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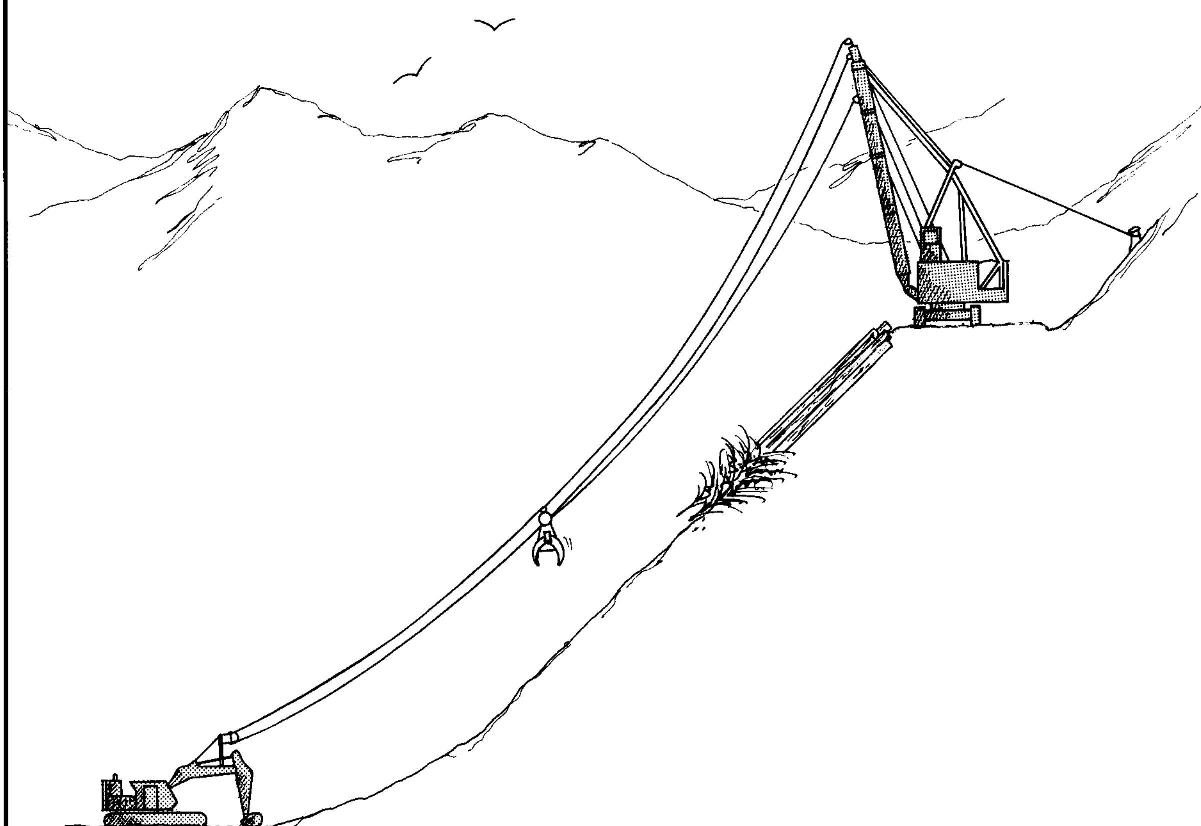
INSTITUT CANADIEN DE RECHERCHES EN GÉNIE FORESTIER

FERIC

HARVESTING ECONOMICS: GRAPPLE YARDING SECOND-GROWTH TIMBER

J.T. Peterson

July 1987



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AUTHOR

John Peterson received his B.Sc. in Forest Engineering from Oregon State University in 1965. Since that time, he has been involved with logging and transportation operations in Western Oregon, Coastal British Columbia, Saskatchewan, and Alberta. He worked for MacMillan Bloedel Ltd., Trimac Transportation Services, and as a private consultant before joining FERIC in 1985. He is currently Group Supervisor--Harvesting Economics and Silviculture.

TABLE OF CONTENTS

	PAGE
ACKNOWLEDGEMENTS	ii
AUTHOR	ii
SUMMARY	S-1
SOMMAIRE	S-2
INTRODUCTION	1
STUDY APPROACH AND PROCEDURES	1
SITE AND SYSTEM DESCRIPTION	1
RESULTS AND DISCUSSION	3
1. Setting Layout and Falling Patterns	3
2. Overall Results	6
3. Actual Systems Comparison	8
4. Regression Analysis	9
5. Predicted Yarding Costs	11
6. Marginal Log Analysis	13
CONCLUSIONS	16
REFERENCES	18

LIST OF FIGURES

FIGURE		PAGE
A	Yarding Direction	4
B	Falling Pattern	5
C	Pieces Out of Lead in Grapple	5
D	Comparison of Predicted Cycle Times	11
E	Predicted Yarding Cost per Cubic Metre by Turn Size and Yarding Distance--Bunched-Wood Area	13
F	Marginal Log or Turn Sizes (Bunched-Wood Area)	16

LIST OF TABLES

TABLE		PAGE
1	Stand Description	2
2	1982 Madill 084 Swing Yarder Operating Specifications	3
3	Timing Summary	6
4	Productivity and Cost Summary--Actual Results	8
5	Relationships Between Variables	9
6	Predicted Cycle Times per Turn	11
7	Predicted Yarding Cost per Turn--by Yarding Distance	12
8	Yarding Cost per Cubic Metre by Turn Size and Yarding Distance	12
9	Log Values (April 1986)	15

LIST OF APPENDICES

APPENDIX		PAGE
I	Logging Costs	19
II	Trainee Operator Results	20
III	Grapple Yarding Time Element Definitions	22
IV	Delay Time Summary (Regular Operator)	23
V	Summary of Line Speeds: Outhaul and Inhaul (Regular Operator)	24
VI	Madill 084 Swing Yarder	26

SUMMARY

This is the first report in a series of studies investigating the effect of log size, turn size, yarding distance, and terrain on yarding productivity and costs.

The study was conducted at MacMillan Bloedel Ltd.'s Northwest Bay Division on the east coast of Vancouver Island. Stand composition was mainly second-growth Douglas-fir, with lesser amounts of hemlock and cedar. The stand was divided into two blocks to facilitate comparing grapple yarding feller-bunched wood with handfelled wood.

Falling patterns and methods play a decisive role in yarding productivities. The main advantage of bunching was to increase turn size. There was a 57% increase in the number of pieces yarded per turn in the bunched-wood area. Bunching reduced the yarding cost (alone) by over $1.50 per piece.

Both turn size and yarding distance significantly affect costs. Costs per cubic metre doubled when turn size decreased from 1.0 to 0.5 m^3. The cost of yarding a 1.0 m^3 turn 150 m was 67% more than yarding it 50 m.

The higher costs and lower productivities associated with training new operators are contained in this report. The regular operator produced 236 more pieces per shift at a cost reduction of $5.31/$m^3$.

SOMMAIRE

Le présent rapport est le premier d'une série d'études portant sur l'influence du diamètre des grumes, du volume des charges, de la distance de téléphérage, et du terrain sur la productivité et sur les coûts de téléphérage.

L'étude a eu lieu chez MacMillan Bloedel Ltd., Northwest Bay Division, sur la côte est de l'Île de Vancouver. Le peuplement se composait principalement de sapin de Douglas de seconde venue, ainsi que de pruche et de cèdre en quantités plus faibles. Il était divisé en deux blocs, afin de faciliter la comparaison entre le téléphérage par câble-grue à grappin d'arbres abattus manuellement et celui d'arbres abattus à l'aide d'une abatteusse-groupeuse.

Les schémas d'abattage et les méthodes utilisées jouent un rôle décisif dans la productivité du téléphérage. Le fait de grouper les arbres a pour principal avantage de permettre une augmentation du volume des charges. Le nombre de pièces débardées était de 57% plus élevé par voyage dans la section où les arbres étaient groupés. Le groupage réduisait le coût de téléphérage (seulement) de plus de 1,50 $ par pièce.

