A CASE STUDY OF PREBUNCHING AND SWINGING

A THINNING SYSTEM FOR YOUNG FORESTS

by

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A PAPER

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Forestry

June 1976

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Date paper is presented: May 7, 1976

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AN ABSTRACT OF THE PAPER OF

Loren D. Kellogg for the degree Master of Forestry

in Forest Engineering presented on May 7, 1976

Title: A CASE STUDY OF PREBUNCHING AND SWINGING - A THINNING SYSTEM FOR YOUNG FORESTS

Commercial thinning young growth forests is an increasingly important silvicultural technique for improving second growth management of Douglas-fir stands. Research aimed at advancing the efficiency of skyline logging operations in small wood timber stands is essential in order to make thinning these young stands economical. The purpose of this study was to evaluate one case of prebunching small logs to a skyline corridor with a portable winch and swinging the logs to a haul road with a conventional mobile yarder. Prebunching involves lateral yarding of logs from both sides of a skyline corridor and decking the logs along the corridor.

The multimoment time study method was used for obtaining data that was analyzed with multiple linear regression procedures. Predicted hourly and daily production rates were determined from the regression equations. The yarding system involving prebunching was compared to a similar system without prebunching on a cost basis.

This study showed that prebunching logs to a skyline corridor reduced the conventional mobile yarder's yarding time 65 percent and more than doubled log and volume production per day. The results

favored the prebunching and swinging yarding technique. Several suggestions, that require additional research, were made for modification in the system that may improve the overall operation.

ACKNOWLEDGMENTS

I am grateful for the funds provided to me through the Forest Research Laboratory of Oregon State University while pursuing my graduate work. It is also a pleasure to acknowledge the people who have made this project possible by providing valuable help, advice and information.

Especially, I wish to thank Ed Aulerich, my major professor. He provided guidance, criticism and a good part of himself not only in the project, but more importantly, in my personal development and education as his student.

Dwight Havens, designer of the Mini-Yarder, was most patient and cooperative with the use of his machine. I sincerely wish him good luck in the forest products industry with the Mini-Yarder. The workers of Tree Farm Stewards helped with part of this study and were always a pleasure to work with. Others who in some way contributed to this study with valuable advice and help include: Marv Rowley, Forest Properties Manager; Dennis Dykstra, instructor; and students in the Forest Engineering Department, especially Denis Van Winkle and Bob Weir. I also extend my appreciation to professors John O'Leary and Hank Froehlich for reviewing this manuscript and serving on my graduate committee.

To my wife Peggy, goes my deepest appreciation for her support and encouragement during the many months I worked on the project and for her help in preparing and typing this manuscript.

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A CASE STUDY OF PREBUNCHING AND SWINGING A THINNING SYSTEM FOR YOUNG FORESTS

INTRODUCTION

Approximately 24 percent (3.3 million acres, 1.34 million hectares[1]) of the 14-1/2 million acres (5.87 million hectares) of Douglas-fir commercial forest land in Oregon and Washington consist of stands between 20 and 70 years of age. They represent an estimated volume of 37.9 billion board feet[2] (269 million cubic meters[3]) (Williamson and Price, 1971). There is a great resource of wood fiber in these young stands that continually increases in importance as harvesting activities change from old growth forests to second growth stands. Thinning, a silvicultural treatment, is the removal of trees in immature stands to stimulate growth of the residual trees. The time to start thinning is when the value of the products removed will at least cover the expenses of the harvesting operation (Malmberg, 1970). If the first thinning is delayed until the stand is 40 years old on good sites and 50 years old on poorer sites, it is difficult to upgrade the residual trees (Malmberg, 1970).

Malmberg (1970) states that commercial thinning with selective methods taking the largest trees, can be economically successful when stands are 30 years of age provided there is an attractive log market. The importance of market conditions setting the amount of profit was demonstrated comparing mill prices between the summer of 1972 and the

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[1] 1 acre = 0.4047 hectares.

[2] Scribner Log Rule.

[3] 1 cubic meter = 141 board feet.

summer of 1973 during thinning operations in Oregon State's McDonald Forest (Aulerich, Johnson and Froehlich, 1974). Thinning small timber stands and making a profit can often be difficult. Small timber has been identified as a tree under 20 inches (50.8 centimeters[4]) dbh[5] or logs averaging less than 100 board feet[6] (.71 cubic meters)(Aulerich, 1975). If logging costs can be reduced when thinning these stands, a lower market price for the wood fiber can be tolerated and the benefits of increased yields will be achieved.

What type of harvesting systems are available today for thinning operations? This was a question that began an evaluation in 1972 by the Forest Engineering Department at Oregon State University on logging techniques for small timber stands. A questionnaire sent to logging operators in Oregon and Washington revealed that 33 percent used cable systems and 62 percent used ground-based systems (Aulerich, 1975).

There are various advantages and disadvantages to the different ground-based systems. Tractors best for thinning operations often are not versatile for other jobs such as road building. Rowley (1970) found that medium-sized tractors with an 8-foot blade and 60-80 horsepower worked most efficiently in thinning operations. Wheel skidders have proven useful in many areas but also have definite limitations on wet, fragile coastal soils. There have been improvements in ground-based systems with attachments such as grapples and arches to reduce

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[4]1 inch = 2.54 centimeters.

[5]dbh = diameter breast height.

[6]Scribner Log Rule.

hook time and lift the load off the ground. There are certain advantages to yarding with horses in the proper areas. Horses maneuver logs in dense stands without causing much residual stand damage and ground disturbance. All of the ground-based systems are inadequate for thinning much of the terrain in the Pacific Northwest that is steep or on fragile soils.

O'Leary (1970) has presented some of the skyline systems used on steep ground. Current equipment used in skyline thinning operations was categorized into three groups from the questionnaire sent to logging operators in Oregon and Washington (Aulerich, 1975). Forty-one percent of the operators used small systems that were under 100 horsepower and included the Skagit SJ series, the Schield-Bantam T-350 and small European systems such as the Unimog Urus. Thirty-one percent used yarders such as the Skagit GT-3, Washington 78, and the West Coast Tower that were grouped as medium-class yarders. "Homemade" skyline configurations were also included in the medium-size class. Twenty-eight percent used large systems that were mostly large steel towers yarding partial cuts and loaders converted to yarders.

The yarding cost per M bd. ft.[7] can be high when yarders such as those considered in the small, medium and large size classifications remain idle a good portion of the time during the yarding operation because of high equipment cost. A key factor in the higher skyline yarding cost over tractor yarding cost in a thinning comparison between skylines and tractors on McDonald Forest was the idle time of

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[7]M bd. ft. = thousand board feet.

the yarder during the hooking operation and the high lateral yarding time (Aulerich, 1975). The study showed that 46 percent of the turn time was spent in lateral operations, including hooking but not including an additional 10 percent resulting from resets during the lateral inhaul.

What can be done to reduce the lateral yarding time common to most thinning operations? One possible solution involves equipment modifications which could center around the carriage design or the yarder design. Another alternative would be to increase the number of chokersetters. A third alternative is making sure that the lateral yarding distance is optimum. Aulerich (1975) suggests that the optimum distance for lateral yarding should be obtained by balancing the cost per foot of lateral movement for a particular yarding system with the cost of rigging additional skyline roads to reduce the lateral distance. A fourth alternative to reducing lateral yarding time involves cutting herringbone-like strips (strip-thinning) at various angles to the skyline corridor. Adamovich (1968) describes this technique as an approach that compromises between the goal of redistributing growth to fewer trees and the goal of low logging cost for harvesting small wood. Herringbone thinning patterns have been logged in various areas such as Crown Zellerbach's coastal operations and in Oregon State's McDonald Forest. Growth of residual trees in herringbone thinning operations in McDonald Forest is being measured and compared to residual trees in conventional selection thinning operations. A final alternative that eliminates the lateral yarding time with an expensive machine in skyline thinning operations is to prebunch the logs in the skyline corridor with a low-investment machine and later swing the logs to the haul road with the higher-investment yarder. The prebunching may be accomplished with a horse, tractor, skidder or some type of small portable winch. Ground-based prebunching systems would be limited to areas where slopes are not excessive and soil conditions are not fragile. The small portable winch would be adaptable to terrain suitable for ground-based systems as well as steeper slopes or critial soils.

For this study, a small portable winch is defined as a unit contained on a sled that weighs less than 2000 pounds (907 kilograms[8]) and consists of a power plant that drives one drum containing less than 400 feet (121.92 meters[9]) of not greater than one-half inch (1.27 centimeters) line. It does not include small winches powered by a chain saw.

Small single-drum winch machines are common in European logging operations. In the United States, I am aware of only two different single-drum winch units that have been used in logging operations. One was manufactured by Warn Winch Company of Kent, Washington for Weyerhaeuser. The other machine, which was used in this study, is manufactured by Modern Logging Equipment, Inc., Sandy, Oregon.

The Forest Engineering Department at Oregon State University became involved with the radio-controlled single-drum winch built in Sandy, Oregon through a demonstration for a small-wood harvesting short course sponsored by the Oregon State University Extension Service. A study was started in the summer of 1974 with the single-drum winch

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[8]1 pound = .4536 kilograms.

[9]1 foot = .3048 meters.

prebunching logs to a skyline corridor. The study was not completed because mechanical problems existed with the machine. The machine was redesigned and tested on a slash yarding and thinning operation in the McDonald and Paul Dunn Forests during the spring of 1975. A few additional mechanical problems were corrected and the study for the basis of this report was done in the winter of 1976.

OBJECTIVES

The specific objectives of this study are:

1. To develop reliable production rates and yarding costs for thinning small timber stands by prebunching logs in a skyline corridor with a radio-controlled single-drum winch and then swinging the prebunched logs to the haul road with a mobile yarder skyline system.

2. To compare the yarding costs between the thinning technique described above and thinning the area with a mobile yarder skyline system without prebunching.

PROCEDURES

Area and Stand Description

A 2.76 acre unit (1.12 hectares) in McDonald Forest was selected for thinning (Figure 1). The 35-40 year old stand of Douglas-fir (Pseudotsuga menziesii) was on Site III (Index 140) land. The average slope of the unit was 25 percent.

The felling was done by a contract logging crew working in the school forest. The selection of cut trees was done by the fallers. Specifically, the better dominant and codominant trees were left by crown spacing judgments. Defective dominant and codominant trees, including merchantable intermediate and overtopped trees, were removed. A .11 acre (0.45 hectares) corridor that averaged 15 feet (4.57 meters) in width was clearcut approximately in the center of the unit. The cutters attempted to fall the trees away from the corridor and to lead for the lateral yarding.

Stand characteristics before and after thinning are shown in Table 1. Thirty-nine percent of the stems were removed from the unit. This accounted for 36 percent of the total volume. A frequency distribution by tree diameter class of the residual stand is shown in Figure 2.

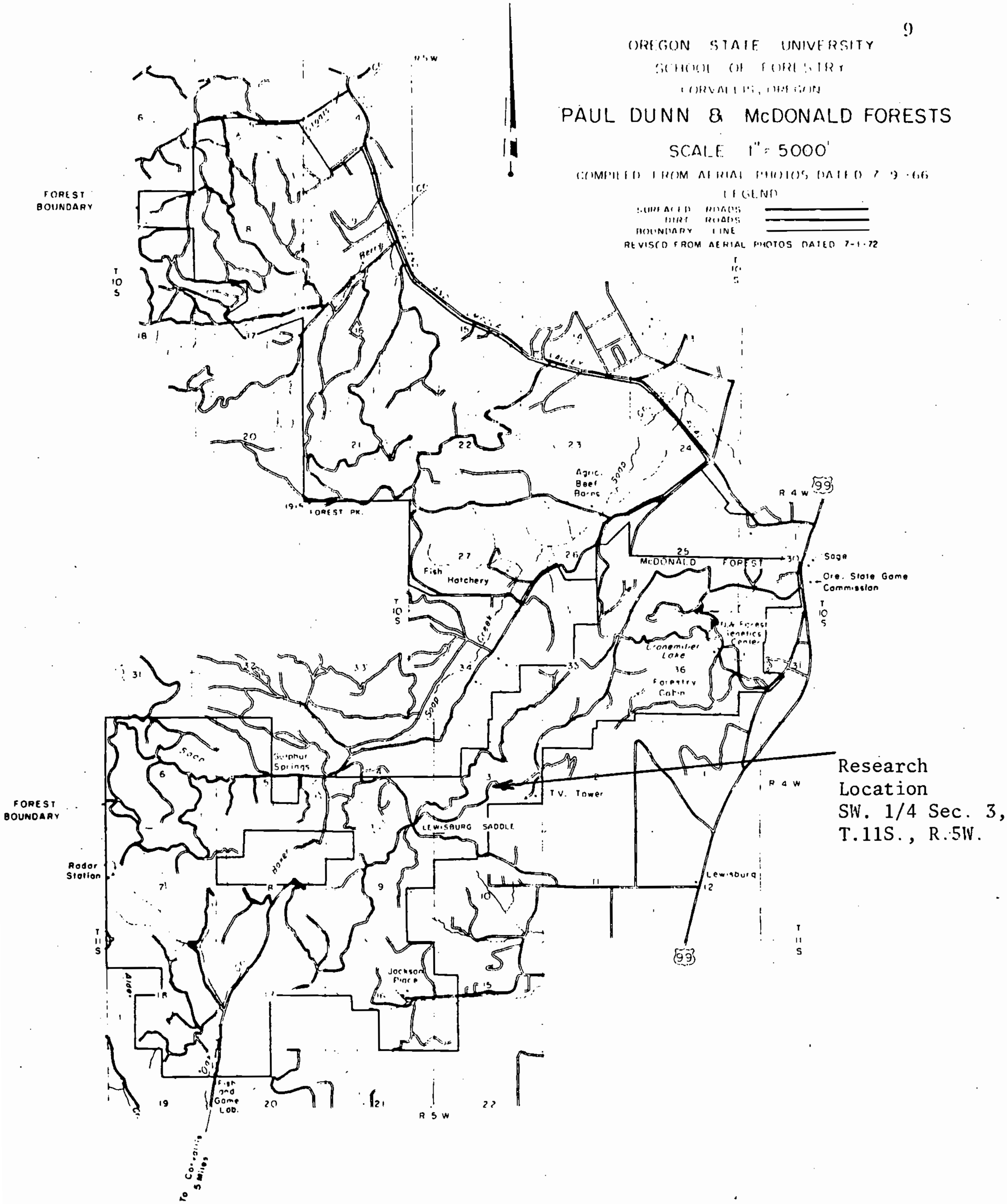


Figure 1. Study unit location.

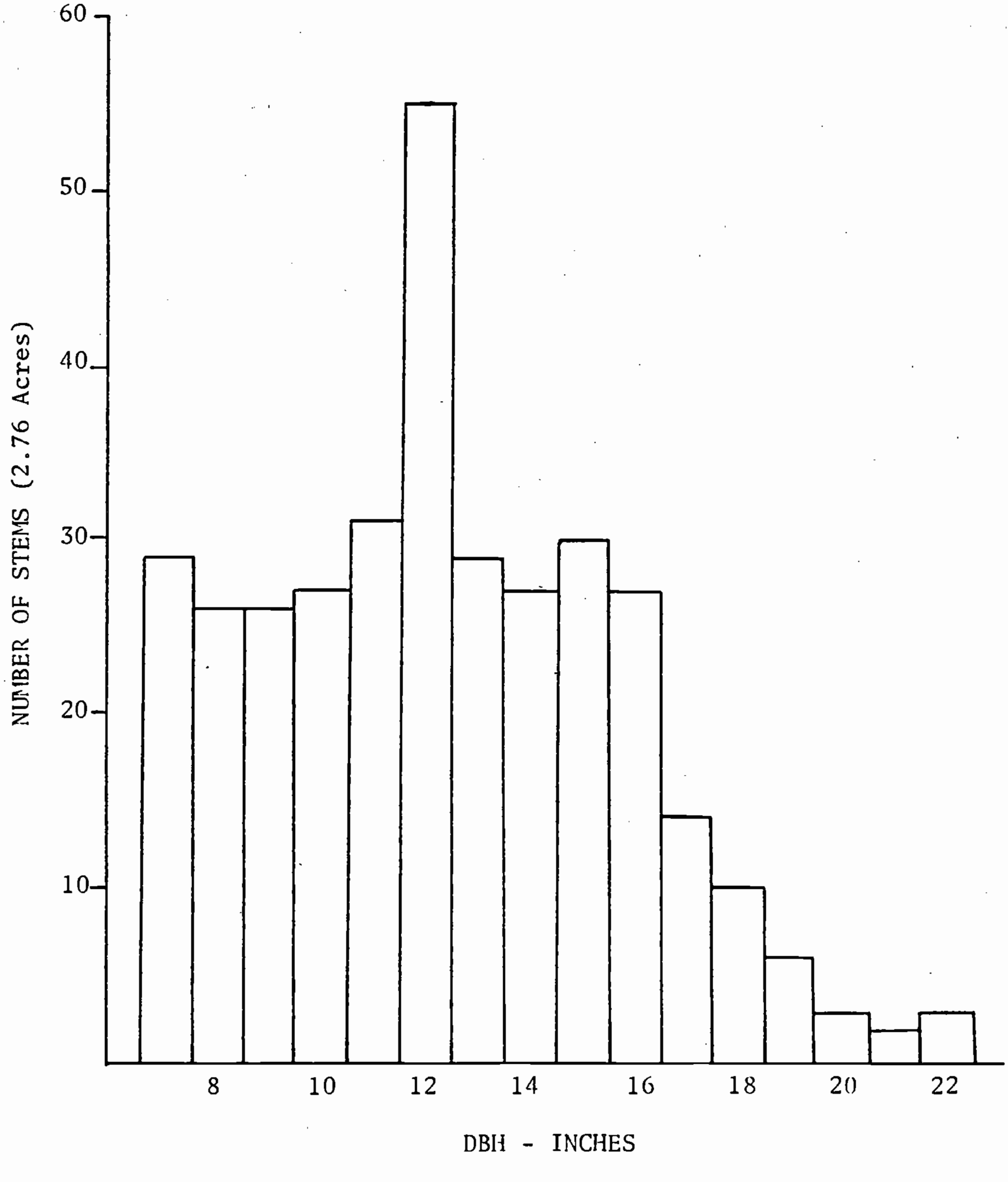


Figure 2. Diameter distribution - residual stand.

