information can be included in an economic model. The areas of study requiring particular attention include:

1) Establishment of a more accurate price-size gradient for the valuation of the logs.

2) Further analysis of the effect of defect, particularly accelerated growth, upon final product values.

3) Analysis of how the value added varies by site index and stand age.

4) Analysis of the log buyer-log seller relationship. This would help determine how the value added is distributed.

In closing, it should be emphasized that this study resulted from a sampling of only a few plots of a particular species, age and site. The extent to which the findings can be applied to other stands remains to be determined.

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APPENDIX

State of Washington Department of Natural Resources Mill Price Data

January 1974 - July 1979

Table 10: 1974 Average Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1974 Average
#1 Peeler	$260	$193	$190	$201	$223	$219	$233	$220	$219	$218	$215	$222	$214
Special Mill	166	141	145	151	157	154	161	157	160	151	149	145	152
#2 Sawlog	131	125	128	136	139	137	144	142	143	139	133	131	136
#3 Sawlog	114	109	108	112	117	115	119	119	122	113	110	105	114

Table 11: 1974 Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Grade Logs.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1974 Average
Special Mill	$52	$32	$37	$39	$40	$49	$42	$38	$38	$38	$39	$40	$38
#2 Sawlog	16	16	20	24	22	22	25	23	21	26	23	26	22

Table 12: 1974 % Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Grade Logs.

Special Mill	46%	29%	34%	35%	34%	43%	35%	32%	31%	34%	35%	38%	33%
#2 Sawlog	14%	15%	19%	21%	19%	19%	21%	19%	17%	23%	21%	25%	19%

Table 13: 1975 Average Log Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1975 Average
#1 Peeler	$210	$224	$225	$226	$238	$235	$228	$229	$233	$238	$231	$239	$230
Special Mill	145	154	152	150	164	161	160	161	158	162	159	161	157
#2 Sawlog	126	131	131	138	139	140	141	142	141	139	137	139	137
#3 Sawlog	107	113	112	114	113	115	117	119	118	115	114	117	115

Table 14: 1975 Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Grade Logs.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1975 Average
Special Mill	$38	$41	$40	$36	$51	$46	$43	$42	$40	$48	$45	$44	$42
#2 Sawlog	19	18	19	24	26	25	24	23	23	24	23	22	22

Table 15: 1975 % Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Grade Logs.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1975 Average
Special Mill	36%	36%	36%	32%	44%	40%	37%	35%	34%	42%	39%	38%	37%
#2 Sawlog	18%	16%	17%	21%	23%	23%	21%	19%	19%	21%	20%	19%	19%

Table 16: 1976 Average Log Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1976 Average
#1 Peeler	$249	$244	$243	$250	NA	NA	NA	$280	$280	$275	$290	$299	$268
Special Mill	163	174	177	185	NA	NA	NA	189	196	194	197	201	186
#2 Sawlog	149	138	145	154	NA	NA	NA	163	164	166	170	174	158
#3 Sawlog	114	116	128	125	NA	NA	NA	133	139	136	138	140	130

Table 17: 1976 Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Logs.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1976 Average
Special Mill	$49	$58	$49	$60	NA	NA	NA	$56	$57	$58	$60	$61	$56
#2 Sawlog	35	22	18	29	NA	NA	NA	30	25	30	32	34	28

Table 18: 1976 % Price Difference Between #3 Sawlog, and #2 Sawlog and Special Mill Grade Logs.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1976 Average
Special Mill	43%	50%	38%	48%	NA	NA	NA	42%	41%	43%	43%	44%	43%
#2 Sawlog	31%	19%	14%	23%	NA	NA	NA	23%	18%	22%	23%	24%	22%

Table 19: 1977 Average Log Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1977 Average
#1 Peeler	$273	$297	NA	$305	$306	$323	NA	$314	$312	$309	$311	$311	$306
#2 Peeler	259	264	NA	275	276	290	NA	287	266	282	285	285	280
#3 Peeler	227	226	NA	235	215	241	NA	253	238	252	251	254	239
Special Mill	197	201	NA	202	203	210	NA	223	215	222	215	222	211
#1 Sawlog	189	196	NA	192	198	194	NA	217	190	204	206	209	200
#2 Sawlog	171	178	NA	177	181	171	NA	197	189	193	199	196	185
#3 Sawlog	140	142	NA	147	145	140	NA	160	154	158	156	163	151
#4 Sawlog	118	124	NA	119	122	136	NA	142	132	140	138	139	131
Utility	60	53	NA	53	53	50	NA	50	50	51	55	53	53