Le volume des charges et la distance de téléphérage influençaient les coûts de façon significative. Les coûts par mètre cube doublaient quand le volume de la charge diminuait de 1,0 à 0,5 m^3. Il en coûtait 67% de plus pour débarder une charge de 1,0 m^3 sur 150 m, plutôt que sur 50 m.

Le rapport fait également état des coûts plus élevés et des productivités plus faibles qu'occasionne la formation de nouveaux opérateurs. L'opérateur régulier produisait 236 pièces de plus par poste de travail, d'où une réduction de coûts de 5,31 $/$m^3$.

INTRODUCTION

Historically, loggers have known the average logging costs for each phase of their operation (falling, skidding, yarding, and loading). A shortcoming of average costs is that they are a mixture of high and low costs. A given average cost may seem satisfactory and in line with profitable operations, yet a breakdown into component costs may reveal individual cost situations that are not satisfactory and not profitable (Adams 1965). To address this problem, the Harvesting Economics Project was initiated by FERIC member companies in 1983, and a budget was established in 1984. Field work on the project started in 1985.

This report describes the first of several grapple-yarding studies conducted for the Harvesting Economics Project. The group of yarding studies will show average results and, more specifically, how productivity and cost vary with tree size, log size, and terrain.

Data in this report have been obtained through on-site, detailed measurements of yarding operations. Results are specific to the study conditions and should be applied elsewhere with caution.

STUDY APPROACH AND PROCEDURES

Data were collected with timing boards and hand-held stop watches. To gather data by tree size, individual full trees were measured with tapes and pre-marked by painting. Trees were classified into 10-cm butt diameter classes with the first class midpoint being 12.5 cm, (i.e., the range was 7.6 to 17.5 cm).

The results, in which all mechanical and operational delays were recorded, were converted to an 8-hour-shift basis to determine productivity. Delay time includes all delays no matter what their duration, i.e. includes minor delays (less than 10 minutes). The machine utilization levels used were those observed during timing. Costs (Appendix I) were estimated by FERIC using current labour rates and information from equipment suppliers.

Piece volumes were derived from the operational cruise done by MacMillan Bloedel Ltd., Woodland Services (April 1985) and compiled by Reid, Collins Associates Ltd., and from on-site measurements done by FERIC.

The study was conducted over a period of seven months. During this period, detailed information by diameter class was gathered on 1789 pieces. At the same time, as part of another study (Peterson 1986), more general time and production data were gathered on an additional 7662 pieces.

SITE AND SYSTEM DESCRIPTION

The study site was located on the east coast of Vancouver Island, 5.3 km west of Buckley Bay, B.C. The stand (Table 1) was established in 1984 (approximately) when heavy winds devastated the original stand. Understory consisted of sword fern and Oregon grape, with a few dense patches of conifer saplings (2- to 5-cm diameter). Species composition, by volume, was 60% Douglas-fir, 21% western hemlock, 16% western red cedar, and 3% deciduous species.

TABLE 1. Stand Description.

	BUNCHED-WOOD AREA	HANDFELLED AREA
Cutting Area (ha)	11.2	10.3
Slope % - Range	0-38	0-52
- Average	18	23
- Aspect	East	East
Terrain	Rolling	Rolling
Exposed Rock	None	None
Underbrush	Light	Light
Obstacles	Some Windfalls	Some Windfalls
No. Stems per Hectare	939	778
Estimated Volume, m^3		
- Gross/ha	566	713
- Net/ha	518	665
- Gross/piece	0.59	0.91

The stand was divided into two blocks to facilitate comparing the systems. The area designated to be feller-bunched was chosen because of the smaller tree size and gentler terrain. The area to be handfelled had a small stream with steep banks, which would have made the feller-buncher less efficient.

In the bunched-wood area, trees under 50 cm in diameter were mechanically felled and bunched by a Case 1187 feller-buncher equipped with a 50-cm Drott shear head. Trees were bunched at approximately 45° to the haul road with butts facing the road. Oversize trees were handfelled. Trees under 60-cm butt diameter were not processed at the stump after falling. Selective bucking was done on trees with a butt diameter greater than 60 cm; the bottom one or two logs were hand bucked and the remainder of the tree was left for roadside processing. Based on the operational cruise data, 3% of the stems (13% of the volume) was greater than 50 cm in diameter and therefore were handfelled. In addition, the handfaller felled snags and a few trees that were inaccessible to the feller-buncher, and bucked a few large windfalls.

In the second area, all trees were handfelled parallel to the haul road to improve yarding efficiency. No effort was made to fall tops in one direction. Trees under 60-cm butt diameter were yarded as full trees. As in the bunched-wood area, selective bucking was done on those trees with a butt diameter greater than 60 cm. Only 5% of the trees required hand bucking.

Yarding on both areas was done by a 1982 Madill 084 swing yarder (Table 2) with a 1978 Hitachi UH14 mobile backspar. Pieces were yarded to the roadside and decked in windrows.

TABLE 2. 1982 Madill 084 Swing Yarder Operating Specifications.

Engine	GM 12V71
Undercarriage	M10 tank
Swing Capability	Yes
Tower Type	A-frame
Height to Top of Fairlead	15.2 m
Number of Guylines	3
Weight	63 500 kg
Mid-Drum Performance	
Mainline	--22 700 kg stall line speed --400 m/min no-load line speed
Haulback	--11 100 kg stall line pull --800 m/min no-load line speed

The yarding crew averaged 2.75 men per shift. The operator and hooktender were present continually, and a utilityman was on-site when frequent machine moves were required. Two grapple-yarder operators were observed during this study. The regular operator was above average in skill and efficiency. For a three-day period when he was sick, a relief operator was utilized. He had little prior experience on the machine and was considered to be in training.

RESULTS AND DISCUSSION

The first data presentations review general operating and maintenance aspects, and show the overall results for the regular operator. Subsequent presentations are based on the 1789 measured trees only and show the influence of turn size, yarding distance, and other variables on productivity and cost. Results for the trainee operator are shown in Appendix II.

Regression analysis was done to derive expressions for making predictions. The effects of yarding distance, number of pieces per turn, and turn volume were tested on yarding element times. Further discussions of statistical analysis will be covered in a separate publication.

1. Setting Layout and Falling Patterns

Slope ranged from 0 to 38% (average 18%) in the bunched-wood area and from 0 to 52% (average 23%) in the handfelled area. The maximum yarding distance (slope distance) was 150 m, with the average being 70.7 m for the bunched-wood area and 76.6 m for the handfelled area.

Yarding chance was generally good except for one section in the northwest corner of the handfelled block (Figure A). The placement of the spur road created a situation where the yarder operator could not see many of the pieces he was hooking up. He required assistance from the hooktender who gave directions by radio. Hookup time in this area increased by 22% relative to earlier performance.

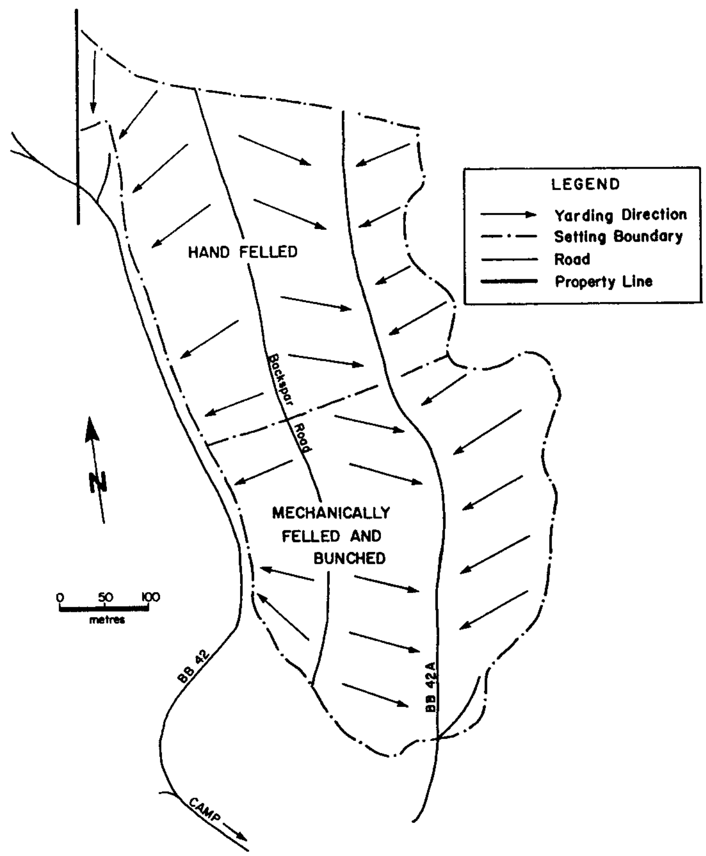

FIGURE A. Yarding Direction.