TABLE 1. STAND CHARACTERISTICS FOR THINNING STUDY

	Stems/ acre	Stems/ Hectare	Volume/Acre cubic feet	Volume/Acre board feet[1]	Volume/Hectare cubic meters
Before thinning	221.4	547.1	4,824.00	28,944	507
Thinning removal	85.9	212.3	1,732.50	10,395	182
Residual stand	135.5	334.8	3,091.50	18,549	325

[1] 1 cubic foot = 6 board feet.

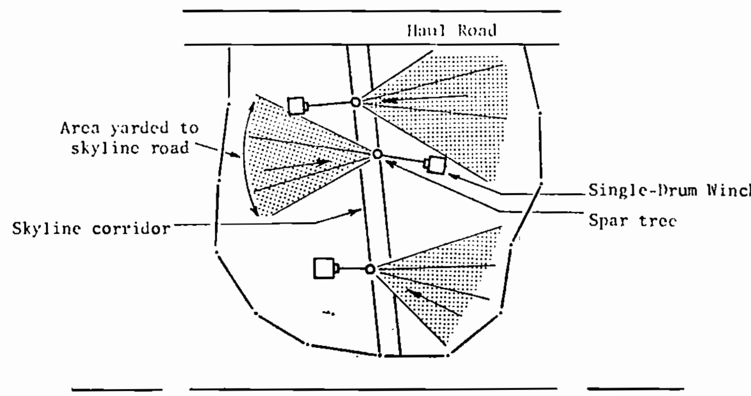
The Yarding System

The yarding system studied includes two machines. The "Mini-Yarder" designed by Modern Logging Equipment, Inc., was used for prebunching logs into the skyline corridor. After the logs were prebunched and the Mini-Yarder was out of the unit, a Schield-Bantam T-350 rubbermounted three-drum mobile yarder swung the prebunched logs to the haul road. Figure 3 shows how the yarding system with the two machines functioned.

Prebunching with Single-Drum Winch

The term "Mini-Yarder" is a vague description of a machine that can create different impressions of a machine, ranging anywhere from a chain saw winch to an expensive mobile yarder such as a Skagit GT-3. The Mini-Yarder used in this study will be referred to as a radio-controlled single-drum winch that fits the definition stated earlier

Step 1. Prebunching with single-drum winch.



Step 2. Swinging prebunched decks with mobile yarder.

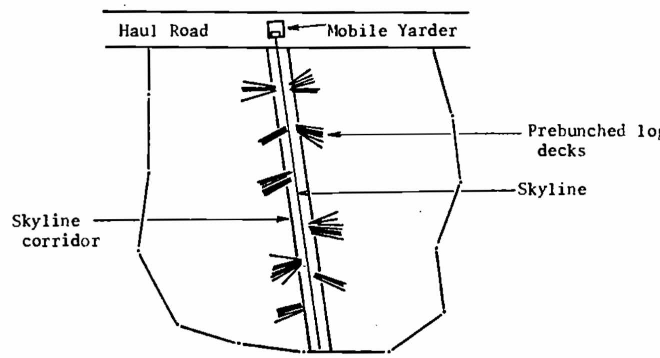


Figure 3. Two-step thinning system (not to scale).

Figure 4. Modern Logging Equipment's Mini-Yarder.

of a small portable winch (Figure 4). The single-drum winch consists of a Gerramatic 9 Winch that is powered by a 47 horsepower Volkswagen Industrial Engine. The unit is contained on a metal sled that is 7 feet (2.13 meters) long and 3 feet 10 inches (1.17 meters) wide and approximately 3 feet (.91 meters) high. The power from the engine is transferred to the winch through a transmission and two reduction gears with a 3 to 1 gear reduction ratio (Figure 5). The winch is rated at a maximum line pull of 9,000 pounds (4.082 kilograms).

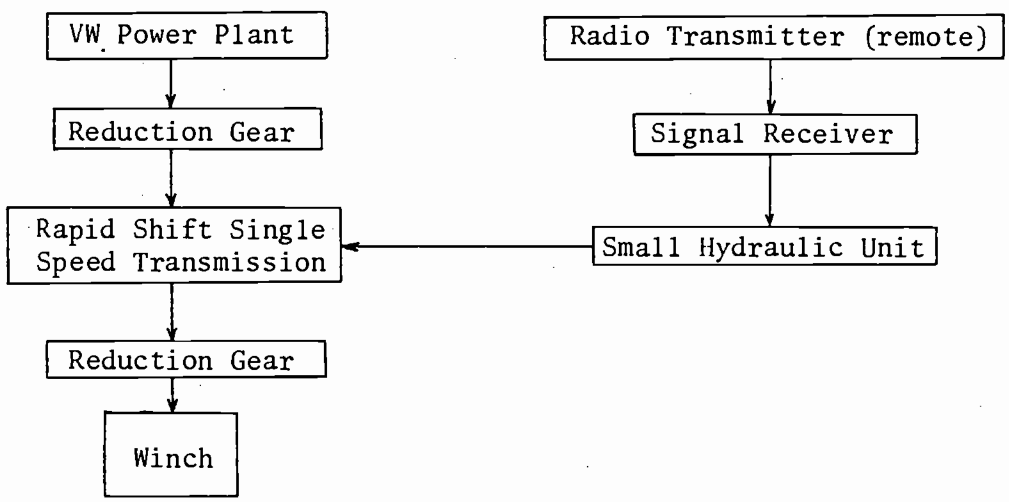


Figure 5. Power flow and control schematic of Mini-Yarder.

A remote-controlled radio transmitter, worn by the machine operator, activates the winch--forward, reverse and free spool modes (Figure 6). A small hydraulic unit controls the transmission. The speed of the winch can be slightly governed by the engine speed. The winch line passes through a small fairlead to aid in spooling the line on the drum. Specific machine specifications include the following:

Figure 6. Radio transmitter worn by operator.

Power Plant - 47 horsepower Volkswagen engine
Variable speed governor
2 gallons (7.57 liters[10]) per hour fuel consumption rating

Gerramatic 9 Winch - 120 feet/minute (36.58 meters/minute) line speed
Drum capacity 316 feet (96.32 meters) of 3/8 inch (.95 centimeters) line

"Electro-bug" radio transmiter and receiver - Model 150 by Challenger Electronics, Inc.
Weight of the machine - 1,600 pounds (726 kilograms)

The radio-controlled single-drum winch was designed to be used as a one-man yarding operation. The machine was moved into a setting by wrapping the end of the winch line around a stump or tree and activating the forward mode of the winch that pulled the yarder through the brush (Figure 7). The machine traveled over small debris. Larger material could require winching the material out of the way before moving the machine. Experience helped to acquire a knowledge of what the machine would do during the moving operation. The machine could tip over when crossing over debris or when moving across the slope instead of parallel with the slope (Figure 8). When the machine tipped over on its side, the operator would use a "hand come-along" to get it upright. At the setting, the back of the machine was anchored with a chain or cable to a nearby stump or tree (Figure 9). Two small outriggers were fastened into place to help stabilize the machine when yarding (Figure 9). During the yarding operation, many times the machine did not remain completely stationary with the ground.

A 5-inch (12.7 centimeters) block was hung in a tree to lead with the yarding that was done at the particular setting (Figure 10). Three

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[10] 1 gallon = 3.7853 liters.

Figure 7. Moving the single-drum winch. (Note the operator in the right hand corner)

Figure 8. Machine tipped over during moving operation.

Figure 9. Stump tie-down to back of machine, outriggers at front of machine.

Figure 10. Strap and block in spar tree. (Note the tree plate on right side of tree)

tree plates were used to protect the residual trees from the strap and block cutting into the tree. Sometimes a second block close to the ground was used to keep the yarder from lifting completely in the air when yarding (Figures 11 and 12).

Quite often more than one spar tree was used from the same machine location for yarding. In this paper, a spar tree refers to the tree where the block was hung to obtain lift. Spar trees were not topped or guyed. A setting refers to a spar tree and the material yarded to that particular tree. The machine location was the actual location of the single-drum winch. In this study, there were 5 machine locations and 10 settings (Figure 13).

Prebunching the logs to the skyline corridor was accomplished by one man pulling the winch line out to the logs, hooking a turn, and following the logs into the corridor where they were unhooked.

Swinging with Mobile Yarder

The Schield-Bantam T-350 mobile yarder used for swinging the prebunched logs was powered by a 453-Detroit diesel engine. Line specifications for the yarder are shown in Table 2.

TABLE 2. LINE SPECIFICATIONS FOR SCHIELD-BANTAM T-350.

	Length		Diameter	
Type	(feet)	(meter)	(inch)	(centimeter)
Skyline	1000	305	3/4	1.90
Mainline	900	275	5/8	1.59
Haulback line	1600	488	7/16	1.11
Chokers	10	3	1/2	1.27

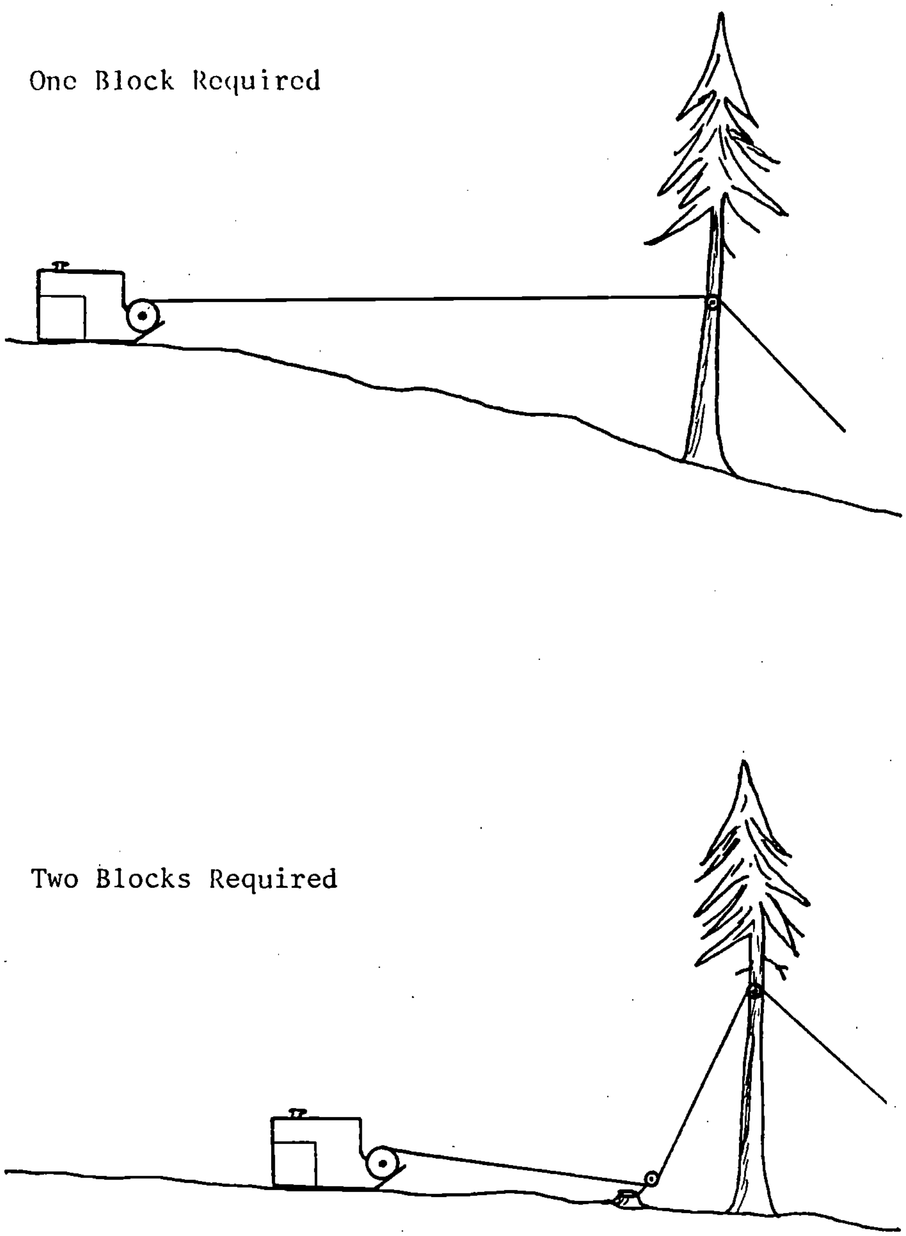


Figure 11. Rigging spar tree for yarding with single-drum winch.

Figure 12. Block at base of tree.
(Note protection of residual
tree from strap)

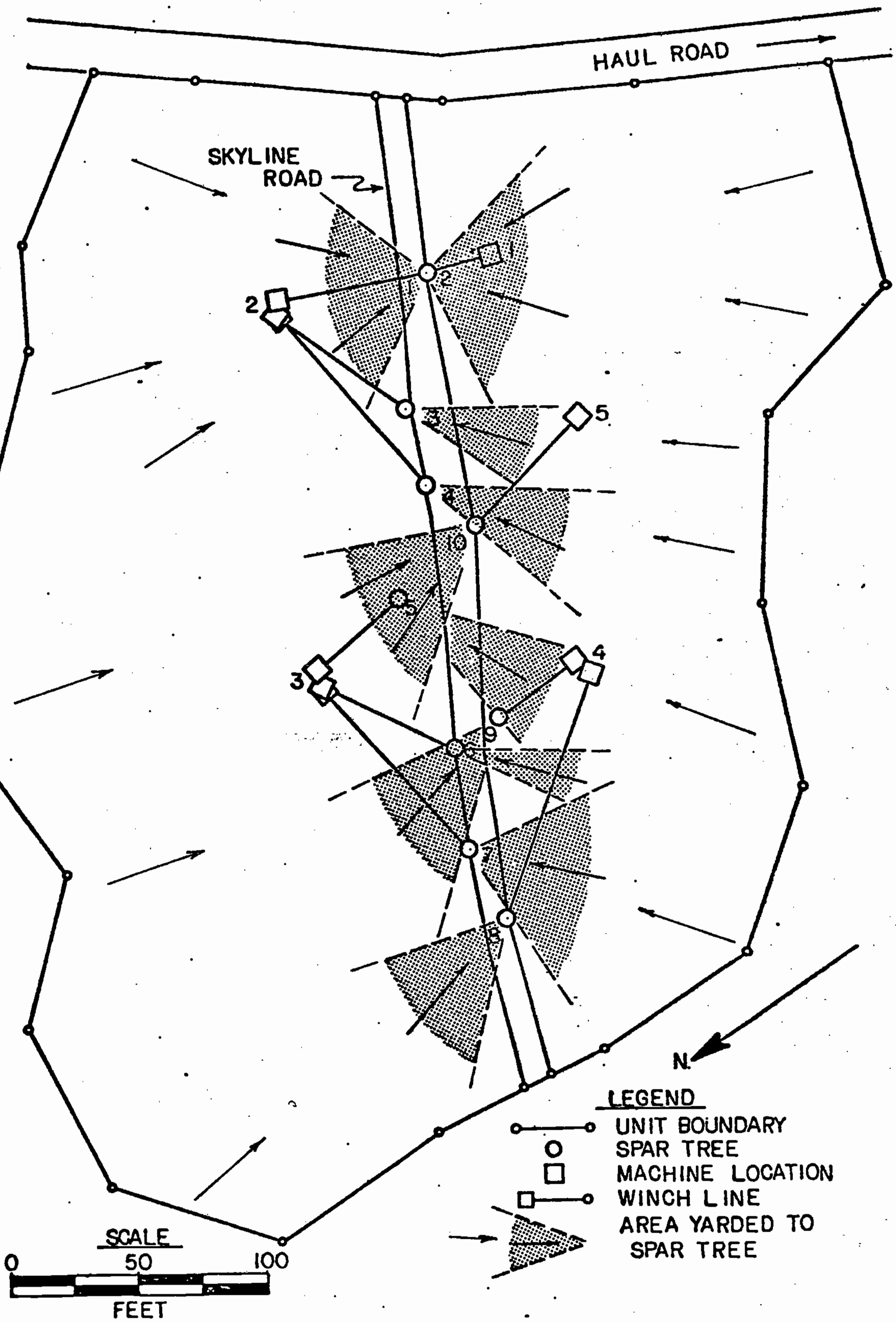


Figure 13. Single-drum winch locations and settings.