Table 20: 1977 Price Difference Between a #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1977 Average
Special Mill	$57	$59	NA	$55	$58	$60	NA	$53	$61	$64	$59	$59	$60
#2 Sawlog	31	36	NA	30	36	31	NA	37	35	35	43	33	34
#4 Sawlog	(22)*	(18)	NA	(28)	(23)	(4)	NA	(18)	(22)	(18)	(18)	(24)	(20)

Table 21: 1977 % Price Difference Between a #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1977 Average
Special Mill	41%	42%	NA	37%	40%	43%	NA	33%	40%	41%	38%	36%	40%
#2 Sawlog	22%	25%	NA	20%	25%	22%	NA	23%	23%	22%	28%	20%	23%
#4 Sawlog	(16%)*	(13)	NA	(19)	(16)	(3)	NA	(11)	(14)	(11)	(11)	(15)	(13%)

*( ) Designates lower value.

Table 22: 1978 Average Log Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1978 Average
#1 Peeler	$320	$303	$361	$348	$308	$360	$338	$346	$362	$371	$381	$368	$347
#2 Peeler	299	287	325	319	288	330	314	321	335	344	352	340	321
#3 Peeler	258	257	288	264	261	296	278	283	297	307	312	299	283
Special Mill	224	230	230	234	233	245	241	247	257	254	255	259	243
#1 Sawlog	211	190	263	234	223	263	233	244	246	249	228	235	235
#2 Sawlog	189	202	202	206	214	218	216	218	215	237	230	238	217
#3 Sawlog	161	161	149	166	186	175	180	178	174	196	190	194	177
#4 Sawlog	135	148	113	134	153	125	151	147	156	157	164	154	146
Utility	53	75	53	53	55	53	73	55	55	73	58	58	60

Table 23: 1978 Price Difference Between a #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1978 Average
Special Mill	$63	$69	$81	$68	$47	$70	$61	$69	$83	$58	$65	$65	$61
#2 Sawlog	28	41	53	40	28	43	36	40	41	41	40	44	40
#4 Sawlog	(26)*	(13)	(16)	(22)	(33)	(50)	(29)	(31)	(18)	(39)	(26)	(40)	(31)

Table 24: 1978 % Price Difference Between a #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	1978 Average
Special Mill	39%	43%	54%	41%	25%	40%	34%	39%	48%	30%	34%	34%	35%
#2 Sawlog	17%	25%	36%	24%	15%	26%	20%	22%	24%	21%	21%	23%	23%
#4 Sawlog	(16%)*	(8)	(11)	(13)	(18)	(29)	(16)	(17)	(10)	(20)	(14)	(21)	(18%)

* ( ) designates lower value

Table 25: 1979 Average Log Prices for Douglas-fir.

Grade	Jan	Feb	Mar	Apr	May	June	July
#1 Peeler	$374	$360	$397	$286	$382	$374	$393
Special Mill	252	225	273	237	258	274	277
#2 Sawlog	234	212	253	210	232	246	251
#3 Sawlog	190	186	200	192	200	212	241
#4 Sawlog	149	156	174	168	139	164	163
Utility	58	55	59	55	57	60	59

Table 26: 1979 Price Difference Between #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July
Special Mill	$62	$39	$73	$55	$58	$62	$63
#2 Sawlog	44	26	53	18	32	34	37
#4 Sawlog	(41)*	(30)	(31)	(24)	(61)	(48)	(51)

*( ) designates lower value

Table 27: 1979 % Price Difference Between #3 Sawlog, and a #4 Sawlog, #2 Sawlog and a Special Mill Grade Log.

	Jan	Feb	Mar	Apr	May	June	July
Special Mill	33%	21%	37%	29%	29%	29%	29%
#2 Sawlog	23%	14%	27%	9%	16%	16%	17%
#4 Sawlog	(22)*	(16)	(16)	(13)	(31)	(23)	(24%)

*( ) designates lower value.