In the bunched-wood area, the bunching pattern (Figure B) resulted in good operator visibility and the opportunity for yarding multiple pieces per turn. Bunching also had the advantage of all butt ends facing the road. This increased the efficiency of roadside processing (Peterson 1986).

In the handfelled area, the falling pattern (trees perpendicular to the yarding road) allowed the operator to grab the trees easily. Some disadvantages were:

a. Tops were laying in both directions which does not make for efficient butt-first yarding. To facilitate roadside processing, it is preferable to have all butts facing the road.

b. If more than one piece was grappled, often a piece would not stay in lead (Figure C). This caused hangups, more strain on the grapple, and longer decking time.

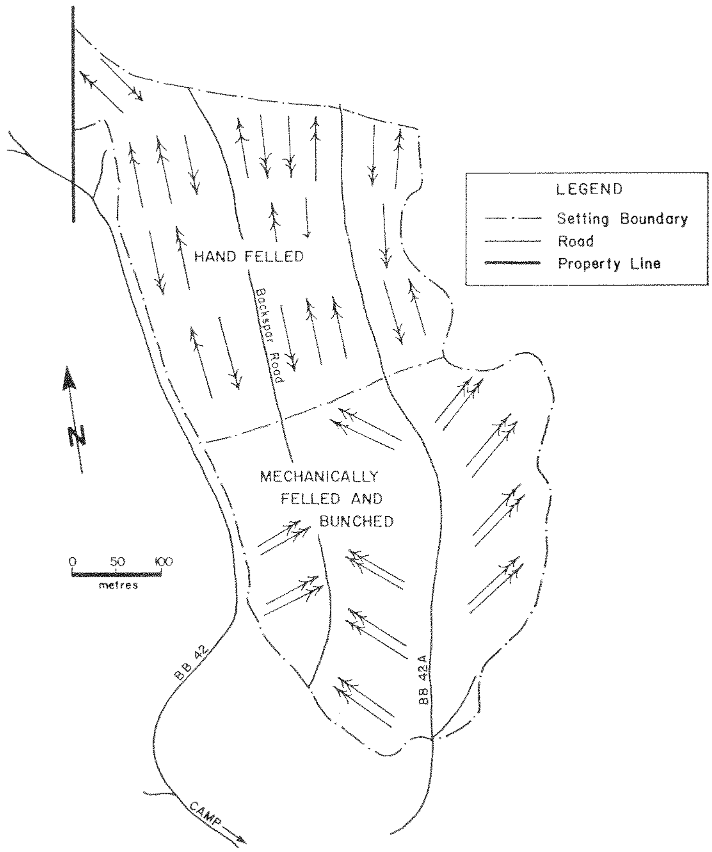

FIGURE B. Falling Pattern.

FIGURE C. Pieces Out of Lead in Grapple.

Trees and logs along the haul road were not picked up and loaded prior to yarding. Many of these pieces had to be pulled away from the road and aligned for windrowing; this decreased yarder productivity.

2. Overall Results

Summary statistics for individual time elements are given in Table 3. Appendix III defines the time elements used. These were computed using observations made on both measured and unmeasured pieces.

TABLE 3. Timing Summary.

	BUNCHED-WOOD AREA		HANDFELLED AREA	
PHASE	HOURS	%	HOURS	%
Productive				
Move	9.2	17	11.6	13
Yard	29.4	56	46.9	55
Deck	2.0	4	7.5	9
Subtotal	40.6	77	66.0	77
Delay				
Mechanical	7.9	15	13.5	16
Other	4.4	8	5.8	7
Subtotal	12.3	23	19.3	23
Total	52.9	100	85.3	100
Yarding Phase, %				
Outhaul	25		25	
Hookup	34		36	
Inhaul	33		32	
Unhook	8		7	
Total	100		100	
Average Time per Turn, min				
Move	0.27		0.22	
Outhaul	0.22		0.22	
Hookup	0.29		0.32	
Inhaul	0.29		0.28	
Unhook	0.07		0.06	
Deck	0.06		0.14	
Total	1.20		1.24	
Average Piece Size, m^3	0.59		0.91	
Total No. Pieces Yarded	4 380		4 538	
Total No. Turns	2 011		3 197	
Average Yarding Distance, m	70.7		76.6	
Average Move Time, min	3.2		6.5	
No. Moves per PMH	3.6		1.7	

Moving time for yarding road changes was substantially lower in the bunched-wood area than in the handfelled area (3.2 minutes vs. 6.5 minutes). One of the causes was that when a setup change was made in the handfelled area, the backspar machine would usually rearrange the logs nearest the backspar road for easier hookup. Another cause was narrowness of the backspar road in parts of the handfelled area. In these cases, the backspar machine was used to widen the road.

The number of moves per productive machine hour (PMH) was greater in the bunched-wood area (3.6 versus 1.7). This is a result of more area being yarded per hour.

Hookup time per turn decreased by 10% when yarding bunched wood. The bunched wood made a larger target for the operator to hit when dropping the grapple. Also, concentration of the trees in fewer locations improved overall visibility. Range of hookup time was 0.02 to 2.39 minutes in the bunched-wood area and 0.02 to 3.18 minutes in the handfelled area.

In the bunched-wood area, the turn size averaged 2.2 pieces with a range from 1 to 8 pieces. Turn volumes averaged 1.3 m^3 with a range of 0.04 to 8.7 m^3. In the handfelled area, the range was from 1 to 5 pieces (average 1.4), and from 0.04 to 6.40 m^3 (average 1.3 m^3). Based on average number of pieces per turn, yarding of the bunched wood was 57% more productive. Volume per turn was essentially the same for the two areas. This was mainly a result of the bigger average piece size (54%) in the handfelled area.

Decking time per turn in the handfelled wood was 133% greater than for the bunched wood. The main reason for this was that grappling all logs from the butt end and at basically the same distance resulted in a more integral bunch that was easier to deck. With the bunched turns, very little time was spent aligning the bunch on the windrow at the roadside. Figure C illustrates the type of turns in handfelled wood that result in increased decking time.

Mechanical delays accounted for 15% of the total yarding phase time in the bunched-wood area, and 16% of the time in the handfelled area. A summary of delays is given in Appendix IV.

The timing data allowed the calculation of average line speeds at various yarding distances. Appendix V gives a summary of line speeds by yarding distance. The no-load line speeds calculated by the manufacturer are shown in Appendix VI.

The trainee operator worked only in the handfelled area. His times per turn were higher than the regular operator in all phases. The largest time difference was in decking where he took 93% more time per turn. This was followed next by hookup at 69%, then unhook at 67%, move at 41%, inhaul at 21%, and lastly outhaul at 9 percent. On a total productive time basis, the trainee operator took 45% more time per turn than the regular operator. See Appendix II for a detailed breakdown of the trainee operator results.

3. Actual Systems Comparison

The labour rates used in the cost analysis are current IWA rates plus 35% burden (Appendix I). Machinery costs are FERIC estimates based on information from equipment and supplies distributors and use a standard owning, repairing, and operating formula format. Unless stated, costs such as supervision and overhead, and crew and equipment transportation are not included. Also, interest or opportunity costs are excluded from the machinery costs reported in the text, but are listed in Appendix I.

The number of pieces per PMH was 57% more in the bunched-wood area than in the handfelled area (Table 4).