A shotgun skyline system with a Maki Carriage was rigged for yarding the skyline corrdior (Figure 14). The Maki Carriage was held stationary during lateral yarding with a stop device (Figures 15 and 16). The carriage was released from the stop when a ferrule near the end of the mainline snapped into the lock in the carriage.

Normally, a four man crew is used when thinning with the Schield-Bantam. In such a system, both the lateral yarding and skyline corridor yarding are done with the mobile yarder. The crew would consist of a yarder engineer, chaser and two chokersetters that communicate by radio signals from transmitters worn by the chokersetters. In this study, swinging the prebunched logs with the mobile yarder was mostly accomplished with a three man yarding crew: a yarder operator, a chaser and one chokersetter.

Time Study Method

The purpose of time studies is to determine the time required by a qualified person, working at a normal pace, to do a specific operation (Barnes, 1968). Time information is a prerequisite to obtaining production rates and costs.

Some type of work sampling technique is needed to obtain the time information. I used the multimoment method of time analysis for this thinning study. A notebook was set up for recording times and field measurements (Figure 17). At regular intervals of 0.1 minute, a dot was recorded under the particular activity in the operation that was occurring.

The multimoment method or "dot tally" technique of time analysis

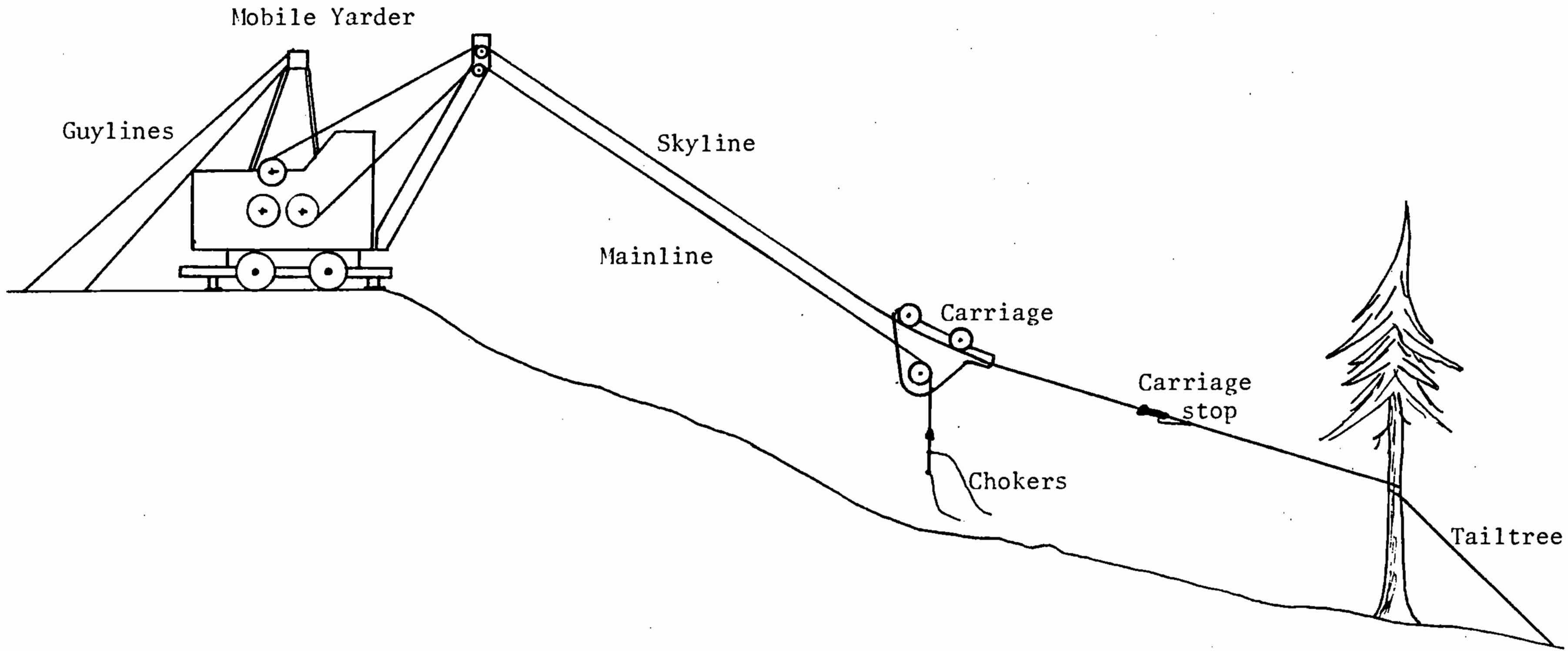


Figure 14. Shotgun system for swinging.

Figure 15. Maki Carriage.

Figure 16. Maki Carriage stop on skyline.

Prebunching - Single-Drum Winch

Turn No.	Out haul	Hook	Inhaul	Unhook	Reset	Equip delay	Yard delay	Slope dist.	Lead∢	Volume	No. chokers	Comments

Swinging - Schield-Bantam

Turn No.	Out haul	Hook	Inhaul	Unhook	Reset	Delay	Slope dist.	Zone	Volume	No. chokers	No. chok-setters	Comments

Figure 17. Examples of field notebook recording form.

has several advantages over other timing methods that made it useful for this study (Sinner, 1973):

1. It is convenient for one man doing all the timing,
2. It is adapted to studies with many activities, especially ones that are of a short duration,
3. It is relatively easy to record the time data with good accuracy,
4. No calculations are needed to obtain times for the activities.

From December 30, 1975 through January 12, 1976, 207 observations were recorded on a prebunching operation with the radio-controlled single-drum winch. From January 26-27, 1976, 113 observations were recorded while swinging the prebunched logs with the Schield-Bantam.

The Yarding Cycle and Influencing Variables

The yarding cycles for the prebunching and swinging operations were divided into regular activities that occurred nearly all the time and irregular activities that occurred randomly. Independent variables that were believed to influence the dependent variable time, were measured during the time study. Also, moving the single-drum winch was divided into three activities and measurements were made on factors believed to influence the move times.

Prebunching Yarding Cycle

Four regular activities and three irregular activities occurring during the radio-controlled single-drum winch operation were:

Outhaul

The activity started when the operator transmitted a signal to the winch to engage the reverse mode and then began pulling the line out from the skyline corridor.

Hook

The outhaul activity stopped and the hook activity began when the operator stopped his forward walking motion and wrapped a choker around a log and hooked the ferrule into the bell. The activity ended when the operator stepped back from the logs and transmitted a signal to engage the winch in the forward mode. This activity could be repeated during the yarding cycle.

Inhaul

Inhaul began when the operator transmitted a signal to the winch to engage the forward mode and then the log was pulled toward the skyline corridor. The activity ended when the logs reached the skyline corridor and the inhaul mode of the winch was stopped.

Unhook

Unhook began when the operator removed the chokers from the logs on the prebunched decks and ended when another regular yarding cycle was ready to begin.

Reset

A reset was a random activity that was caused by obstacles interrupting the inhaul activity and required the operator to set the choker in a new position, obtain a different lead on the log or cut debris out of the yarding path. The hang-ups most often were stumps, residual trees or debris. This activity ended when the logs were free of the obstacle and the inhaul activity was resumed.

Equipment Delay

Machine malfunctions that interrupted the work cycle were considered equipment delays. Two types of delays occurred in this study--short delays less than an hour or delays greater than an hour. The operator would try to alleviate the problem that caused the interruption (taking less than one hour) or he would leave the area to get parts or seek extra help to repair the machine. Times were recorded under equipment delay when the operator remained on the site and worked towards correcting the delay caused by the machine. Gross times were recorded for machine caused delays that exceeded one hour but they were not considered equipment delays during the yarding process.

Yarding Delay

Any uncommon activity within the work cycle that occurred at random and was not a machine caused delay or a reset was classified as a yarding delay. These delays were mostly due to the operator deciding the best way to yard a turn of logs or the operator repositioning some of the equipment.

Variables Influencing the Prebunching

Many variables can be identified that influence logging operations but it is difficult to obtain accurate objective measurements for all the variables. Four influencing variables were identified and measured with the radio-controlled single-drum winch prebunching operation. These were slope distance, lead angle, volume and number of chokers.

Slope Distance

The length on the slope over which the inhaul operation occurred was considered slope distance. This was from the position of the log where it was bucked to the skyline corridor where the log was prebunched. Before yarding, the distance every 25 feet (7.62 meters) laterally from both sides of the skyline corridor was measured and tagged. During the yarding operation, slope distances were estimated and recorded to the nearest 5 feet (1.52 meters) using the tagged distances as a guide.

Lead Angle

Lead angle can best be explained by referring to Figure 18.

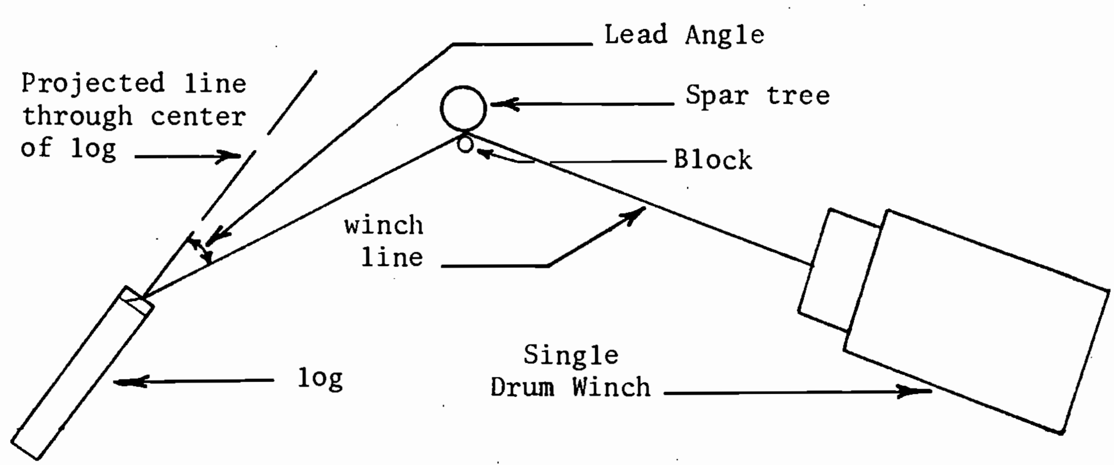


Figure 18. Diagram of lead angle.

A 0° lead angle implies that the projected line through the center of the log coincided with the winch line. A 90° lead angle implies that the log was at a right angle to the winch line. When a turn consisted of more than one log with different lead angles, the lead angle furthest from 0° was recorded. The lead angle was measured to the nearest 5° with a "homemade" angle device.

Volume

Log diameters and lengths were measured prior to yarding and tagged with a number. Log tag numbers were recorded for each turn. Cubic foot volume per turn was later calculated.

Number of Chokers

The number of chokers was the number during each yarding cycle. Normally one or two chokers were used and these usually coincided with the number of logs being yarded per turn. Occassionally a bonus was encountered.

Moving the Single-Drum Winch

Three activities and two influencing variables were identified and measured during the moving operation.

Tear Down

The tear down activity involved removing rigging equipment and preparing the machine to be moved. The strap, tree plates and block in the spar tree were removed. The outriggers on the machine were removed and the strap anchoring the back of the machine was also removed.

Move In

The machine was moved from one location to another during the move in activity. This included winching material out of the path of the machine.

Rig Up

The rig up activity included several parts. The machine was secured in a new location by anchoring the back of the machine to a nearby stump or tree, and installing the outriggers. Tree plates were driven into a spar tree, a strap was hung and the block was attached to the strap. The winch line was then threaded through the block in the spar tree (Figures 10 and 11).

Variables Measured During the Moving of the Single-Drum Winch

Distance

The length on the slope that the single-drum winch traveled during the move in activity was estimated to the nearest 10 feet (3.05 meters).

Block Height

The distance from the ground to the block in the spar tree was estimated to the nearest foot (.30 meters).

Swinging Yarding Cycle

Four regular activities and two irregular activities occurring during the swinging operation with the mobile yarder were:

Outhaul

The activity started when the Maki Carriage left the landing by gravity and traveled down the skyline. The activity ended when the carriage locked into the stop on the skyline.

Hook

The activity started when the chokersetters took the chokers and set them around a turn of logs. They then moved to a safe position and signaled the yarder operator with a radio transmitter to take-up on the mainline drum. At this moment, the activity ceased.

Inhaul

This activity started when the turn of logs moved toward the yarder as the mainline wrapped around the drum. The activity ended when the logs stopped their forward motion and landed on a log deck in front of the yarder.

Unhook

Unhook began when the logs were settled on the deck. The chokers were released from the logs by the chaser and the skyline was raised by the yarder engineer. The activity ended when the brake on the mainline drum was released and the carriage left the landing. The logs could be repositioned on the deck before the chokers were released during this activity.

Reset

A reset was a random activity that was caused by an obstacle interrupting the inhaul activity. Usually this activity required repositioning the carriage to obtain a different lead angle or repositioning the choker to free the turn from the hang-up.

Delay

A delay was an interruption in the work cycle caused by men or the equipment that occurred randomly and was of relative short duration (less than 20 minutes). This activity included moving the stop on the skyline.

Variables Influencing the Swinging Operation

Five variables were identified and measured as influencing the swing operation. These were slope distance, zone, volume, number of chokers and crew size.

Slope Distance

Slope distance was the length on the slope in the skyline corridor over which the inhaul operation occurred. This was from the position of the turn of logs in the prebunched decks to the mobile yarder location. Slope distance in the skyline corridor was measured before logging to aid in the recording of data. Residual trees were tagged every 25 feet (7.62 meters). During the yarding operation, slope distances were estimated using the tagged distances as guides and recorded to the nearest 5 feet (1.52 meters).

Zone

Zone referred to the average lead angle the turn of logs formed with the skyline (Figure 19). A 0° lead angle indicates that the turn of logs was parallel to the skyline while a 90° lead angle implies that the logs were at a right angle to the skyline.

Zones were established before logging with the mobile yarder by

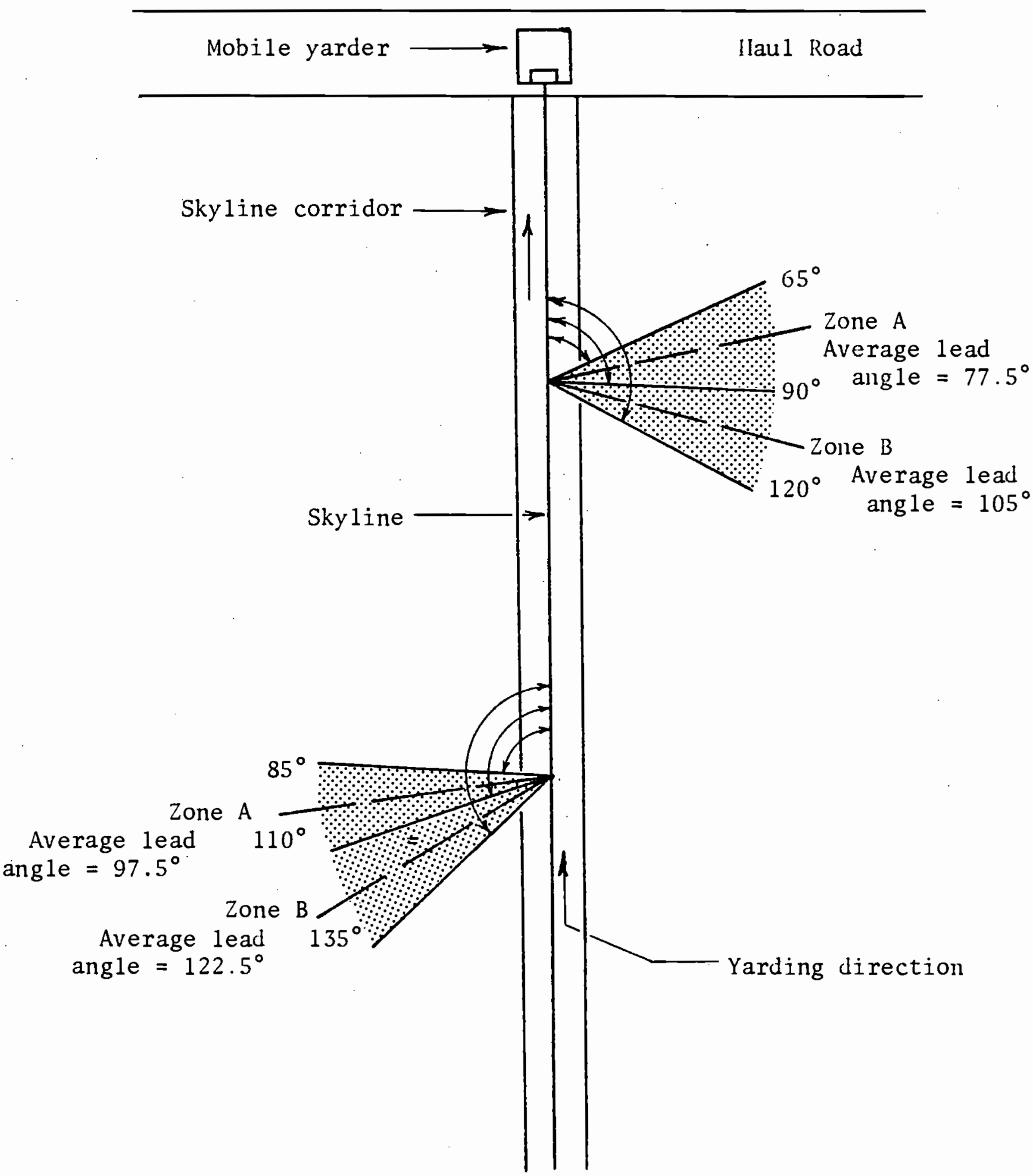


Figure 19. Diagram of zone.

bearings with a hand compass. Stakes were driven in the ground and color-coded with ribbon to associate the correct zone with the particular prebunched deck. Prebunched decks were separated into different zones mainly by residual tree locations (Figure 20).

A zone letter was recorded for every turn that was yarded in the swinging operation and the average lead angles for the zones were calculated later. When the logs in a turn were located in more than one zone, the zone nearest to a 0° lead angle was recorded. Lettered zones with the average lead angle and the number of logs prebunched in the zone are shown in Table 3.

Volume

Many logs had to be remeasured and tagged after prebunching with the single-drum winch. Log tag numbers were recorded for each turn during the swinging operation. Cubic foot volumes per turn were later calculated.

Number of Chokers

Number of chokers was the number used in the yarding operation for each turn.

Crew Size

Crew size was the number of chokersetters. This was either one or two.

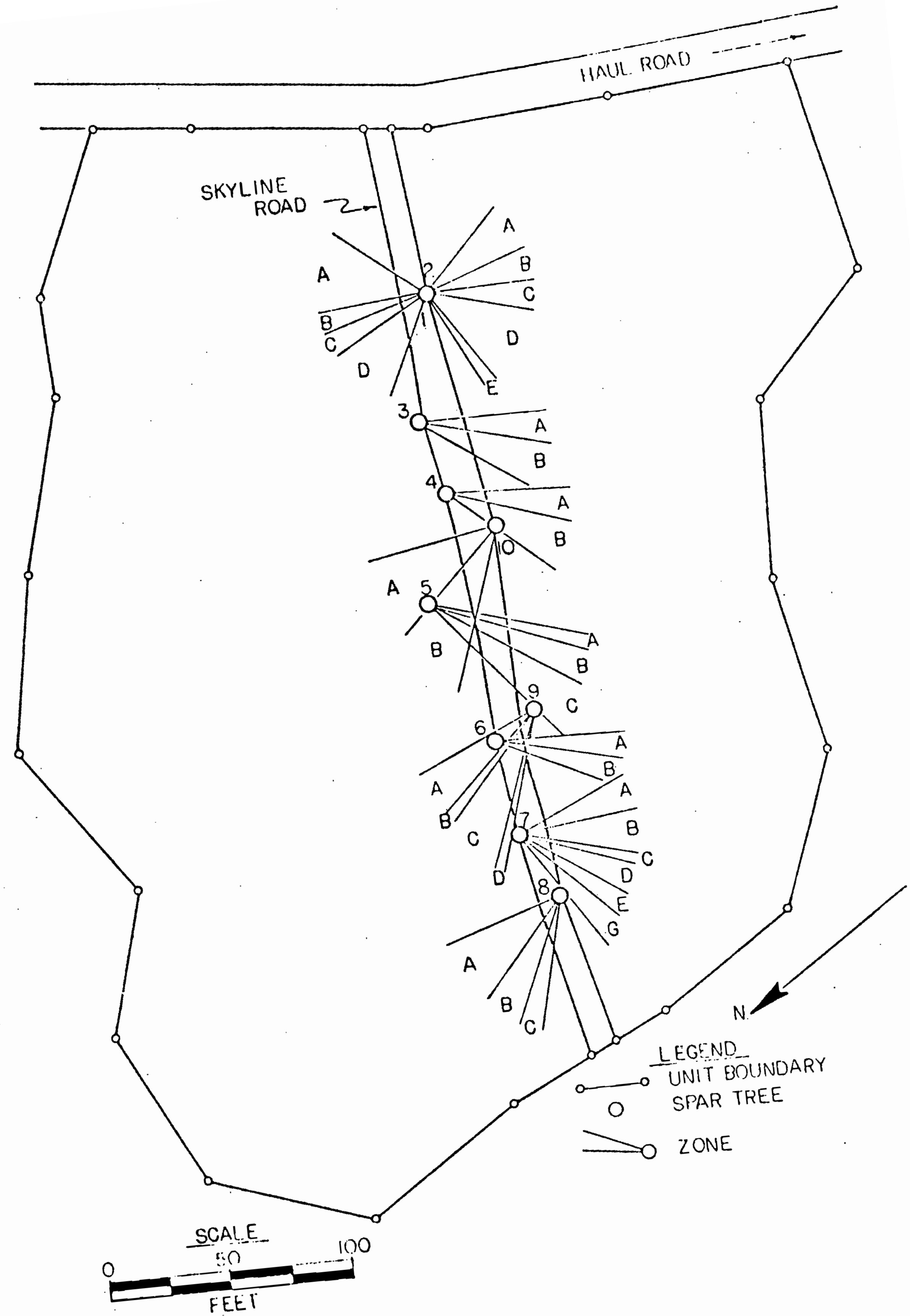


Figure 20. Zones for swinging operation.

Table 3. AVERAGE LEAD ANGLE AND NUMBER OF LOGS FOR ZONES.

Zone		Average Lead Angle with Skyline (degrees)	Number of Logs
1	A	65	14
	B	92.5	2
	C	104.5	10
	D	129	8
2	A	66	10
	B	88	15
	C	105	35
	D	134	10
	E	158	2
3	A	103	3
	B	125	10
4	A	108.5	12
	B	127	17
5	A	115.5	1
	B	123.5	7
	C	137.5	6
6	A	105.5	15
	B	117.5	6
7	A	83.5	1
	B	102.5	10
	C	115.5	3
	D	125.5	6
	E	138	6
	G	149	2
8	A	116.5	17
	B	140.5	8
	C	154	13
9	A	115	11
	B	127	5
	C	140	5
	D	153	4
10	A	108.5	2
	B	127	17

DATA ANALYSIS

Basic Time Study Results

The arithmetic means of the independent variables show the average logging characteristics for the thinning operation (Table 4). The means of the dependent variables show the time spent in each of the regular and irregular activities for the average logging conditions. The means and percentages of total yarding time in each activity help identify elements of the work cycle that are the major time consumers (Table 5).

The average yarding time per turn, including delays, with the single-drum winch was 5.08 minutes. Thirty-four percent of yarding time with the single-drum winch was involved with either equipment or yarding delays. The next most time consuming element was reset which accounted for 17 percent of the total yarding time.

The average yarding time per turn, including delays, on the swing operation was 3.44 minutes. The most time consuming activities were hook and unhook which accounted for 54 percent of the yarding time per turn.

Average values and percentages for moving the single-drum winch are shown in Table 6.

Average values yield important information that aid in analyzing logging operations. However, it may be equally important to consider the range of values that contribute to the averages and the distribution of their values between a maximum and minimum. Frequency distributions of the dependent variable, total turn time, and independent

Table 4. AVERAGE VALUES FOR INDEPENDENT VARIABLES INFLUENCING THE YARDING OPERATION.

	Single-Drum Winch[1]	Mobile Yarder[2]
Yarding Distance		
(feet)	76	178
(meters)	23.16	54.25
Lead Angle (degrees)	28.3	110.8
Number of Logs per Turn	1.3	2.8
Volume per Turn		
(cubic feet)	20.69	42.31
(board feet)	124	254
(cubic meters)	0.88	1.80
Number of Chokers	1.4	2
Crew Size	1	1.2
Move Distance[3]		
(feet)	130	
(meters)	39.62	
Block Height[4]		
(feet)	12.2	
(meters)	3.72	

[1]Based on 207 observations.

[2]Based on 113 observations.

[3]Based on 3 observations.

[4]Based on 10 observations.

Table 5. AVERAGE YARDING TIME IN MINUTES AND PERCENT BY ACTIVITY FOR PREBUNCHING AND SWINGING.

Yarding Activity	Single Drum Winch[1] Average Time (minutes)	Single Drum Winch[1] Percent of Average Total Time	Schield-Bantam[2] Average Time (minutes)	Schield-Bantam[2] Percent of Average Total Time
Outhaul	.58	11.4	.28	8.1
Hook	.67	13.2	.86	25.0
Inhaul	.77	15.2	.58	16.9
Unhook	.43	8.5	.98	28.5
Reset	.89	17.5	.10	2.9
Equipment Delay	1.24	24.4	.64	18.6
Yarding Delay	.50	9.8		
Total Turn Time (delay free)	3.34	65.7	2.80	80.4
Total Turn Time (including delays)	5.08	100.0	3.44	100.0

[1]Based on 207 observations.

[2]Based on 113 observations.

Table 6. AVERAGE MOVING TIME FOR THE SINGLE-DRUM WINCH IN MINUTES AND PERCENT BY ACTIVITY.

	Average Time (minutes)	Percent of Average Total Time
Tear Down (based on 8 observations)	6.4	15
Move In (based on 3 observations)	26.7	61
Rig Up (based on 8 observations)	10.4	24
Total	43.5	100

Average Move Time per Turn = 1.04 minutes variables for the single drum winch operation and the Schield-Bantam operation are included in Figures 21 through 28.

Regression Analysis

I developed regression equations for the activities in the yarding cycle for prebunching with the single-drum winch and swinging with the mobile yarder. First, a hypothesis was formed with the independent variables thought to influence the dependent variable time for the activities in the yarding cycle. The backstep procedures in the SIPS computer program at Oregon State University were used for testing the hypothesis and determining regression equations. Multiple correlation coefficients were determined that measure the degree of linear association between the variables. Time estimated by the regression equation are in minutes.

A 0.20 probability level was used to define significance of the variables influencing yarding times for the prebunching and swinging. Many variables were also significant at the 0.01 probability level[11].

---

[11] In the regression equations:

**** indicates significance of a variable at the 0.01 probability level,

*** indicates significance of a variable at the 0.05 probability level,

** indicates significance of a variable at the 0.10 probability level,

* indicates significance of a variable at the 0.20 probability level,

n.s. indicates that the variable is not significant at the 0.20 probability level,

R is the multiple correlation coefficient,

S is the standard error of the regression equation.

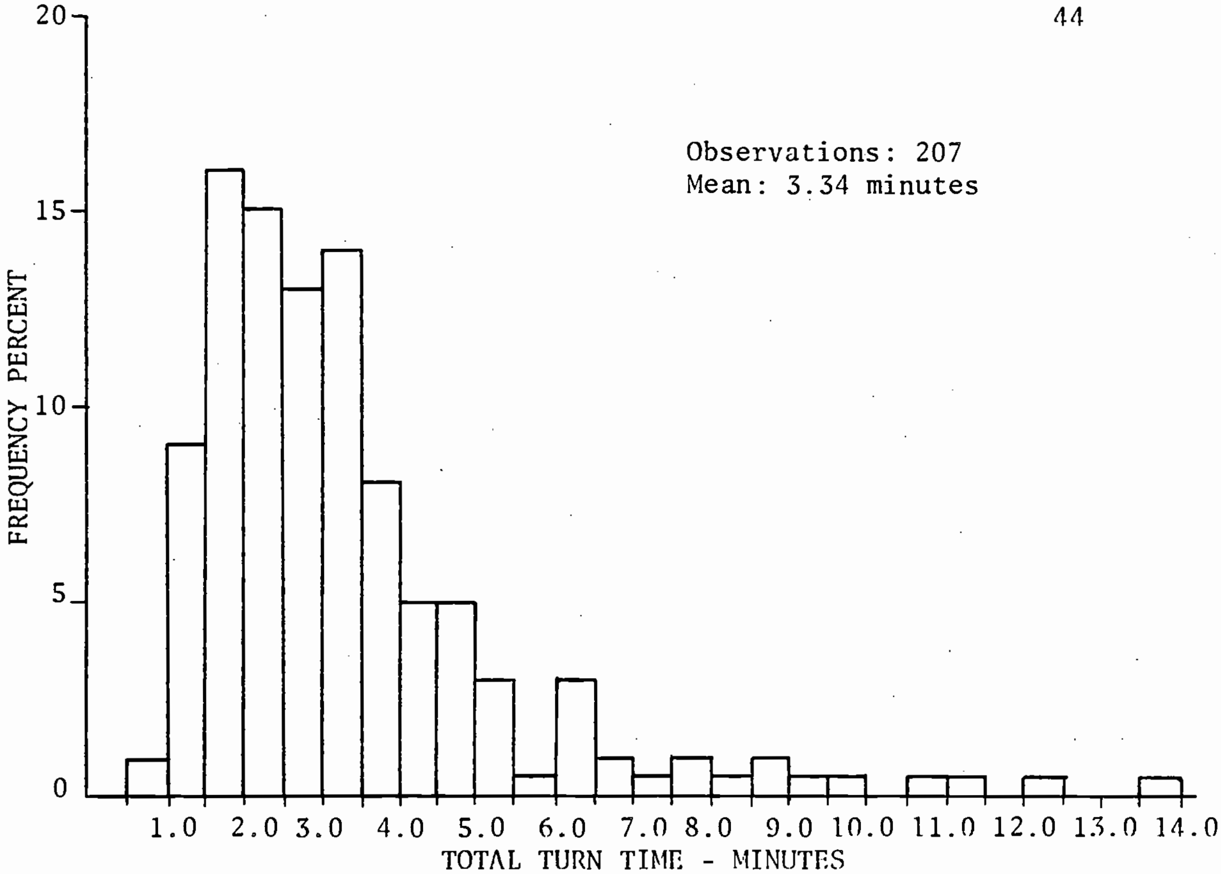


Figure 21. Frequency distribution of total turn time, delay free (Single-Drum Winch).