TABLE 4. Productivity and Cost Summary--Actual Results.

ACTIVITY	BUNCHED-WOOD AREA	HANDFELLED AREA
Avg No. Pieces per Turn	2.2	1.4
Pieces per PMH	107.9	68.8
Pieces per SMH	82.8	53.2
No. Turns per PMH	49.5	48.4
No. Turns per SMH	38.0	37.5
m^3 per PMH	63.7	62.6
m^3 per SMH	48.9	48.4
Pieces per 8-Hour Shift	662.4	425.6
Volume per 8-Hour Shift, m^3	390.8	387.3
Total Equipment Cost* per 8-Hour Shift	$1650.16	$1650.16
Cost per Piece	$2.49	$3.88
Cost per m^3	$4.22	$4.26

*Costs include the machine and crew (operator, hooktender, and 75% of a utilityman) and the backspar. Interest excluded.

When grapple yarding of bunches was compared with grapple yarding of handfelled wood, it was found that:

a. Pieces yarded per PMH increased by 57% in the bunched-wood area. The bunches resulted in better operator visibility (a larger and more visible target) and thus a better chance for the grapple to yard multiple pieces per turn. The average number of pieces yarded per turn also increased by 57% for the bunched wood.

b. The cost of yarding bunches was $1.39/piece less than yarding handfelled wood.

c. On a volume comparison, there was only a $0.04/m³ cost difference. This was owing to the piece size disadvantage of 0.32 m³ in the bunched-wood area.

d. When windrowed, bunched wood results in all butts facing the road. This facilitates subsequent roadside processing.

e. If the piece volumes are assumed to be the same (0.91 m³) in the two areas, then the yarding cost per cubic metre in the bunched-wood area would decrease from $4.22 to $2.74. This results in the yarding cost of bunched wood being $1.14/m³ cheaper than the handfelled wood.

4. Regression Analysis

Regression analysis was done to derive expressions for predicting yarding element times. Linear relationships between yarding cycle time and potential independent variables were tested using the least squares method.

The effects of yarding distance, number of pieces per turn, and turn volume were tested on yarding element times including move, outhaul, hookup, inhaul, unhook, and deck times. Table 5 shows summary statistics for the analysis.

TABLE 5. Relationships Between Variables.

		BUNCHED-WOOD AREA			HANDFELLED AREA		
INDEPENDENT VARIABLE	DEPENDENT VARIABLE	SAMPLE SIZE	r^2	STANDARD ERROR OF ESTIMATE (min)	SAMPLE SIZE	r^2	STANDARD ERROR OF ESTIMATE (min)
Distance	Outhaul	430	0.63	0.058	215	0.71	0.054
	Hookup	429	0.03	0.28	215	0.03	0.30
	Inhaul	430	0.61	0.11	215	0.62	0.09
	Unhook	401	0.01	0.028	194	0.09	0.026
	Deck	39	0.02	0.43	34	0.03	0.26
Pieces	Outhaul	430	0.03	0.09	215	0.00	0.10
	Hookup	429	0.02	0.28	215	0.00	0.30
	Inhaul	430	0.13	0.16	215	0.00	0.14
	Unhook	401	0.04	0.028	194	0.00	0.027
	Deck	39	0.04	0.42	34	0.00	0.26
Volume	Outhaul	430	0.05	0.09	215	0.00	0.10
	Hookup	429	0.03	0.28	215	0.00	0.10
	Inhaul	430	0.17	0.16	215	0.04	0.14
	Unhook	401	0.00	0.03	194	0.00	0.027
	Deck	39	0.09	0.42	34	0.00	0.27
Distance and Pieces	Outhaul	430	0.64	0.58	215	0.72	0.05
	Hookup	429	0.04	0.28	215	0.03	0.30
	Inhaul	430	0.65	0.10	215	0.63	0.09
	Unhook	401	0.04	0.028	194	0.10	0.026
	Deck	39	0.05	0.43	34	0.03	0.27
Distance and Volume	Outhaul	430	0.64	0.057	215	0.71	0.05
	Hookup	429	0.05	0.28	215	0.03	0.30
	Inhaul	430	0.67	0.099	215	0.66	0.08
	Unhook	401	0.01	0.028	194	0.09	0.026
	Deck	39	0.11	0.42	34	0.04	0.27

Of the three independent variables, yarding distance, number of pieces, and turn volume, yarding time is primarily dependent on yarding distance. Of the yarding phases, only outhaul and inhaul times are related to yarding distance.

Given the settings, the maximum yarding distance, the piece size, and the weight of turns, distance did not have an appreciable effect on hookup, unhook, or deck times. Inhaul times were not significantly affected by the number of pieces yarded nor by the turn volume which indicates the yarder had sufficient or excess pulling capacity. Hookup times were not affected by distance, indicating the operator had good visibility to 150 m.

The following equations can be used to predict the yarding cycle times per turn for bunched and handfelled wood:

a. Bunched Wood:

Outhaul Time (min) = 0.0296 + 0.0027 x Distance
Inhaul Time (min) = 0.0044 x Distance
Fixed Time (excluding delays) per turn is estimated at 0.69 min

b. Handfelled Wood:

Outhaul Time (min) = 0.0323 + 0.0026 x Distance
Inhaul Time (min) = 0.0247 + 0.0035 x Distance
Fixed Time (excluding delays) per turn is estimated at 0.74 min

Example: yarding cycle time for handfelled wood for a yarding distance of 150 m is:

Outhaul Time	= 0.0323 + 0.0026 x 150	=	0.42 min
Inhaul Time	= 0.0247 + 0.00351 x 150	=	0.55 min
Fixed Time		=	0.74 min
	Total Time/Turn	=	1.71 min

Fixed time is made up of average move, hookup, unhook, and deck times as listed in Table 3. Delay time is not included. Table 6 shows calculated yarding times per turn for yarding distances up to 150 m.

As expected, there is little variance in outhaul times. Starting at 20 m, inhaul time of bunched wood becomes greater than handfelled wood. The inhaul variance rises to 20% at a 150-m yarding distance. The larger number of pieces per turn in the bunched-wood area probably accounts for this difference.

Because of the higher fixed time for handfelled wood, total yarding time per turn of the bunched wood is less up to 70 m. As distance increases, the total cycle times converge (Figure D). This reflects the faster inhaul time for handfelled wood.

TABLE 6. Predicted Cycle Times per Turn.

YARDING DISTANCE (m)	MINUTES PER TURN							
	BUNCHED-WOOD AREA				HANDFELLED AREA			
	OUTHAUL	INHAUL	FIXED	TOTAL	OUTHAUL	INHAUL	FIXED	TOTAL
10	0.06	0.04	0.69	0.79	0.06	0.06	0.74	0.86
20	0.09	0.09	0.69	0.86	0.08	0.09	0.74	0.92
30	0.11	0.13	0.69	0.93	0.11	0.13	0.74	0.98
40	0.14	0.18	0.69	1.01	0.14	0.17	0.74	1.04
50	0.17	0.22	0.69	1.08	0.16	0.20	0.74	1.10
60	0.20	0.26	0.69	1.15	0.19	0.24	0.74	1.16
70	0.22	0.31	0.69	1.22	0.21	0.27	0.74	1.22
80	0.25	0.35	0.69	1.29	0.24	0.31	0.74	1.29
90	0.28	0.39	0.69	1.36	0.27	0.34	0.74	1.35
100	0.31	0.44	0.69	1.44	0.29	0.38	0.74	1.41
110	0.33	0.48	0.69	1.51	0.32	0.41	0.74	1.47
120	0.36	0.53	0.69	1.58	0.34	0.45	0.74	1.53
130	0.39	0.57	0.69	1.65	0.37	0.48	0.74	1.59
140	0.42	0.61	0.69	1.72	0.40	0.52	0.74	1.65
150	0.45	0.66	0.69	1.79	0.42	0.55	0.74	1.71

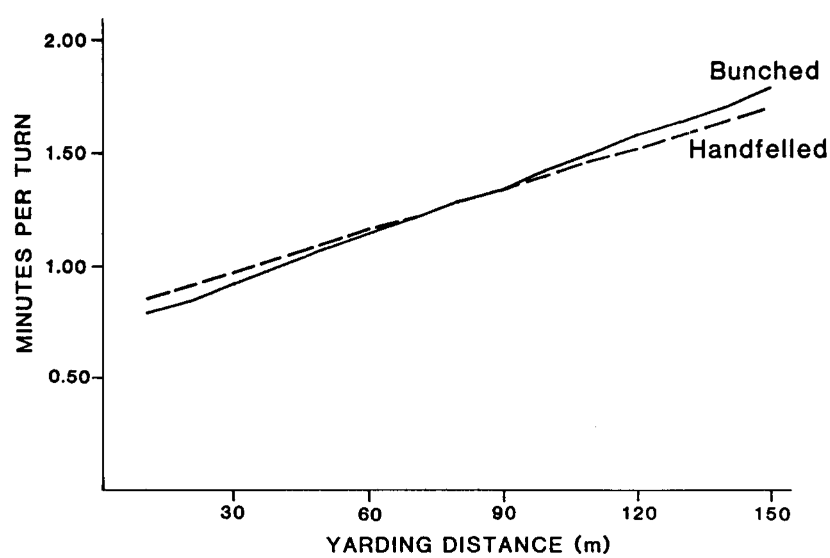

FIGURE D. Comparison of Predicted Cycle Times.

5. Predicted Yarding Costs

The costs in Table 7 are based on the predicted yarding cycle times per turn (Table 6) and a yarding cost of $159.02 per hour. Supervision and overhead costs, and crew and equipment transportation costs are not included. Also, ownership costs are excluded from the machinery costs, but are listed in Appendix I.

TABLE 7. Predicted Yarding Cost per Turn--by Yarding Distance.

YARDING DISTANCE (m)	BUNCHED-WOOD AREA ($/Turn)	HANDFELLED AREA ($/Turn)
10	$2.09	$2.28
20	$2.28	$2.44
30	$2.46	$2.60
40	$2.68	$2.76
50	$2.86	$2.92
60	$3.05	$3.07
70	$3.23	$3.23
80	$3.42	$3.42
90	$3.60	$3.58
100	$3.82	$3.74
110	$4.00	$3.90
120	$4.19	$4.05
130	$4.37	$4.21
140	$4.56	$4.37
150	$4.74	$4.53

As shown in Table 5, yarding time is dependent on yarding distance, but generally independent of turn size. Therefore, yarding costs per cubic metre by turn size and yarding distance can be predicted (Table 8). Figure E is a graphical display of the bunched-wood area. The graph for the handfelled wood is similar.

TABLE 8. Yarding Cost per Cubic Metre by Turn Size and Yarding Distance.

TURN SIZE (m^3)	Bunched-Wood Area: Yarding Distance and Corresponding Yarding Cost per Turn			Handfelled Area: Yarding Distance and Corresponding Yarding Cost per Turn		
	50 m $2.86	100 m $3.82	150 m $4.74	50 m $2.92	100 m $3.74	150 m $4.53
0.5	$5.72	$7.64	$9.48	$5.84	$7.48	$9.06
1.0	$2.86	$3.82	$4.74	$2.92	$3.74	$4.53
1.5	$1.91	$2.55	$3.16	$1.95	$2.49	$3.02
2.0	$1.43	$1.91	$2.37	$1.46	$1.87	$2.27
2.5	$1.14	$1.53	$1.90	$1.17	$1.50	$1.81
3.0	$0.95	$1.27	$1.58	$0.97	$1.25	$1.51
3.5	$0.82	$1.09	$1.35	$0.83	$1.07	$1.29
4.0	$0.72	$0.96	$1.19	$0.73	$0.94	$1.13
4.5	$0.64	$0.85	$1.05	$0.65	$0.83	$1.01
5.0	$0.57	$0.76	$0.95	$0.58	$0.75	$0.91
5.5	$0.52	$0.69	$0.86	$0.53	$0.68	$0.82
6.0	$0.48	$0.64	$0.79	$0.49	$0.62	$0.76
6.5	$0.44	$0.59	$0.73	$0.45	$0.58	$0.70
7.0	$0.41	$0.55	$0.68	$0.42	$0.53	$0.65
7.5	$0.38	$0.51	$0.63	$0.39	$0.50	$0.60
8.0	$0.36	$0.48	$0.59	$0.37	$0.47	$0.57
8.5	$0.34	$0.45	$0.56	$0.34	$0.44	$0.53

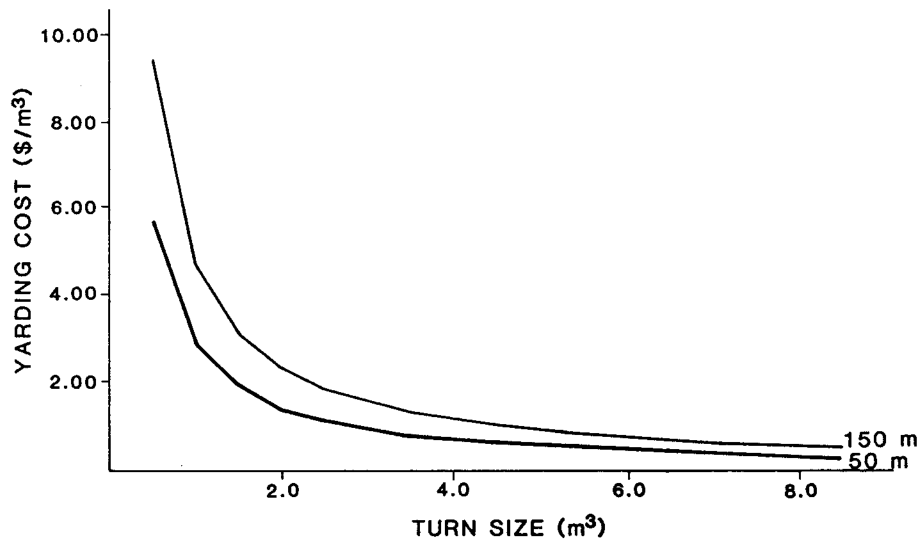

FIGURE E. Predicted Yarding Cost per Cubic Metre by Turn Size and Yarding Distance--Bunched-Wood Area.

Costs rapidly decrease with an increase in turn size in both areas. For a turn size of 0.5 m^3 in the bunched-wood area, costs are $9.48/$m^3$ at a 150-m yarding distance. They decrease to $4.74/$m^3$ or by 50% when turn size rises to 1.0 m^3. A further 33% decrease occurs when the turn size increases to 1.5 m^3. In the handfelled area, the same percentage relationships apply. After 1.5 m^3, the steeply declining curve begins to level off.

Yarding distance also significantly affects costs. For a turn size of 1.0 m^3 in the bunched-wood area, costs vary from $4.74/$m^3$ at a 150-m yarding distance to $2.86/$m^3$ at 50 m. This is a cost range of $1.88/$m^3$ or 66 percent. In the handfelled area, this range in costs is 55 percent.

At a yarding distance of 50 m, bunched wood is about 2% cheaper than handfelled wood ($/turn). At 100 m, this variance reverses. This reflects the findings shown in Figure D, where total cycle times converge as yarding distance increases.

6. Marginal Log Analysis

The marginal tree is the one at which the cost is equal to the revenue. In effect, inputs of individual trees are added up to the point where the marginal cost becomes equal to or greater than the marginal revenue. Fixed costs such as timber-growing costs or road costs do not enter into this calculation. Regardless of the fixed costs involved, it will never pay to harvest a tree that is submarginal in terms of direct logging profit (Worrell 1959).

Once a tree has been felled, a similar situation exists. As far as utilizing the material in the tree is concerned, the felling cost is "sunk" and must be treated as a sunk cost (Worrell 1959).

Past costs are considered sunk. Expenditures that have been made for capital and labour are irreversible because their value cannot be recovered. As such, sunk costs are irrelevant to current decisions among alternatives that will affect future events. In other words, they are "water over the dam", and cannot be changed by any choices among current options (Gunter 1984).