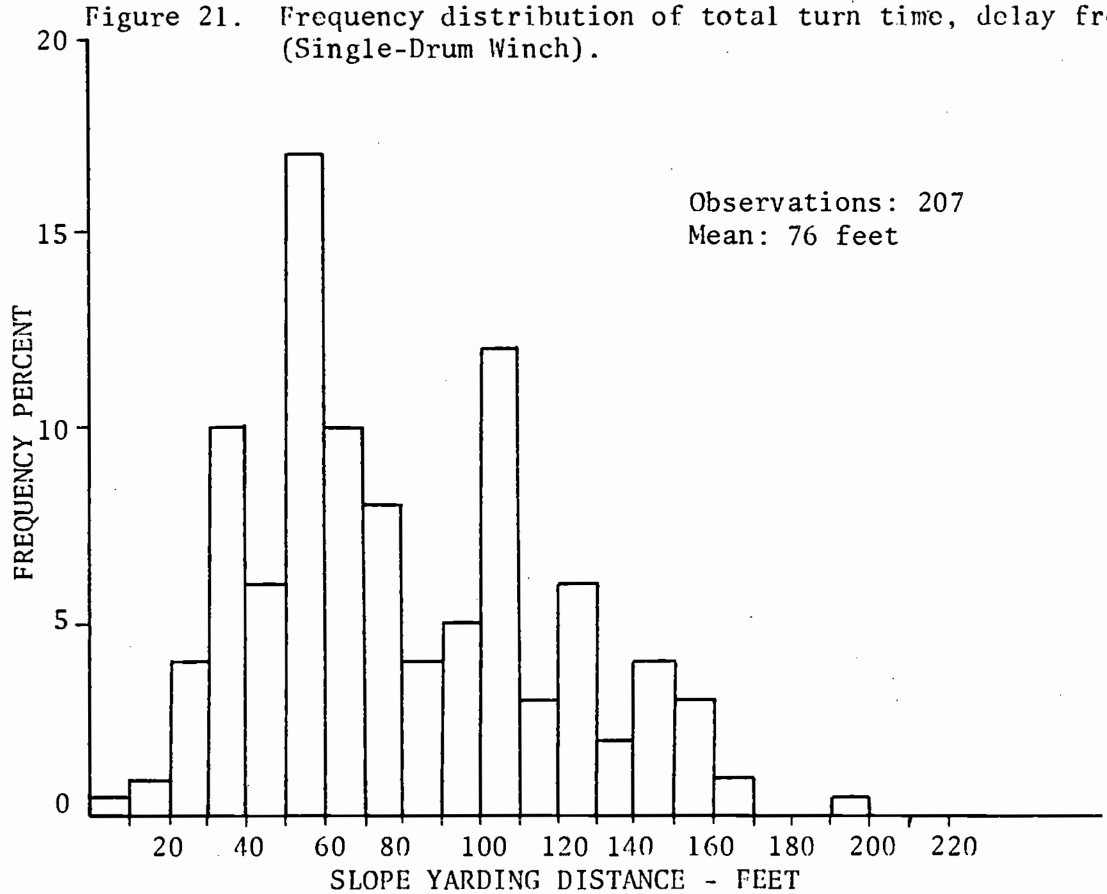


Figure 22. Frequency distribution of slope yarding distance (Single-Drum Winch).

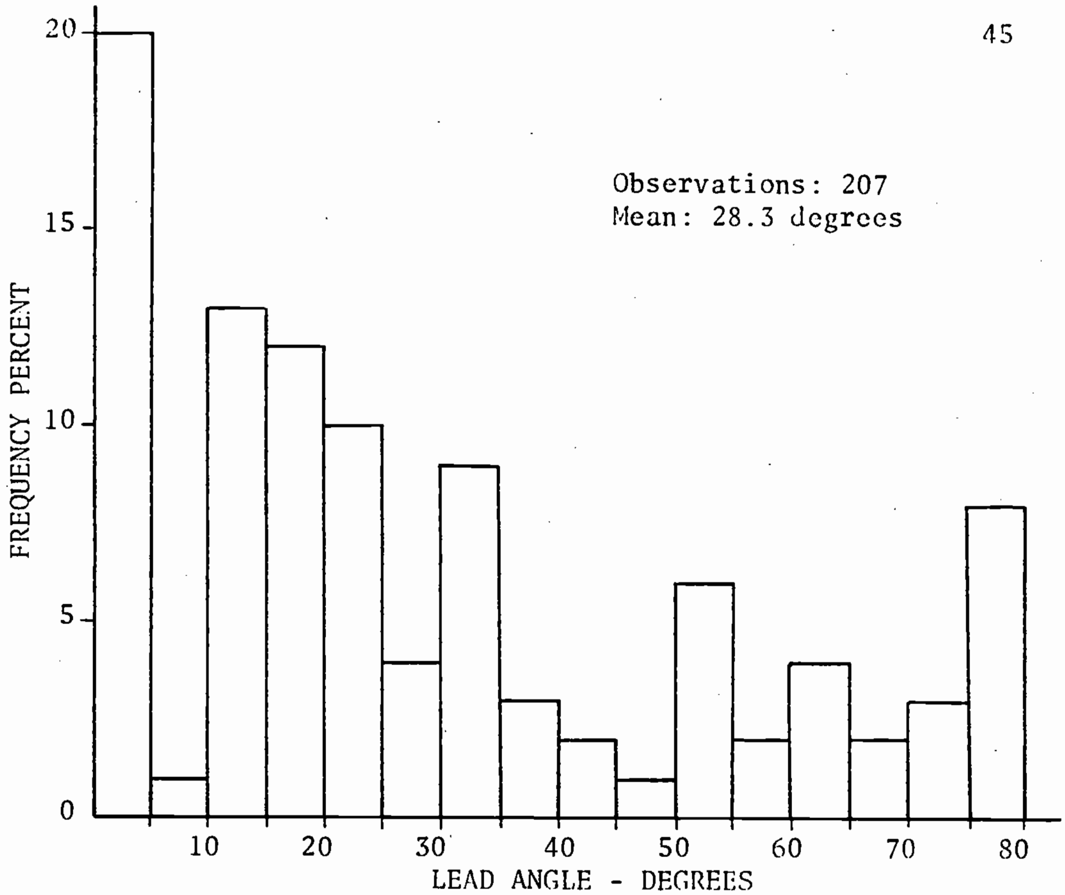


Figure 23. Frequency distribution of lead angle (Single-Drum Winch).

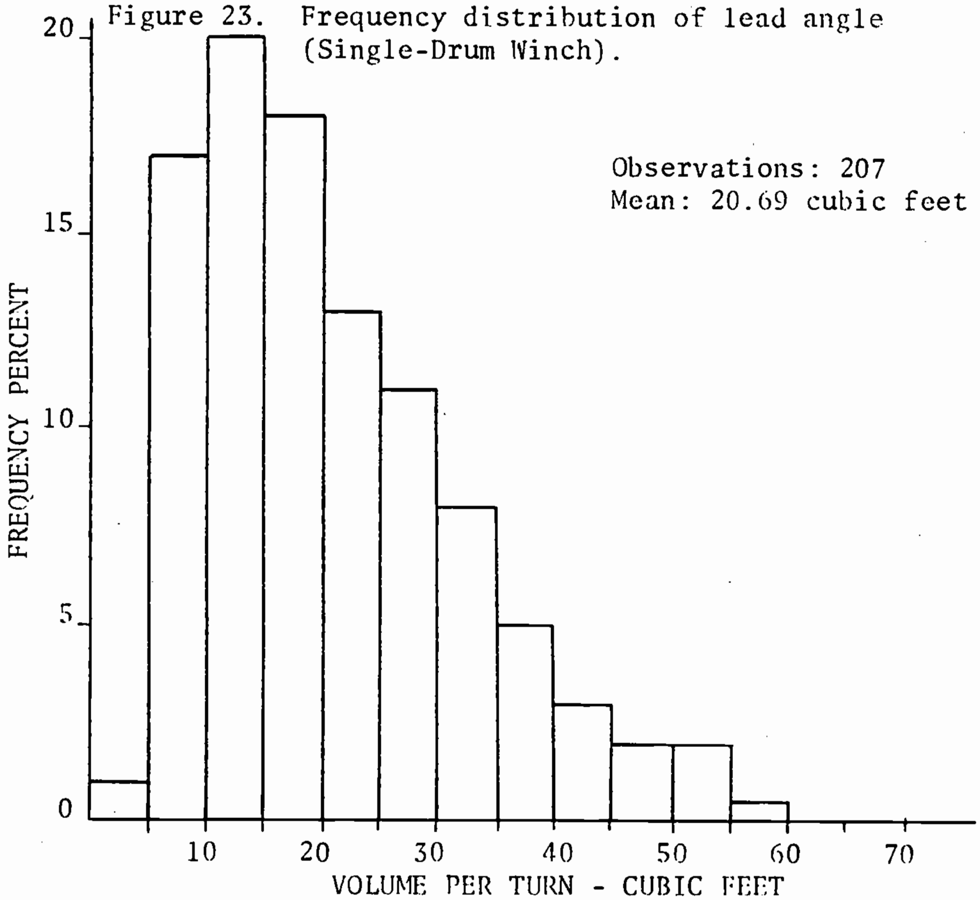


Figure 24. Frequency distribution of volume per turn (Single-Drum Winch).

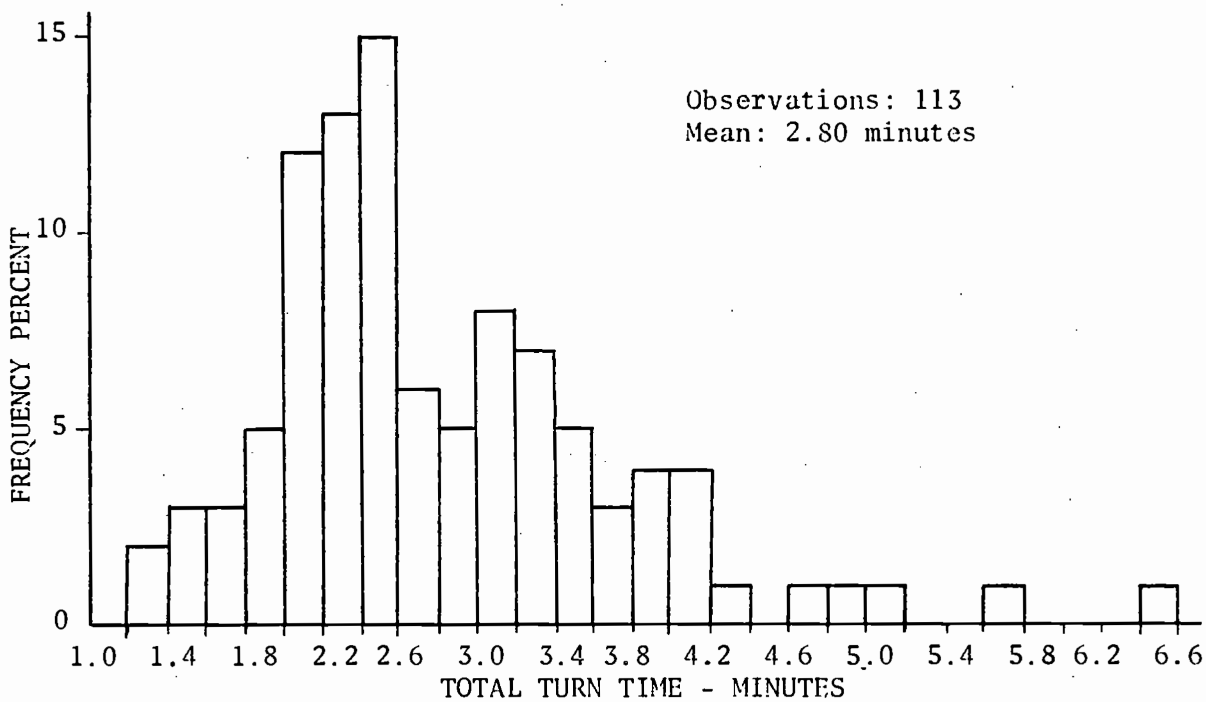


Figure 25. Frequency distribution of total turn time, delay free (Mobile Yarder).

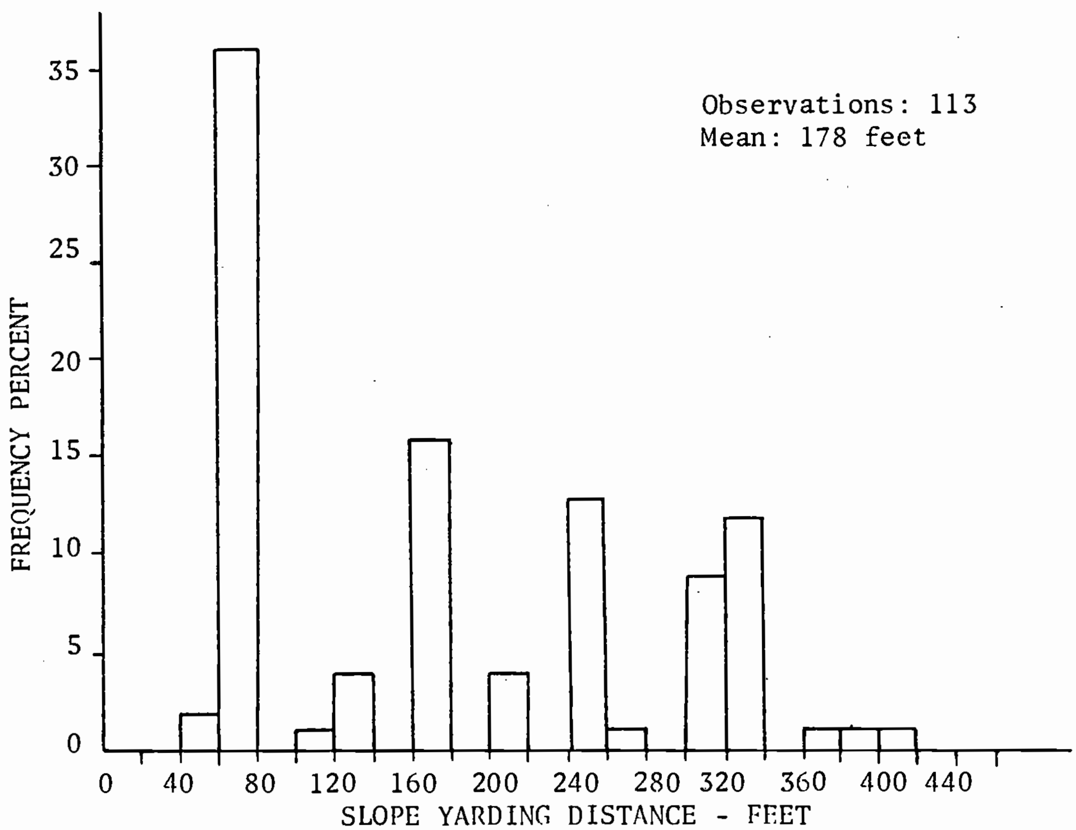


Figure 26. Frequency distribution of slope yarding distance (Mobile Yarder).

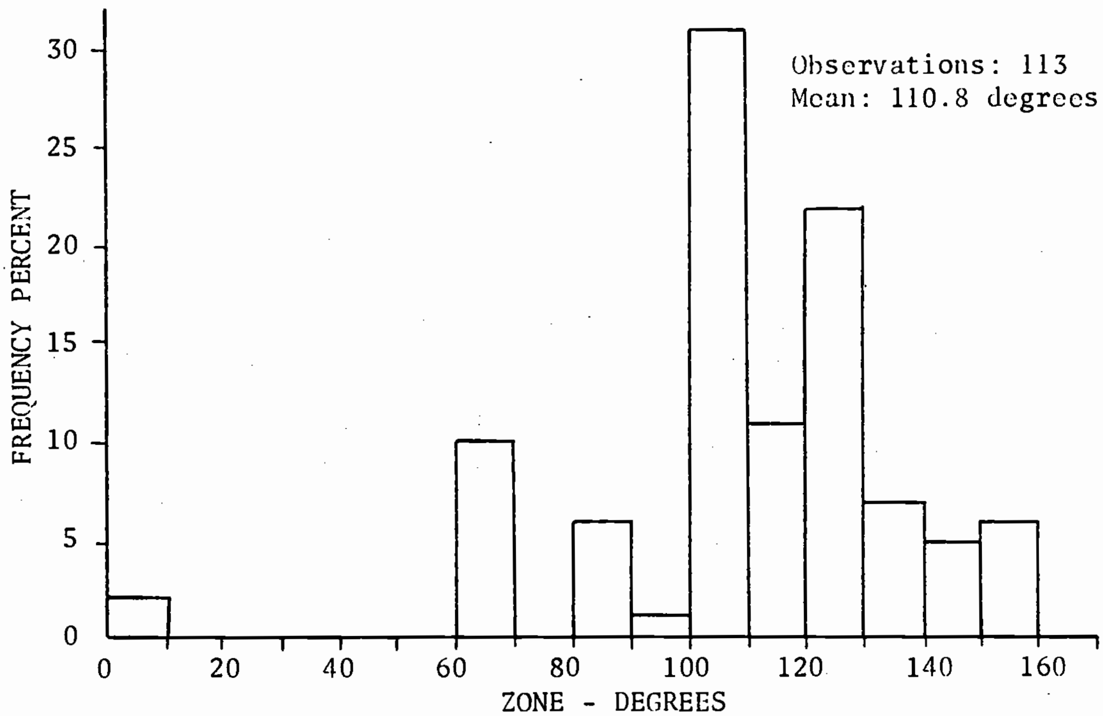


Figure 27. Frequency distribution of zone (average lead angle) (Mobile Yarder).