Note that the only costs that are charged against a section of a tree are those incurred directly because that particular section is produced. For example, in order to remove the butt log from a tree, it must be bucked off at the top. The cost of this cut is charged entirely to the butt log because it must be incurred whether a second log is removed from the tree or not. If revenue from the second log will more than cover the cost of cutting it from the top and transporting it to the sale point, it should be bucked out and removed. This decision process can be continued up the tree until a section is reached which will produce a direct loss if it is logged. The last section showing a direct profit is the marginal log (Worrell 1959).

Every logging operation has some logs so small that their value does not cover the cost of logging. But how can the economic limits be identified? The answer lies in accurately determining the value of logs of different volumes and in comparing these values with the extra cost of harvesting these logs. The key question for any specific log concerns only the actual value of that log compared with the marginal or extra cost of harvesting it (Adams 1965).

In this report, the operating and repair costs have been treated as variable costs. Ownership costs are considered as sunk costs and have been excluded. Log values are based on the Vancouver Log Market. In order to compare values to yarding cost (f.o.b. roadside) the downstream costs (load, haul, boom, sort, tow, and stumpage) must be deducted from the Vancouver log-market value. This calculation is shown in Table 9.

By taking predicted yarding cost per cubic metre by turn size and yarding distance (Table 8) and superimposing log values (f.o.b. roadside--Table 9) marginal log or turn size can be identified. This is shown graphically, for bunched wood, in Figure F where the intersection of yarding cost curves and log values identify marginal log or turn sizes.

The marginal log sizes identified vary with species, grade, location of the log with respect to the road, transport to market, log value, and stumpage payable. As can be seen in Figure F, some logs had a negative roadside log value.

TABLE 9. Log Values (April 1986).

			$/m³							
Species	Sort	Grade	Vancouver Log Mkt. Value	Stumpage Charge[1]	Towing Cost[2]	Boom/ Sort Cost[2]	Haul Cost[2]	Load Cost[2]	Sales[3]	Value F.O.B. Roadside
Cedar	Lumber	D	120.00	9.60	3.00	5.00	6.50	2.50	3.00	90.40
		F	110.00	8.80	3.00	5.00	6.50	2.50	2.80	81.40
	Sawlog	H	60.00	4.80	3.00	5.00	6.50	2.50	1.50	36.70
		I	57.00	4.60	3.00	5.00	6.50	2.50	1.40	34.00
		J	53.00	4.20	3.00	5.00	6.50	2.50	1.30	30.50
	Shingle	K	63.00	5.00	3.00	5.00	6.50	2.50	1.60	39.40
		M	63.00	5.00	3.00	5.00	6.50	2.50	1.60	39.40
	Utility	X	8.00	0.60	3.00	5.00	6.50	2.50	0.20	(9.80)
	Chip	Y	8.00	0.60	3.00	5.00	6.50	2.50	0.20	(9.80)
Douglas-Fir	Peeler	A	80.00	6.40	3.00	5.00	6.50	2.50	2.00	54.60
		B	73.00	5.80	3.00	5.00	6.50	2.50	1.80	48.40
		C	60.00	4.80	3.00	5.00	6.50	2.50	1.50	36.70
	Lumber	D	63.00	5.00	3.00	5.00	6.50	2.50	1.60	39.40
	Sawlog	H	57.00	4.60	3.00	5.00	6.50	2.50	1.40	34.00
		I	55.00	4.40	3.00	5.00	6.50	2.50	1.40	32.20
		J	38.00	3.00	3.00	5.00	6.50	2.50	1.00	17.00
	Utility	X	28.00	2.20	3.00	5.00	6.50	2.50	0.70	8.10
	Chip	Y	19.00	1.50	3.00	5.00	6.50	2.50	0.50	0.00
Hemlock	Lumber	D	50.00	4.00	3.00	5.00	6.50	2.50	1.30	27.70
	Sawlog	H	47.00	3.80	3.00	5.00	6.50	2.50	1.20	25.00
		I	46.00	3.70	3.00	5.00	6.50	2.50	1.20	24.10
		J	32.00	2.60	3.00	5.00	6.50	2.50	0.80	11.60
	Utility	X	27.00	2.20	3.00	5.00	6.50	2.50	0.70	7.10
	Chip	Y	22.00	1.80	3.00	5.00	6.50	2.50	0.60	2.60
Deciduous	Chip	Y	18.00	1.40	3.00	5.00	6.50	2.50	0.50	(0.90)

NOTE: [1] Stumpage and royalty charges vary with type of tenure. For ease of calculation, stumpage charge is set at 8% of market value.
[2] Estimated average cost for southeast Vancouver Island.
[3] Estimated at 2.5% of market value.

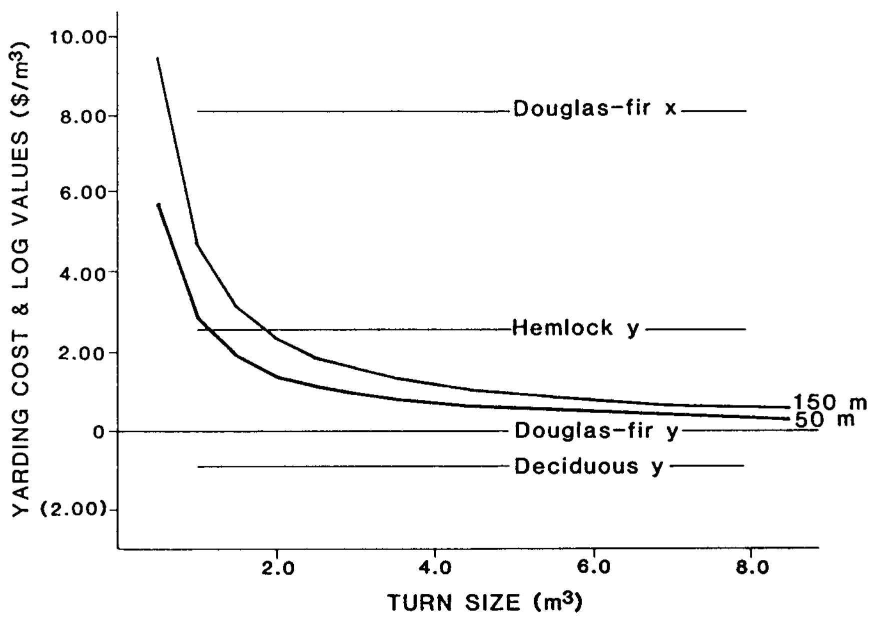

FIGURE F. Marginal Log or Turn Sizes (Bunched-Wood Area).

Example: Hemlock Chip Grade Y has a log value of $2.60/m³ at roadside. At a 50-m yarding distance, the cost of yarding a 1.0 m³ log is greater than its value; therefore, it should not be yarded.

CONCLUSIONS

The falling pattern and method used is critical to the efficiency of the yarding phase that follows. In this study, the bunching pattern resulted in good operator visibility and opportunity for the grapple to yard multiple pieces per turn. When windrowed, bunched wood results in all butts facing the road. This facilitates subsequent roadside processing.

There was no significant time or cost difference in yarding hand-felled or bunched turns of the same size. The major advantage of bunching is in increasing turn size, i.e. <u>bunching reduces the size of the economically viable log.</u>

The higher costs and decreased productivities associated with training new operators are highlighted in this report. The trainee operator produced 190 pieces per shift at a cost of $9.57/m^3$, versus 426 pieces per shift at a cost of $4.26/m^3$ for the regular operator.

Study results show there is a strong correlation between yarding time and yarding distance. Number of pieces and volume per turn appeared to have little effect on yarding times. This suggests that the yarder had sufficient or excess pulling capacity.

Costs rapidly increase when handling small wood. Costs per cubic metre doubled when turn size dropped from 1.0 to 0.5 m^3.

Yarding distance also significantly affects costs. For a turn size of 1.0 m^3 in the bunched-wood area, costs varied by 66% between yarding distances of 50 and 150 m.

Under the observed conditions of this study, any logs smaller than the marginal log size do not pay their way to the roadside. Removal of these can only be justified by silvicultural, protective, or other reasons. Economic justification can only be accomplished by development of more efficient yarding methods, or by higher log values.

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APPENDIX I

LOGGING COSTS

Machinery costs used in this report are estimated by FERIC and are based on information from equipment and supplies distributors.

Operating labour includes the IWA hourly rate for a particular job plus 35% for fringe benefits. Machine operators' rates include 0.7 of an hour, at overtime rate, for machine servicing. For example, the IWA rate for a grapple-yarder operator is \$17.73/h. The hourly rate charged to the job should be \$17.73 x 1.35 = \$23.94. To account for machine servicing, the \$23.94 should be adjusted by:

$$\frac{0.7 \times \$23.94 \times 1.5}{8} = \$3.14 \qquad \$3.14 + \$23.94 = \$27.08/h$$

	HITACHI UH14 BACKSPAR	MADILL 084 GRAPPLE YARDER
OWNERSHIP COSTS		
Purchase Price (P)	\$135 000	\$700 000
Salvage Value (30% of P)	\$40 500	\$210 000
Expected Life (yr)	7	10
Expected Life (h)	10 000	14 400
Interest Rate (I) %	12.5	12.5
Insurance Rate (Ins) %	1	1
Average Investment (AVI) = (P+S)/2	\$87 750	\$455 000
Loss in Resale Value (\$/h) = (P-S)/h	\$9.45/h	\$34.03/h
Interest (\$/h) = (I*AVI)/(h/yr)	\$7.68/h	\$39.50/h
Insurance (\$/h) = (Ins*AVI)/(h/yr)	\$0.61/h	\$3.16/h
Total Ownership Costs (\$/h)	\$17.74/h	\$76.69/h
OPERATING AND REPAIR COSTS		
Fuel Consumption (L/h)	20	45
Fuel Cost (\$/L)	\$0.36	\$0.36
Operating Supply Cost Per Year (O)	\$1 500	\$25 000
Annual Tire Consumption (T) (yrs)	0	0
Tire Replacement Cost (\$/T)	\$0	\$0
Annual Repair & Maintenance Cost (R)	\$10 000	\$55 000
Wages (\$/h)	\$0.00	\$51.56
Wage Benefit Loading (%)	0	35
Fuel Cost = (L/h)*(\$/L)	\$7.22/h	\$16.25/h
Lube & Oil Cost = 10% * Fuel Cost	\$0.72/h	\$ 1.62/h
Operating Supply Cost = O/(h/yr)	\$1.05/h	\$17.36/h
Tire Cost = T*(\$/T)/(h/yr)	\$0.00/h	\$0.00/h
Repair & Maintenance Cost = R/(h/yr)	\$7.00/h	\$38.19/h
Labour Cost = (\$/h)*{1+(%/100)}	\$0.00/h[1]	\$69.61/h[2]
Total Operating and Repair Costs (\$/h)	\$15.99/h	\$143.03/h
TOTAL COSTS		
Ownership Costs (\$/h)	\$17.74/h	\$76.69/h
Operating and Repair Costs (\$/h)	\$15.99/h	\$143.03/h
Total Cost (\$/h)	\$33.73/h	\$219.72/h
System Cost (Excludes Interest)	\$206.27/h	
System Variable Cost (Excludes Ownership)	\$159.02/h	

[1] Operator included with Grapple Yarder

[2] Operator \$27.08
Hooker 27.08
Utilityman \$20.59 x 0.75 = 15.45
\$69.61

APPENDIX II

TRAINEE OPERATOR RESULTS

SUMMARY OF TIME AND PRODUCTION

PHASE	Hours	%
Productive		
Move	2.0	9
Yard	8.0	36
Deck	1.8	8
Subtotal	11.8	53
Delay		
Mechanical	9.7	43
Other	1.0	4
Subtotal	10.7	47
Total	22.5	100
Yarding Phase, %		
Outhaul	20	
Hookup	44	
Inhaul	28	
Unhook	8	
Total	100	
Avg Time per Turn (min)		
Move	0.31	
Outhaul	0.24	
Hookup	0.54	
Inhaul	0.34	
Unhook	0.10	
Deck	0.27	
Total	1.80	

Avg Piece Size (m^3)	0.91	m^3 per PMH	41.1
Total No. Pieces Yarded	533	m^3 per SMH	21.6
Total No. Turns	395	Pieces per 8-Hour Shift	189.6
Avg Yarding Distance (m)	76.6	Volume per 8-Hour Shift (m^3)	172.5
Avg Move Time (min)	17.4	Total Equipment Cost* Per 8-Hour Shift	$1650.16
No. Moves per PMH	0.6	Cost per Piece	$8.70
Avg No. Pieces per Turn	1.3	Cost per m^3	$9.57
Pieces per PMH	45.2		
Pieces per SMH	23.7		

* Costs include the machine and crew (operator, hooktender, and 75% of a utilityman) and the backspar. Interest is excluded.

SUMMARY OF DELAYS

	HANDFELLED AREA (h)
Mechanical Delays	
Batteries--Replace	-
Butt Rigging--Repair	-
Fuel	0.2
Guyline Winch--Repair	-
Haulback Cable--Repair/Replace	0.5
Main Drive Chain--Repair	6.4
Mainline Cable--Repair/Replace	-
Mainline Winch Drum--Repair	-
Operator Cab	
--Control Lever Repair	0.4
--Replace Window	-
Other[1]	0.2
Service	0.1
Yarding Grapple	
--Closing Cable Repair/Replace	0.2
--Exchange	1.6
--Repair	0.1
Subtotal Mechanical	9.7
Non-Mechanical Delays	
Coffee/Smoke Break	0.2
Hooktender Check Yarding Road	0.2
Other[2]	0.6
Safety Meeting	-
Visitors	-
Wait	
--Crews walk by	-
--Fire truck to arrive	-
Subtotal Non-Mechanical	1.0
Total Delays	10.7

[1] Includes such activities as radio repair, re-spool lines, and unknown.
[2] Includes such activities as radio communications, untangle yarding lines, talk to supervisor, and unknown.

APPENDIX III

GRAPPLE YARDING

TIME ELEMENT DEFINITIONS

TIME ELEMENT	BEGINS	ENDS
Outhaul	When grapple starts travel away from yarder.	When grapple stops and positioning onto log starts.
Hookup	End of outhaul--includes travel to position on logs.	When grapple begins travel with one or more pieces.
Inhaul	End of hookup.	When the incoming turn stops above the windrow (deck).
Unhook	End of inhaul.	When grapple starts travel away from yarder or decking begins.
Decking	End of inhaul or end of unhook--includes straightening of pieces in the windrow and reyarding of pieces which slide out of the pile.	When grapple starts travel away from yarder.
Delay	When a productive function is interrupted.	When the productive function recommences.
Move	When crew start to prepare to move backspar machine or grapple yarder, e.g. slacken yarder guylines.	When machine is ready for productive function to recommence.

APPENDIX IV

DELAY TIME SUMMARY (REGULAR OPERATOR)

	BUNCHED-WOOD AREA (h)	HANDFELLED AREA (h)
Mechanical Delays		
Batteries--Replace	0.5	-
Butt Rigging--Repair	-	0.1
Fuel	0.4	0.5
Guyline Winch--Repair	-	0.9
Haulback Cable--Repair/Replace	3.5	1.2
Main Drive Chain--Repair	-	0.7[1]
Mainline Cable--Repair/Replace	0.1	6.8
Mainline Winch Drum--Repair	-	0.2
Operator Cab		
--Control Lever Repair	-	-
--Replace Window	-	0.6
Other[2]	0.2	0.1
Service	0.3	0.4
Yarding Grapple		
--Closing Cable Repair/Replace	1.9	1.4
--Exchange	0.8	0.6
--Repair	0.2	-
Subtotal Mechanical	7.9	13.5
Non-Mechanical Delays		
Coffee/Smoke Break	0.3	0.6
Hooktender Check Yarding Road	0.5	1.1
Other[3]	1.6	2.7
Safety Meeting	1.3	0.5
Visitors	-	0.5
Wait		
--Crews walk by	0.3	0.4
--Fire truck to arrive	0.4	-
Subtotal Non-Mechanical	4.4	5.8
Total Delays	12.3	19.3

[1] Carry-over time from day before when trainee operator was on machine.
[2] Includes such activities as radio repair, re-spool lines, and unknown.
[3] Includes such activities as radio communications, untangle yarding lines, talk to supervisor, and unknown.