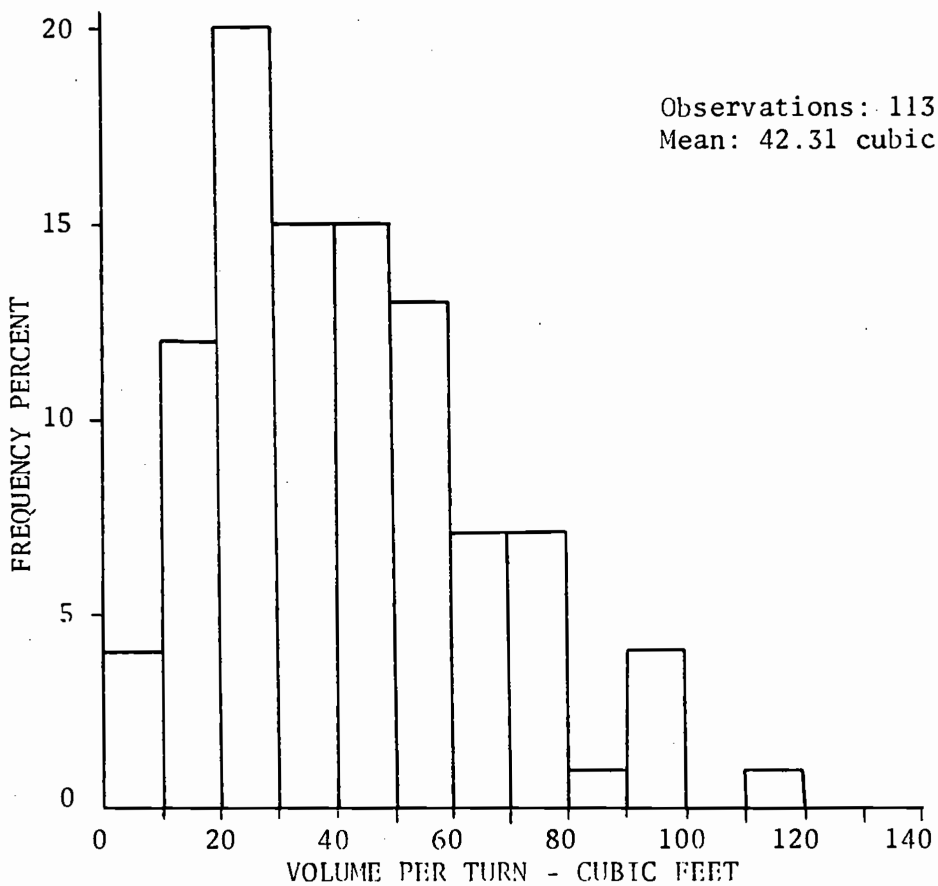


Figure 28. Frequency distribution of volume per turn (Mobile Yarder).

There were 207 observations of the prebunching yarding cycle and 113 observations of the swinging yarding cycle.

Radio-Controlled Single-Drum Winch - Prebunching

In the regression equations that follow:

SDIST = slope yarding distance

LANGLE = lead angle of the log before yarding

VOLUME = log volume per turn

NCHOKS = number of chokers used

Outhaul

Ho: Outhaul Time = f (SDIST)

Outhaul Time = .25896 +.0041813 (SDIST)**** R = .645 S = .189

It took longer to pull the winch line out laterally from the skyline corridor as the slope yarding distance increased.

Hook

Ho: Hook Time = f(VOLUME, NCHOKS)

Hook Time = -.19851 +.010476 (VOLUME)**** +.4646 (NCHOKS)**** R = .521 S = .476

Hooking is influenced by the efficiency of the person hooking the logs as well as by the many characteristics of the logging unit, some of which may be difficult to objectively measure (Dykstra, 1975). An example of this would be brush density. In this study, two measurable variables, volume per turn and number of chokers, increased hook time as they increased in size or number. The number of chokers per turn and the number of logs per turn were usually the same. Very few bonus logs were hooked and two logs were yarded most of the time when two chokers were used. Since the logs in the study unit had approximately the same volume, volumes per turn that were higher than the average log volume usually indicated that more than one log was hooked per turn.

Inhaul

Ho: Inhaul Time = f(SDIST, LANGLE, VOLUME, NCHOKS)

```
Inhaul Time = -.23064                          R = .808
              +.0086502 (SDIST)****            S = .22
              +.0015168 (LANGLE)****
              +.20869 (NCHOKS)****
```

Past studies of cable operations have shown that inhaul time increases as the slope yarding distance increases (Dykstra, 1975). This applied to the prebunching operation also. This study revealed that the lead angle was a significant variable that increased inhaul time as the lead angle increased: This indicates, as expected, faster inhaul times were achieved when the logs were closer to a straight lead toward the spar tree. It also indicates the importance of a felling job where trees are felled as close to a direct lead to the skyline corridor as possible. At first, it might seem that the number of chokers would have nothing to do with the inhaul yarding time. In the single-drum winch operation, the number of chokers increased the inhaul time because two logs were very seldom hooked at the same location. One log was inhauled close to a second log and then the eye of the choker was removed from the hook on the end of the winch line and another log was hooked and inhauled towards the second log. Then both chokers were attached to the hook on the winch line and the inhaul operation was continued.

Unhook

Ho: Unhook Time = f(VOLUME, NCHOKS)

```
Unhook Time = .1449                            R = .351
              +.0049622 (VOLUME)****           S = .260
              +.12773 (NCHOKS)****
```

The unhook time increased as the volume per turn and number of chokers increased in size or number. The same relationship exists in the regression equation that was explained previously for the hook activity.

Reset

Ho: Reset Time = f(SDIST, LANGLE, VOLUME, NCHOKS)

```
Reset Time = -1.9226                           R = .414
             + .013405 (SDIST)****             S = 1.387
             +1.2767 (NCHOKS)****
```

Reset time was influenced by slope yarding distance and the number of chokers. As the slope yarding distance increased, the possibility of hang-ups increased.

Reset time also increased with the number of chokers used because hang-ups took longer to free when there was more than one log per turn. A common hang-up during the inhaul operation occurred when the logs reached the back end of the prebunched deck and there was insufficient lift to clear the back of the deck. One log would require unhooking while the other one was reset and yarded onto the deck. The second log would then be rehooked and yarded onto the prebunched deck.

Total Turn Time

Ho: Total Turn Time = f(SDIST, LANGLE, VOLUME, NCHOKS)

$$\text{Total Turn Time} = -2.8897 + .028864\,(\text{SDIST})^{****} + .010653\,(\text{LANGLE})^{***} + .036543\,(\text{VOLUME})^{****} + 2.1101\,(\text{NCHOKS})^{****}$$

R = .624
S = 1.67

The estimated total turn time for the single-drum winch operation increased as slope distance, lead angle, volume and number of chokers increased. Forty percent of the variation in total turn time is explained by these variables. This equation seems self-explanatory based on previous discussion of the sub-activities that contribute to total turn time. I substituted the average logging unit conditions as stated in Table 2 into the total turn time regression equation and obtained a close comparison to the average total turn time shown in Table 3:

Total Turn Time predicted from Regression Equation = 3.32 minutes

Average Total Turn Time = 3.34 minutes

During this study, one or two chokers were used when yarding with the single-drum winch. Less time was spent in the hooking and reset activity when one choker was used but more volume per turn was obtained when two chokers were used. From observations, it seemed that with relatively short yarding distances, the inhaul and outhaul time was a short duration and the additional time spent obtaining two logs that were not close together was unproductive. On the other hand, it seemed advantageous to yard two logs at long yarding distances because it was more time consuming and fatiguing to pull the winch line a long distance. I determined a break even point between one and two chokers based on volume yarded to the skyline corridor per hour (Figure 29). At yarding distances less than 89 feet (27.13 meters), the operator should not spend extra time with a two log turn unless the logs are close together, easy to reach and the possibility of hang-ups during the inhaul operation is not very high. For distances beyond 89 feet (27.13 meters), it is more advantageous to use two chokers and spend some extra time obtaining a two log turn.

Block Height

When reviewing the move data for the single-drum winch operation, it seemed that the height of the block in the spar tree that the winch line passed through would influence reset and yarding time. Regression equations were not significant for block height. Part of this can be explained by the fact that from the turns observed, there was not much variation in the height of the block in the spar tree. Most of the unit was logged with the block height varying between 5 to 12 feet (1.52 to 3.66 meters). One setting was completely logged at an average block height of 23.5 feet (7.16 meters).

Moves

During the prebunching operation, the single-drum winch changed locations four times and ten different spar trees were used. There was not enough data to develop reliable regression equations that predict move time.

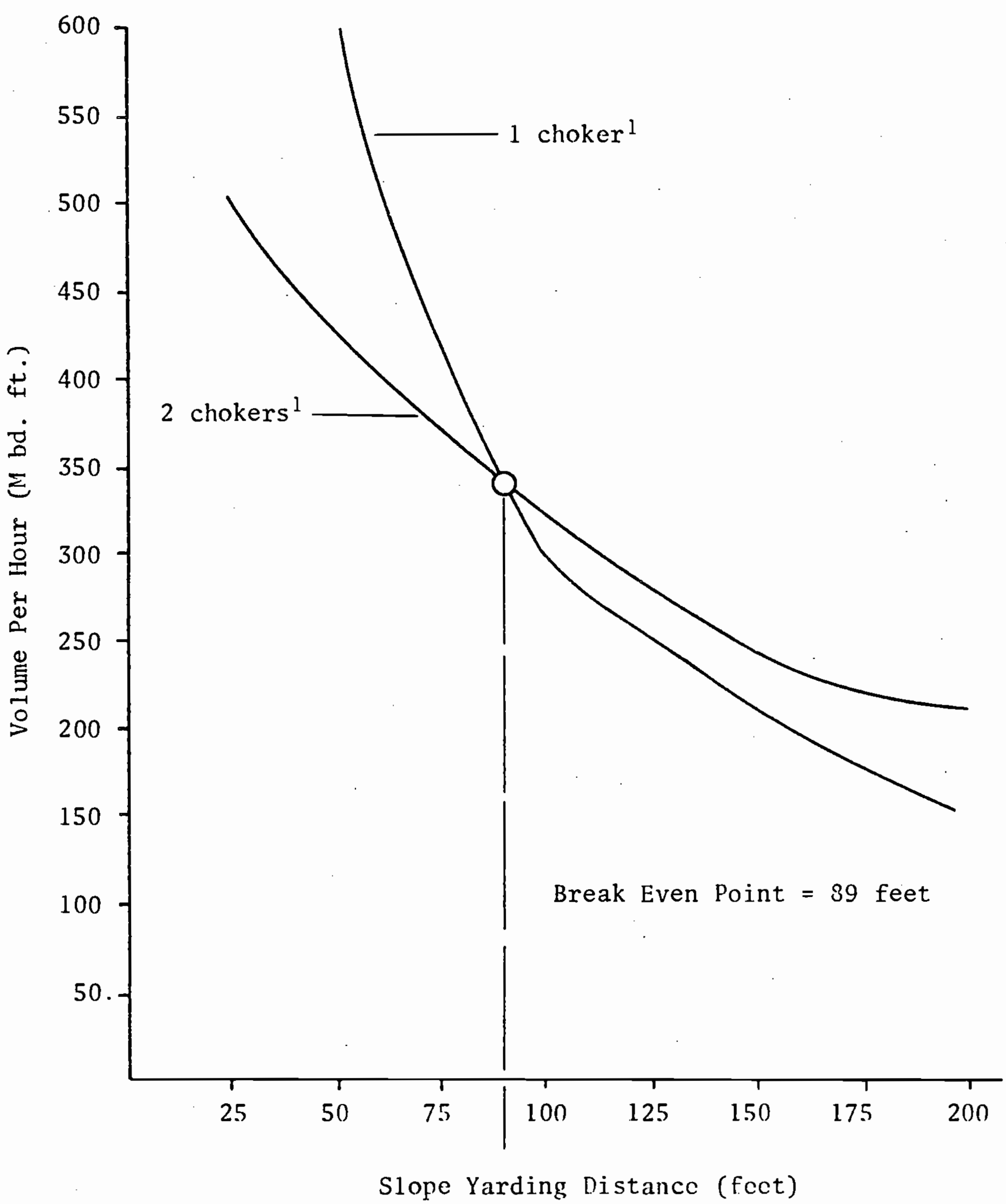


Figure 29. Break even distance between one and two chokers for the prebunching operation.

---

[1]Assumptions: 1 choker = 1 log, 15 cubic feet.
2 chokers = 2 logs, 30 cubic feet.

Mobile Yarder - Swinging

In the regression equations that follow:

SDIST = slope yarding distance

ZONE = the average lead angle of the turn of logs during yarding

VOLUME = the log volume per turn

NMEN = the number of persons setting chokers

Outhaul

Ho: Outhaul Time = f(SDIST)

Outhaul Time = -.022806 +.0016817 (SDIST)**** R = .963 S = .048

It took longer for the carriage to return by gravity down the skyline corridor as the slope yarding distance increased.

Hook

Ho: Hook Time = f(ZONE, VOLUME, NMEN)

Hook Time = .67028 +.0042266 (VOLUME)**** R = .311 S = .297

The variables ZONE and NMEN were not significant to explain part of the variation in hook time. Hook time should normally decrease as the number of men setting chokers increases. In the swinging part of the thinning study, one chokersetter set the turn of logs 82 percent of the time. This chokersetter appeared to be an excellent worker and performed well when working alone. The other chokersetter that helped occasionally tended to offer more verbal advice than actual physical help. As a result, hook time was not significantly reduced when two men set chokers instead of one.

Inhaul

Ho: Inhaul Time = f(SDIST, ZONE, VOLUME, NMEN)

Inhaul Time = .30198 +.0015782 (SDIST)**** R = .786 S = .118

Inhaul time was dependent only on slope distance for this study. I had thought that zone would influence inhaul time. One reason it may not have been significant is the fact that many residual trees surrounding prebunched decks with critical lead angles (around 90° or less) were small trees (6 inches (15.24 centimeters) dbh or less). The Schield-Bantam had sufficient power to pull the small residual trees out of the way. Once the residual trees were bent over, logs would slide over the trees. This made it just as easy and fast to inhaul logs with a lead angle near 90° as it did to inhaul logs with a better lead angle greater than 90°.

Unhook

Ho: Unhook Time = f(VOLUME)

Unhook Time = .90226 +.0019126 (VOLUME)n.s. R = .110 S = .400

In this study, unhooking time was not significantly influenced by volume. Other variables that were not measured during the swinging operation, such as the height of the log deck, appeared to influence the variance in the unhook data.

Reset

Ho: Reset Time = f(SDIST, ZONE, VOLUME, NMEN)

Reset Time = -.03145 +.0029884 (VOLUME)* R = .148 S = .456

Reset time increased as volume per turn increased. As mentioned previously, the logs in this study had approximately the same volume. As the volume per turn increased, the number of logs per turn usually increased. It took longer to reset a turn of logs as the number of logs yarded per cycle increased.

Total Turn Time

Ho: Total Time = f(SDIST, ZONE, VOLUME, NMEN)

```
Total Time = 1.0935                          R = .586
           + .0040312 (SDIST)****            S = .718
           + .00519 (ZONE)***
           + .0092485 (VOLUME)****
```

The estimated total turn time for swinging the prebunched logs in this study with the mobile yarder increased as slope distance, zone and volume increased. Thirty-four percent of the variation in total turn time is explained by these variables. The logic of increased time per turn with increased slope distance and volume is self-explanatory based on previous discussion of the sub activities that contribute to total turn time. However, increasing the lead angle of the turn of logs seems like it would decrease the total yarding time.

I believe that characteristics of this particular time study contributed to an illogical relationship between turn time and zone. This was due to three factors:

1. During the prebunching operation, it was recognized that the angle the logs were decked in the skyline corridor could influence the swinging operation and the damage to residual trees. Therefore, most of the logs were prebunched at an acceptable lead for the swinging operation (Figure 20). A lead angle greater than 90° was considered

acceptable. The average lead angle for the swinging operation was 110.8°.

2. One area where logs were prebunched at a potential critical angle for swinging was around the small residual trees at Setting 6 and 7. As noted earlier, these trees were easily pulled over during the inhaul operation and logs slid over the trees. As can be seen from Figure 30, the thinning intensity around the area where most of the stand damage occurred was less than the average thinning intensity over the remainder of the unit.

3. The largest prebunched deck was at Setting 2. This deck had some logs at a lead angle of less than 90° that could have increased the total yarding time but did not because the logs were yarded from the uphill side of the spar tree towards the mobile yarder. The position of residual trees allowed yarding the logs from the uphill side of the spar tree without great difficulty (Figure 20). The logs at a lead angle close to 90° or greater swung out easily on the downhill side of the spar tree but increased turn time slightly by having to swing around the residual trees.