APPENDIX V

SUMMARY OF LINE SPEEDS: OUTHAUL AND INHAUL

(REGULAR OPERATOR)

BUNCHED-WOOD AREA				HANDFELLED AREA			
DISTANCE (m)	OUTHAUL (m/min)	INHAUL (m/min)	NO. OF OBSERVATIONS	DISTANCE (m)	OUTHAUL (m/min)	INHAUL (m/min)	NO. OF OBSERVATIONS
15	169	116	2	20	163	134	5
20	196	166	12	25	221	247	4
25	224	199	3	30	227	197	5
30	279	275	15	35	263	268	7
35	324	307	12	40	330	290	5
40	298	354	17	45	359	306	6
45	298	274	17	55	363	268	13
50	313	289	18	55	325	284	20
55	325	296	15	60	383	312	11
60	337	280	25	65	334	299	8
65	336	255	13	70	331	282	13
70	367	263	26	75	336	263	10
75	346	266	24	80	448	317	7
80	366	274	29	85	347	292	8
85	372	277	36	90	361	294	7
90	346	235	40	95	311	264	5
95	313	258	19	100	382	295	11
100	333	219	28	105	401	309	13
105	327	248	14	110	381	288	10
110	308	211	19	115	318	253	13
115	334	221	21	120	335	271	11
120	355	247	15	125	380	308	7
125	362	244	2	130	336	245	6
135	375	245	1	135	329	241	2
140	263	198	3	140	334	311	2
				145	371	288	4
SUMMARY/OVERALL AVERAGE:							
76	328	258	426	80	341	278	213

COMBINED SUMMARY/OVERALL AVERAGE:	DISTANCE	OUTHAUL	INHAUL	NO. OF OBSERVATIONS
	77	333	265	639

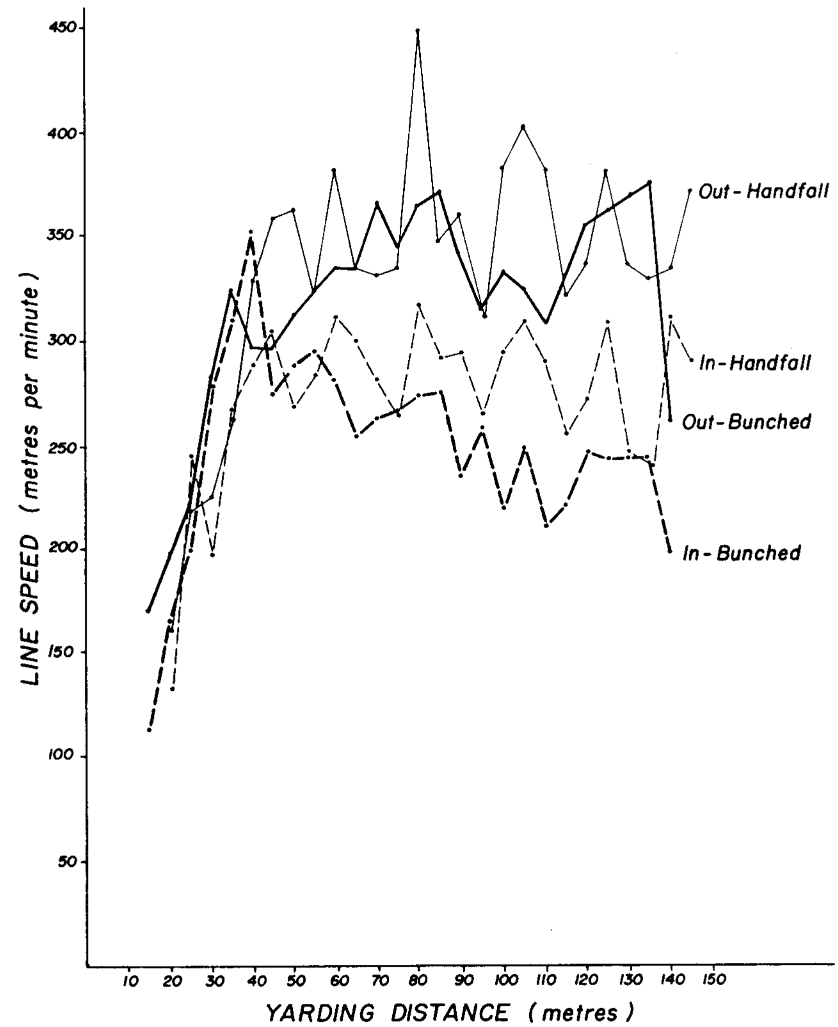

FIGURE V-A. Line Speed Comparisons (Regular Operator).

The rapid rise in speed up to 40 m is a result of the acceleration/deceleration effect. The inhaul speed for the bunched wood is generally slower than for the handfelled wood. The larger number of pieces per turn in the bunched-wood area probably accounts for this difference.

As yarding distance increases, there is a general decrease in average inhaul line speeds for both areas. This is caused because the effective operating radius of the main drum decreases with yarding distance and, given the same drum rotation speed, the line speed decreases. Also, exposure to hangups increases as yarding distances increase.

As would be expected, there is no general difference in outhaul speeds between the two areas because the grapples were empty. There is a slight increasing trend in line speed as distance increases. Again, this is primarily caused by the increase in the effective haulback-drum working radius with increased distance.

APPENDIX VI

MADILL 084 SWING YARDER

(Reprinted curtesy of S. Madill Ltd., Canada)

General Construction:

Our designs require that gears and clutches be outside the frame for easy access and maintenance. This ensures that bearing housings can be as close to drum bosses as possible for maximum strength. This form of construction-precision gearing, accurate shaft spacing, external gears, and clutches provides for a trouble free long service winch.

Power:
Detroit Diesel 12V71N70 with Twin Disc 3 stage torque converter. Provides 450 horsepower.

Brakes:
Operating Drums have both multi-disc water cooled brakes and band brakes.

Gears:
Helical gears are provided to give smooth and quiet operation.

Special Features:
Live boom, hydraulic swing, swivel haulback fairlead, walk-over guylines, tilt cab and tilt gantry.

Sold & Serviced

S. MADILL LTD.

in Canada

EVANS ENGINE & EQUIPMENT
in Alaska & Most of Washington

ROSS EQUIPMENT
in Southern Washington
Oregon and California

DRUM DATA

DRUM	SIZE	CAP(FT)	PULL(LBS)	SPEED(FPM)
MAIN 1	39" fling 22" core 32" wide	3500' - 3/4" 2600' - 7/8" 2000' - 1"	bare 69144 mid 49874 full 39004	933 1293 1654
MAIN 2	39" fling 22" core 32" wide	3500' - 3/4" 2600' - 7/8" 2000' - 1"	bare 63450 mid 45767 full 35792	933 1293 1654
HAUL BACK	45" fling 20" core 32" wide	6000' - 3/4" 4400' - 7/8" 3200' - 1"	bare 40428 mid 24501 full 17577	1602 2643 3685
STRAW	34" fling 12" core 12" wide	6000' - 5/16" 4400' - 3/8" 3200' - 7/16"	bare 20000 mid 10909 full 7500	694 1272 1851
GUY LINES	21" fling 8 5/8" core 11 1/4" wide	352' - 7/8" 270' - 1" 213' - 1 1/8"	bare 6800 mid 5000 full 3000	116 180 240

TRAVEL SPEED: 5 mph

GRADEABILITY: 30% (Cable snubbing above 15%)

SWING: Cat 8J6773 with Sundstrand pump.