I substituted the average logging unit conditions as stated in Table 4 into the total turn time regression equations and obtained a close comparison to the average total turn time as stated in Table 5:

Total Turn Time predicted from Regression Equation = 2.78 minutes

Average Total Turn Time = 2.80 minutes

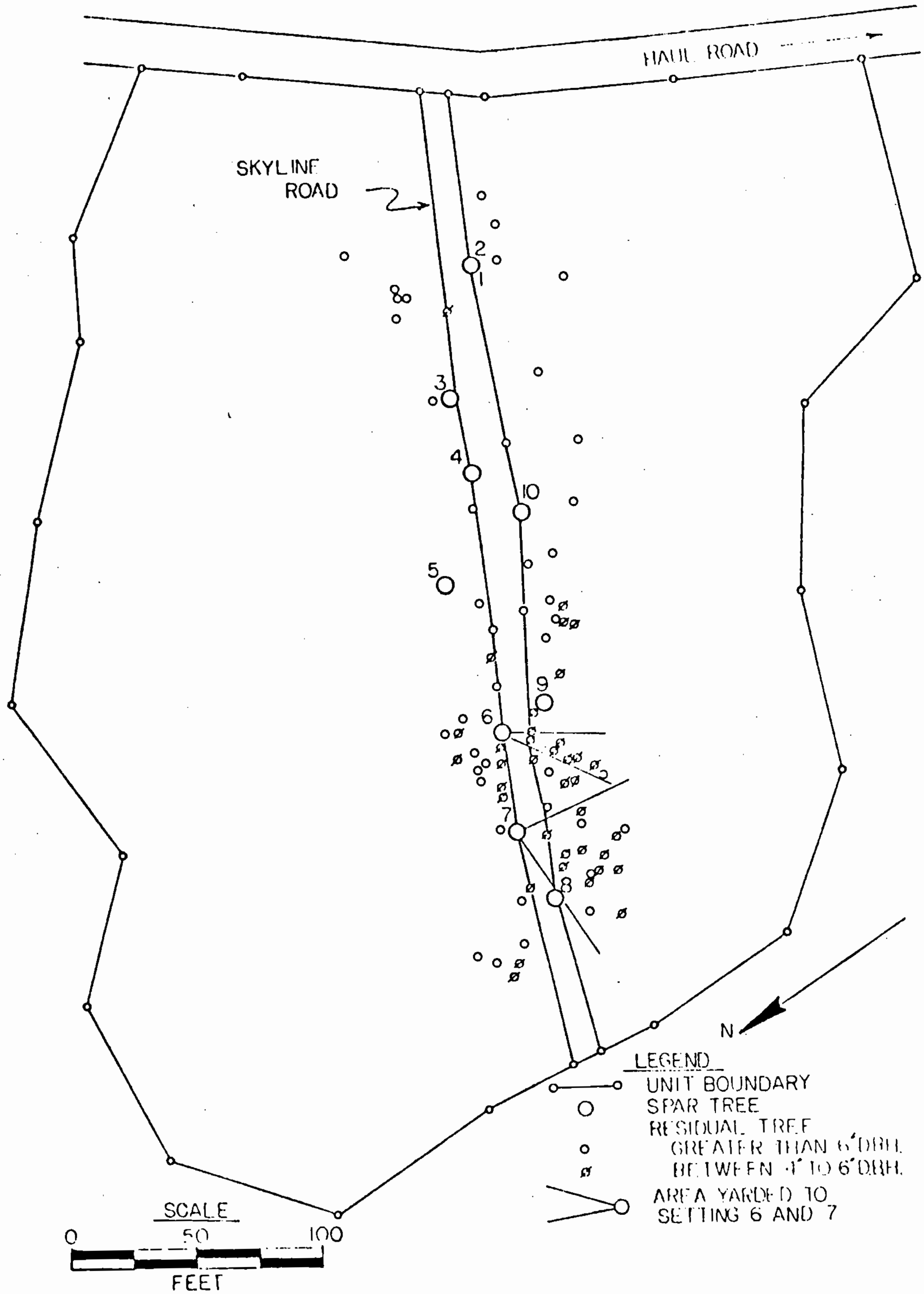


Figure 30. Residual tree locations around skyline corridor.

PRODUCTION RATES

The predicted time per turn under average logging conditions was used for developing production rates for this thinning study. As stated previously, the regression equations give an estimate of delay free yarding times. Delays and move times were added to the predicted times to obtain an estimate of turn time for determining production rates:

Single-Drum Winch - Prebunching

Predicted turn time (from regression equation, page 51) = 3.32 minutes

Average delay and move time per turn (Tables 5 and 6) = 2.78 minutes

Total yarding time per turn = 6.10 minutes

Mobile Yarder - Swinging

Predicted turn time (from regression equation, page 56) = 2.78 minutes

Average delay time (including moving skyline stop) per turn (Table 3) = .64 minutes

Total yarding time per turn = 3.42 minutes

An eight-hour working day was assumed for developing production rates.

I also predicted production rates for the Schield-Bantam thinning a unit with similar conditions to the one in this study but without logs prebunched in the skyline corridor. A regression equation was used from a previous study on the Schield-Bantam rigged with a shotgun system, using a Maki Carriage and thinning under similar conditions as this study (Aulerich, 1975):

Total Turn Time = 1.210 + .009 (Slope Distance) + .015 (Lateral Distance) + .253 (Number of logs/turn)   R = .566

Values for the independent variable as stated in Table 4 were substituted into the regression equation to obtain a predicted delay free yarding time of 4.46 minutes. Delays were added as follows (Aulerich, 1975):

Predicted turn time	= 4.46 minutes
Average delay time per turn	= .46
Average time to move carriage stop per turn	= .34
	5.26 minutes

Production rates for the thinning system that involve prebunching with the single-drum yarder, and swinging with the mobile yarder are compared to yarding with the mobile yarder without prebunching (Table 7).

When the logs were prebunched in the skyline corridor, the turn time with the mobile yarder was reduced 65 percent and the production of logs per day and volume per day more than doubled compared to mobile yarder thinning operations without prebunching.

YARDING COSTS

Two possible ways of comparing the two cable logging techniques for thinning small timber stands are by production rates or by costs. Production rate comparisons between yarding prebunched logs and yarding without prebunching are useful but do not reflect the entire yarding process. There is a definite cost associated with yarding the logs to the skyline corridor and having them prebunched for swinging. Therefore, I chose to compare the two thinning systems on a cost basis where a common comparison can be made (Tables 8 to 10).

Table 7. PREDICTED HOURLY AND DAILY PRODUCTION.

	Prebunching with Single-Drum Winch	Swinging with Mobile Yarder	Mobile Yarder without Prebunching
Time per Turn (minutes)	6.10	3.42	5.26
Logs per Turn	1.33	2.82	2.00
Turns per Hour	9.84	17.54	11.41
Logs per Hour	13.09	49.46	22.72
Volume per Turn			
(cubic feet)	20.69	42.31	30.00
(board feet)	124	254	180
(cubic meters)	0.88	1.80	1.28
Volume per Hour			
(cubic feet)	203.59	742.12	342.30
(board feet)	1222	4452	2054
(cubic meters)	8.67	31.58	14.57
Turns per Day	78.72	140.32	91.28
Logs per Day	104.70	395.68	181.76
Volume per Day			
(cubic feet)	1628.72	5936.96	2738.40
(board feet)	9772	35622	16430
(cubic meters)	69.30	252.64	116.52

Table 8. SINGLE-DRUM WINCH COSTS PER HOUR.

	Cost/hour (dollars)
Equipment Cost	
Machine Depreciation (straight line depreciation method)	$ 1.25
Initial Cost - $12,000	
Estimated salvage value at end of 6 years = $0	
Winch Line Depreciation	.07
300 feet of 3/8 inch line @ $.36/ foot (91.44 meters of 0.95 centimeter line @ $1.18/meter)	
Estimated 1 year life, 0 salvage value	
Maintenance[1]	.62
50 percent of depreciation per hour	
Fuel and Lubrication[2]	.82
Fuel - 2 gallons/hour @ $.40/gallon (7.57 liters/hour @ $.11/liter)	
Lubrication - $.02 per hour	
Insurance and Taxes	.63
15 percent of Average Annual Investment per Year	
Average Annual Investment = $6,750	
Total Equipment Cost	$ 3.39
Labor Cost	8.52
One operator @ $6.00 per hour wage rate	
Payroll expense = 42 percent increase of wage rate	
TOTAL COST PER HOUR	$11.91

[1]From discussion with machine designer.

[2]Fuel consumption for a 47 horsepower industrial Volkswagen engine.

Table 9. SCHIELD-BANTAM COST PER HOUR - SWINGING.

		Cost/hour (dollars)
Equipment Cost[1]		$ 24.54
Labor Cost		
(payroll expense of 42% included)		
Yarder Engineer	$ 8.52	
Chaser	8.52	
Chokersetter	8.09	
	Total Labor Cost	25.13
	TOTAL COST PER HOUR	$ 49.67

[1]1972 Equipment Cost from Aulerich, Johnson and Froehlich, 1974, updated with cost index of 1.58 from Economic Indicators, January 1976.

Table 10. SCHIELD-BANTAM COST PER HOUR - WITHOUT PREBUNCHING

		Cost/hour (dollars)
Equipment Cost[1]		$ 24.54
Labor Cost		
(payroll expense of 42% included)		
Rigging Slinger - Hooktender	$ 9.23	
Yarder Engineer	8.52	
Chaser	8.52	
Chokersetter	8.09	
	Total Labor Cost	34.36
	TOTAL COST PER HOUR	$ 58.90

[1]1972 Equipment Cost from Aulerich, Johnson and Froehlich, 1974, updated with cost index of 1.58 from Economic Indicators, January 1976.

The costs are for yarding only and do not reflect other activities such as falling and bucking, loading, or hauling. Costs were calculated based on an assumed 200-day (8 hours per day) year.

Comparing the two yarding techniques for thinning in a young growth stand of Douglas-fir, there is a $6.52 per M bd. ft. ($.92 per cubic meter) difference that favors prebunching and swinging (Table 11). Several factors contribute to the cost difference between the two systems. Production per day was lower for the mobile yarder skyline operation without prebunching. A main reason for this is that lateral yarding was a major portion of the total turn time when prebunching was not done (Aulerich, Johnson and Froehlich, 1974). Also, most of the resets occurred during the lateral yarding. A second factor that influenced the cost difference is that labor costs were reduced during the swinging operation with only one chokersetter working in the skyline corridor. It appeared that the swinging operation functioned well without an added strain on the one chokersetter. With a manual slackpulling carriage, the lateral yarding is one of the more fatiguing activities in the yarding cycle (Aulerich, Johnson and Froehlich, 1974). A third factor that contributed to the cost difference was the fact that the lateral yarding was accomplished by a relatively low-investment machine. The idle time that a more expensive piece of equipment would spend in the lateral operation including hooking and resets was eliminated. A higher costing piece of equipment was more fully utilized.

Table 11. COST COMPARISON BETWEEN THE TWO THINNING TECHNIQUES.

	Production per day (M bd. ft.)	Production per day (cubic meters)	Cost/hour (dollars)	Cost/day (dollars)	Cost/M bd. ft. (dollars)	Cost/cubic meter (dollars)
Single drum winch prebunching	9.8	69.30	11.91	95.28	9.72	1.37
Mobile yarder swinging	35.6	252.64	49.67	397.36	11.16	1.57
Prebunching and swinging system combined					20.88	2.94
Mobile yarder yarding (without prebunching)	17.2	116.52	58.90	471.20	27.40	3.86

DISCUSSION

This study showed that there was a cost savings per M bd. ft. with the lateral yarding being accomplished by a low-investment machine prior to yarding with a higher-investment, conventional yarder. I believe the yarding technique evaluated with this project could be improved with further research. Also, I believe that skyline corridors could be spaced further than they are today in small timber stand thinning operations by utilizing the prebunching technique. This statement is based on my idea that the yarding cost per M bd. ft. would increase much faster, as lateral yarding distance increases, for a high-investment yarder than it would for a lower-investment prebunching machine.

Two-Man Operation

The single-drum winch yarding system evaluated was a one-man operation. I believe there would be substantial gains by making this a two-man operation: one faller and one yarder operator. The prebunching operation could be improved by felling trees in conjunction with the yarding operation because trees could be felled at a good lead angle for yarding and hang-ups could be removed by the yarder. When trees are immediately yarded after felling, it is not necessary to get the tree completely horizontal to the ground. Fallers would not have to spend extra time fighting hang-ups which are a problem in thinning operations. In this study, hang-ups that had a direct lead towards the single-drum winch were easier to inhaul to the corridor than logs at a bad lead angle (Figure 31). Regression equations showed the influence of lead angle on the turn time. If trees could not be felled at an acceptable lead angle without having a hang-up, they could be directly felled into other trees. When the hang-up is pulled and falls to the ground, the faller could then limb and buck the tree while the yarder operator presets another log close by. It is difficult for a cutting crew to fell trees to lead for the prebunching operation when they have no idea where the machine will be located during the yarding process. Also, it is difficult to predict in advance the single-drum winch locations because much of the operation depends on situations that occur during the prebunching operation.

There is also the question concerning the Logging Safety Code and one man working alone in the woods. With a two-man crew, this would not be a problem.

I believe that the two-man crew would be more productive if they alternated jobs: fell and buck for a period of time and then yard logs. The Europeans have found that it is desirable to change workers' jobs on a crew every two days in order that they get a good understanding of the whole operation (Lisland, 1975). When extra help is needed for a particular activity such as moving the machine, both men could work together. One person could move the machine while the other one rigs the spar tree for the next setting.

Tongs

At the start of this study, tongs were first used on the end of the winch line. They did not work very well for several reasons and

Figure 31. Yarding hang-ups.

the idea was abandoned. One reason was that the manual outhaul operation was more difficult with bulky tongs than chokers. Secondly, with a system that did not have much lift, the tongs did not stay on the small logs very well during the inhaul operation. Hang-ups occurred often during this operation and it appears that they always will when a small ground lead system is used in a thinning operation. It was more difficult to reset the small logs with tongs than it was with chokers. More could be done with chokers to free logs from hang-ups than with tongs.

Time study data showed that hook and unhook times were the most time consuming elements in the swinging operation with the mobile yarder (Table 5). The use of tongs for swinging prebunched log decks should be evaluated. Advantages of using tongs include faster hook and unhook time as well as reducing the crew size by eliminating a chaser. Perhaps the swinging operation could be efficiently accomplished with only a yarder engineer and a chokersetter. A disadvantage of tongs is that bonus logs are not possible. When all the logs are together in decks, there are many possibilities for bonus logs. In this swinging study, as many as six logs per turn were set with two chokers and the average number of logs per turn was 2.8. A production comparison between the use of tongs and chokers on swinging prebunched logs would be advantageous.

Moves and Rigging

Changing settings and machine locations in the prebunching operation increased productive yarding time per turn 17 percent.

As mentioned in the data analysis section, there was not enough data from this study to develop reliable regression equations for a statistical analysis on the moving operation. Various ideas on moving and rigging procedures with the single-drum winch are the best way I can treat this area.

In this study, as many areas as possible were reached from each yarder location which meant using more than one spar tree from the same machine location. Sometimes the lead from the machine, through the block and to the logs being yarded, formed a square lead or V lead. The spar trees were not guyed or topped and tensions should be monitored in further studies. Considering a small machine, a lot of time is not needed for positioning the machine and rigging a spar tree for logging only a few logs from each setting. A fast spar tree rig-up procedure is needed. In this study, the block for the winch line to pass through was hung three different ways. First a tree was climbed approximately 20-25 feet (6.10-7.62 meters) with climbing gear (Figure 32). The added lift achieved by hanging the block high in the tree was helpful when hang-ups occurred in the inhaul operation but tree climbing was also time consuming. The rig-up time was reduced by hanging the block as high as could be reached from the ground. This procedure did not take long and worked well for yarding only a few logs to the corridor. With a lot of yarding, especially at long distances to the skyline corridor, hang-ups became a more critical problem when the block was hung only 5-6 feet (1.52-1.83 meters) from the ground. The last technique was a combination of the first two procedures and appeared to be the most efficient. A 6-foot

Figure 32. Climbing spar tree
to hang block.

Figure 33. Ladder used to hang
block in spar tree.

(1.83 meters) ladder was leaned up against the tree and the operator used the ladder to hang the block between 10-12 feet (3.05-3.66 meters) from the ground (Figure 33). The ladder worked well and did not take much more time compared to standing on the ground. The added height of the block in the tree was helpful in overcoming hang-ups. The Europeans used ladders a great deal in their small wood harvesting operations. The use of ladders should be evaluated further in rigging operations with a small single-drum winch.

Another rigging idea involves the use of a strap and small block used for freeing hang-ups (Figure 34).

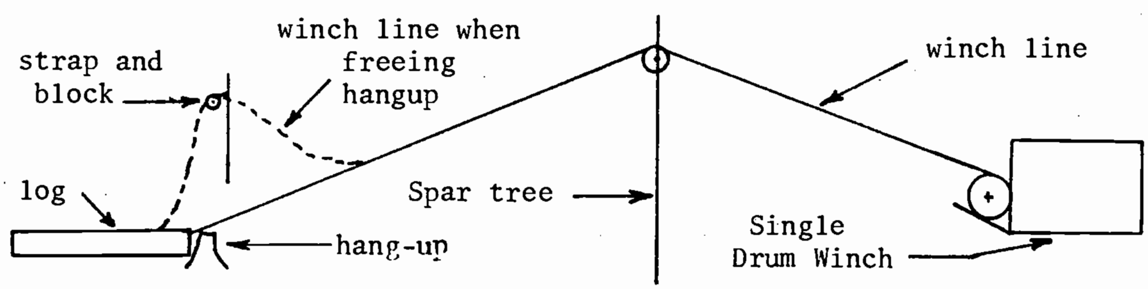


Figure 34. Freeing hang-ups with a strap and block.

Yarding logs in a small timber thinning operation without much lift and with a small machine similar to the protable winch used in this study, requires an operator that has, or can quickly acquire, a knowledge for rigging techniques.

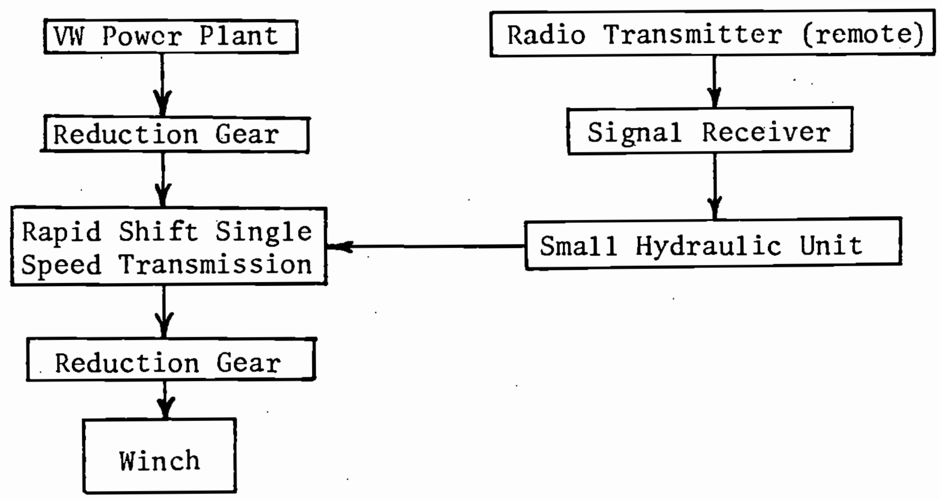
Machine Modifications

I believe that the design of a radio-controlled single-drum "mini-yarder" should be kept simple and the cost of the machine as low as possible.

The machine used in this study definitely had mechanical problems. The major problem with the prototype tested during the summer of 1974 was the winch. The winch was a Ramsey 200 model designed specifically as a truck mounted unit. The winch did not stand up to logging usage. The next prototype tested in March 1975 and for this study used a Gerramatic 9 winch. The winch was fine, the Volkswagen engine has always worked well, and there was not much trouble with the radio unit. The majority of the problem was in transferring the power from the Volkswagen engine through reduction gears and transmission to the winch. The machine designer's new ideas center around a Pull Master model M10F hydraulic winch. New plans involve a design that transfers the power form the engine directly to the winch and eliminates the troublesome transmission currently in the machine. The radio-controlled unit would directly activate the winch (Figure 35). It seems that this new design could be promising and warrants further evaluation when the machine is available.

Also, it should be noted that this project evaluated only one type of machine for prebunching. The necessary design of a small portable winch suitable to yarding small logs does not appear to be very complex. Perhaps shop mechanics could build a low-investment unit to aid company crews working in small timber stands. If the terrain is suitable, other yarding techniques such as a horse, tractor or skidder could accomplish the prebunching operation. The important fact revealed from this study is that prebunching logs to a skyline corridor can result in lower total yarding costs compared to no prebunching.

Power Flow and Control Schematic with Gerramatic 9 Winch



Power Flow and Control Schematic with Pull Master M10F Winch (New Design)

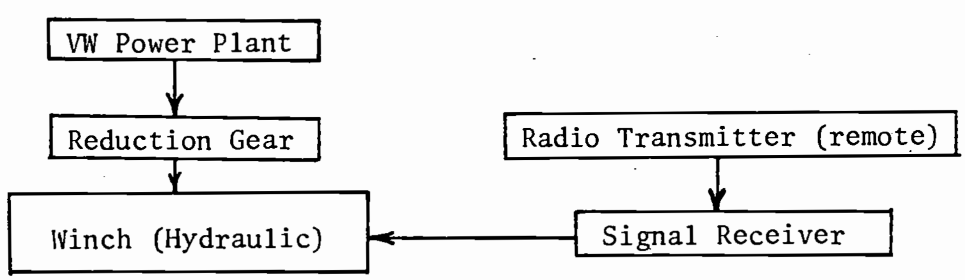


Figure 35. Comparison of Modern Logging Equipment's current radio-controlled single-drum winch design to their future machine design.

Other Uses For a "Mini-Yarder"

Other possible uses for a small single-drum radio-controlled winch that have been tried by the machine designer but not evaluated and require further investigation include tree pulling and stream clean-up projects. Also, when retesting the single-drum winch in the spring of 1975, three types of operations were done with the machine. In the McDonald Forest (NE. 1/4 Sec. 3, T.11S., R.5W.), slash left in skyline corridors was yarded to a main road in the first operation[12]. The slash was later cut for firewood. In the Dunn Forest (NW. 1/4 Sec. 16, T.10S., R.5W.), two thinning operations in a well stocked 20-25 year old stand of Douglas-fir were done[13]. In one of the thinning operations, one man did the falling just ahead of another man doing the yarding. The other thinning operation was done with one man doing the falling and yarding. Tree length yarding was done to a haul road and the trees were later cut on the road into 8-foot (2.44 meters) posts.

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[12]Basic time study results and production rates in Appendix B.

[13]Basic time study results and production rates in Appendix C.

SUMMARY

I studied the skyline lateral yarding component in small timber stand thinnings by evaluating prebunching logs to a skyline corridor with a small portable winch and swinging the logs to a haul road with a conventional mobile yarder. The multimoment time study method was used for obtaining data needed for the system analysis. The prebunching and swinging yarding cycles were divided into five activities:

Outhaul

Hook

Inhaul

Unhook

Reset

Interruptions in the work cycle that were either machine or man caused occurred randomly and were considered delays in the yarding process. Variables thought to influence the yarding times were identified and measured during the logging operation:

Prebunching	Swinging
Slope Distance	Slope Distance
Lead Angle	Zone
Volume	Volume
Number of Chokers	Number of Chokers
	Crew Size

The time study results showed that the average yarding time per turn, including delays, with the single drum winch was 5.08 minutes. Thirty-four percent of the prebunching yarding time per turn was

involved with equipment or yarding delays. The next most time consuming element of the yarding cycle was resets. Swinging the prebunched logs with the mobile yarder required an average yarding time per turn, including delays, of 3.44 minutes. Hook and unhook activities accounted for slightly more than half of the yarding time per turn.

Regression equations were developed that explain part of the variation of the total yarding time as well as the variation of activities within the yarding cycles. The regression equations can be used within the limits of this study to predict time requirements for prebunching and swinging yarding operations.

Predicted daily and hourly production rates were determined from regression equations. With logs prebunched in the skyline corridor, the turn time with the mobile yarder was reduced 65 percent and the production of logs per day and volume per day more than doubled compared to mobile yarder thinning operations without prebunching.

I compared the yarding system involving prebunching to a system without prebunching on a cost basis. Equipment and operating costs were determined and predicted daily production figures were used for the comparison. A $6.52 per M bd. ft. ($.92 per cubic meter) difference between the two yarding techniques was obtained that favored prebunching and swinging.

This project and analysis is based on one logging operation. To test the validity of the data and obtain information for more general use, additional studies should be made under different conditions. Additional studies should further evaluate several suggested modifications in the yarding system that could improve the overall operation:

1. A two man operation, faller and yarder operator, could improve the yarding operation with a small portable winch;

2. There is a break even distance between using one and two chokers that influences the volume yarded per hour with a portable winch. For this study, the break even distance was 89 feet (27.13 meters);

3. The use of tongs with the swinging operation could reduce the crew size and the yarding time per turn;

4. Ladders appear to be a fast technique for efficiently rigging spar trees. Additional rigging techniques such as the use of a small strap and block to free hangups could also improve the yarding operation with a small protable winch;

5. Machine modifications with the single-drum winch used in this study could reduce the excessive equipment delay obtained in this study;

6. Other small portable winch designs or other yarding techniques could prove to be more efficient in prebunching small logs to skyline corridors.

Wood fiber from vigorous young second growth stands is becoming more important today as forestry operations change from old growth logging to second growth management. Commercial thinning small timber stands at an early age continually increases in importance as a silvicultural technique for improving second growth management of Douglas-fir stands. Commercial thinning operations in these young timber stands can be economically feasible when logging costs are kept low and there is an attractive market for the small log wood fiber.

Many timber stands that require thinning are on steep ground where skyline logging techniques are needed. Much of the high skyline logging cost common to thinning operations with a high-investment yarder is caused by the time consuming lateral yarding operation and idle yarder time during the hook and reset activities. This study showed that prebunching logs to a skyline corridor with a low-investment machine is one alternative for eliminating the lateral yarding time with a high-investment yarder that can reduce the yarding cost in thinning operations. Further research along the lines of this study and similar to the continuing research by the Forest Engineering Department at Oregon State University is essential to advance the efficiency of skyline logging operations in small timber stand thinning operations.

BIBLIOGRAPHY

Aulerich, D. E., K. N. Johnson, and H. A. Froehlich. 1974. Tractors or skylines: What's best for thinning young-growth Douglas-fir? Forest Industries 101(12): 42-45.

Aulerich, D. E. 1975. Smallwood harvesting research at Oregon State University. Loggers Handbook, Vol. XXXV, 10-12, 84-88.

Barnes, R. M. 1968. Motion and time study - design and measurement of work. 6th ed. John Wiley and Sons, Inc., New York, N.Y. 407 p.

Brackett, M. 1973. Notes on tarif tree volume computation. Resource Management Report #24. State of Washington Department of Natural Resources. 26 p.

Berg, A. B.(ed.) 1971. Managing young Douglas-fir and Western Hemlock, proceedings of a symposium held June 16-18, 1969. School of Forestry, Oregon State University, Corvallis, Oregon. 175 p.

Berg, A. B.(ed.) 1972. Managing young forests in the Douglas-fir region, proceedings of a symposium held June 15-18, 1970. School of Forestry, Oregon State University, Corvallis, Oregon. 224 p.

Dykstra, D. P. 1975. Production rates and costs for cable, balloon, and helicopter yarding systems in old-growth Douglas-fir. Research Bull. 18. Forest Research Laboratory, School of Forestry, Oregon State University, Corvallis, Oregon. 57 p.

Freese, F. 1962. Elementary forest sampling. Agriculture Handbook No. 232. U.S. Department of Agriculture. 87 p.

Ledoux, C. B. 1975. Simulation of a helicopter yarding system in old growth forest stands. Corvallis, Oregon State University unpublished Master of Science Thesis, 79 p.

Lisland, Torstein. Cable logging in Norway, a description of equipment and methods in present use. A paper presented as a Visiting Scientist to Oregon State University, Forest Engineering Department. 47 p.

Little, G. R. 1972. Tree-volume tarif access tables for Pacific-Northwest species. Vol. 2, Major coastal species. State of Washington Department of Natural Resources, 153 p.

Malmberg, D. 1971. Commercial thinning in Western Hemlock. In: Managing young Douglas-fir and Western Hemlock - economics, yield control, and thinning. Proceedings of a symposium held July 16-18, 1969, edited by Alan B. Berg. School of Forestry, Oregon State University, Corvallis, Oregon. p. 152-166.

McArdle, R. E., W. H. Meyer and D. Bruce. 1961. The yield of Douglas-fir in the Pacific Northwest. Technical Bulletin No. 201. U.S. Department of Agriculture, Washington, D.C. 74 p.

O'Leary, J. E. 1970. Thinning on steep ground. In: Management of young growth Douglas-fir and Western Hemlock, proceedings of a symposium held June 10-14, 1968, edited by Alan B. Berg. School of Forestry, Oregon State University, Corvallis, Oregon, p. 102-105.

Robinson, D. D. 1970. In: Management of young growth Douglas-fir and Western Hemlock, proceedings of a symposium held June 10-14, 1968, edited by Alan B. Berg. School of Forestry, Oregon State University, Corvallis, Oregon. p. 5-8.

Rowley, M. 1970. Equipment for skidding and loading. In: Management of young growth Douglas-fir and Western Hemlock, proceedings of a symposium held June 10-14, 1968, edited by Alan B. Berg. School of Forestry, Oregon State University, Corvallis, Oregon, p. 97-101.

Sears, J. Z. 1975. Yarding system and carriage development, a case study. Corvallis, Oregon State University unpublished Master of Forestry paper, 58 p.

Sinner, H. U. 1973. Simulating skyline yarding in thinning young forests. Corvallis, Oregon State University unpublished Master of Science Thesis, 80 p.

Turnbull, K. J., G. R. Little and G. E. Hoyer. 1963. Comprehensive tree-volume tarif tables. 2nd Edition. State of Washington, Department of Natural Resources, 177 p.

Williamson, R. L. and F. E. Price. 1971. Initial thinning effects in 70-150 year-old Douglas-fir - Western Oregon and Washington. USDA Forest Service Research Paper PNW-117, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 15 p.

APPENDICES

APPENDIX A
ILLUSTRATIONS

Figure 36. Radio transmitter, tree plate, strap and block for rigging in spar tree.

Figure 37. Moving single-drum winch.

Figure 38. Hooking two logs close together.

Figure 39. Walking towards skyline corridor to unhook log.

Figure 40. Reset activity.
(Note back end of
prebunched deck at
top of picture)

Figure 41. Looking down skyline corridor with prebunched logs.

Figure 42. Schield-Bantam used for swinging.

Figure 43. Loading with self-loading truck.
(Note: looking from prebunched
deck in skyline corridor)

APPENDIX B

SLASH YARDING RESEARCH RESULTS

(based on 45 observations)

Average Values for Variables Influencing the Yarding Operation

Slope yarding distance = 120 feet (36.58 meters)

Number of pieces per turn = 2.7
(Slash pieces were from small wood thinnings and ranged in size from 2-inch diameters to 12-inch diameters (5.08 to 30.48 centimeters) and length of 6 feet to 30 feet (1.83 to 9.14 meters).

Average Yarding Time in Minutes and Percent by Activity

Yarding Activity	Average Time (minutes)	Percent of Average Total Time
Outhaul	.71	13.8
Hook	.55	10.7
Inhaul	1.21	23.4
Unhook	.52	10.1
Rehook	.36	7.0
Reset	.29	5.6
Delay	1.52	29.4
Total turn time (delay free)	3.64	70.5
Total turn time (including delays)	5.16	100.0

Predicted Hourly and Daily Production
(Eight hour working day assumed)

Time per turn (minutes	5.16
Turns per hour	11.6
Turns per day	92.8
Pieces per hour	31.3
Pieces per day	250.4

APPENDIX C

THINNING RESEARCH RESULTS[1]

Average Values for Variables Influencing the Yarding Operation

	Two Man Operation	One Man Operation
Slope Yarding Distance (feet)	127.8	57.3
(meters)	38.95	17.47
Number of Trees per Turn	1.2	1.2
Volume per Turn		
cubic feet	7.85	4.90
board feet	47	29
cubic meters	0.33	0.21

Average Yarding Time in Minutes and Percent by Activity for Two Man and One Man Thinning Operation

	Two Man Operation		One Man Operation	
Yarding Activity	Average Time (minutes)	Percent of Average Total Time	Average Time (minutes)	Percent of Average Total Time
Outhaul	.87	22.0	.56	8.9
Hook	.42	10.6	.28	4.5
Inhaul	1.01	25.6	.58	9.2
Unhook	.42	10.6	.33	5.3
Rehook	.04	1.0	.04	0.6
Reset	.67	17.0	.53	8.5
Delay	.52	13.2	.89	14.2
Falling			3.06	48.8
Total Turn Time (delay free)	3.43	86.8	5.38	85.8
Total Turn Time (including delays)	3.95	100.0	6.27	100.0

[1]Two man operation data based on 70 observations; one man operation based on 55 observations.

Predicted Hourly and Daily Production
(Eight hour working day assumed)

	Two Man Operation	One Man Operation
Time per turn (minutes)	3.95	6.27
Turns per hour	15.2	9.6
Trees per hour	18.2	11.5
Volume per hour		
cubic feet	119.32	47.04
board feet	716	282
cubic meters	5.08	2.00
Turns per day	121.6	76.8
Trees per day	145.6	92
Volume per day		
cubic feet	954.56	376.32
board feet	5,727	2,258
cubic meters	40.62	16.01