BUNCH YARDING WITH RADIO-CONTROLLED CHOKERS IN COASTAL BRITISH COLUMBIA SECOND-GROWTH TIMBER

A.J. MacDonald* SR 63

***FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA**
201 - 2112 West Broadway
Vancouver, B.C. V6K 2C8

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Abstract

Two Madill 044 yarding cranes were monitored over a three-week period in 1989 in a Coastal British Columbia stand where chokers were used for yarding mechanically felled and bunched second-growth timber. Productivity, costs, and profitability of the choker system were determined and compared to using grapple systems on the same yarding cranes.

Acknowledgements

The author would like to thank the staff of MacMillan Bloedel Limited's Cameron Logging Division for their help during this project; the project could not have been completed without the help of Chris Whittaker. Special thanks also go to the operators and members of the rigging crews (Dave, Steve, Bob, Dave, Terry, and Wes) for their assistance and cooperation.

The diligent work of Kelly Hutchinson in collecting field data is gratefully acknowledged.

Author

Jack MacDonald graduated from the University of British Columbia Faculty of Forestry in 1976, and joined British Columbia Forest Products Limited as a forest engineer. He worked in that capacity in various locations on Vancouver Island until joining FERIC in 1986. He is currently a Researcher in the Harvesting Operations Group, and works in the areas of machine and systems evaluations.

Disclaimer

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Summary

Forestry Canada contracted the Forest Engineering Research Institute of Canada (FERIC) under the Forest Resource Development Agreement (FRDA) to examine a yarding crane using radio-controlled, self-releasing chokers to yard mechanically felled and bunched timber. The report is one in a series on yarding techniques used in logging British Columbia Coastal second-growth timber. The objectives of this study were to determine the system costs and productivity, to determine the effect of turn volume and hookup times on productivity, to compare choker-yarding costs and productivities with those of grapple yarding, and to determine the marginal log volume for profitable yarding while using chokers. Two Madill 044 yarding cranes, rigged in different yarding configurations, were monitored at a detailed-timing level for three weeks in 1989 in a second-growth Douglas-fir stand near Port Alberni, B.C.

Productivity varied depending on the yarding system and configuration; the highest productivity (108 m^3/PMH) occurred when a grapple system was used over a short time period that did not include any delays or yarder-moving times. The next highest productivity, at 75 m^3/PMH, occurred when a dropline carriage was rigged with two chokers. Average yarding costs for the dropline and grapple systems, including typical moving and delay times, were \$4.08 and \$3.99/m^3 respectively.

The differences in the productivities of the grapple and choker systems related primarily to turn size and fixed times per turn. The chokers required more time than the grapple for hooking, unhooking, and decking but the average turn size was larger. Turn times for the choker and grapple systems averaged about 5.1 and 1.5 min/turn respectively, while the average turn volumes were approximately 6.0 and 2.1 m^3/turn. Models of machine productivity showed that each machine type was suited to different yarding conditions; the grapple system was more productive at short yarding distances, while the choker system was more productive at distances beyond 150 m.

Productivity for all yarding systems, and especially the choker systems, was hindered because stems had been left behind by a loader that had prelogged some of the study site. When the clean-up turns for these stems were removed from the analysis, the average turn volume increased from 6.2 to 7.3 m^3/turn.

The marginal log volume was calculated using marginal economics analysis. The net value at roadside, and thus the marginal log volume, depended on the handling methods used in subsequent phases such as processing and loading. When these costs were assumed to be piece-based, rather than volume-based, the net value at roadside was reduced for smaller stems and the change in marginal log volume was not proportional to the change in number of stems in the turn. Douglas-fir J-grade stems yarded from 120 m in turns of one, four, and twelve stems had marginal volumes of 0.73, 0.37, and 0.28 m^3/stem respectively. As more stems were added to the bunch, the smallest marginal log volume approached 0.27 m^3/stem.

INTRODUCTION

This is the third report in a series of studies on techniques for yarding second-growth timber in Coastal British Columbia. The first study (MacDonald 1987) monitored a grapple yarder in a setting where the timber had been hand-felled and bucked, and the second study (MacDonald 1988) monitored a grapple yarder in mechanically felled and bunched timber. Results from both studies showed that turn volume was a critical factor in determining system productivity, and that productivity increased as turn volume increased. It was also found that the grapple size limited the turn volume in bunched timber so that several turns were often required to yard a complete bunch.

To overcome limitations imposed by grapple size, the Forest Engineering Research Institute of Canada (FERIC) proposed to conduct a study of a yarding crane using radio-controlled chokers in mechanically felled and bunched timber as a possible method of increasing productivity and reducing costs when yarding second-growth timber. It was anticipated that using chokers would enable bunches to be yarded in their entirety and thus increase the average turn volume; however, the additional time required to hookup the chokers would increase the cycle times. The objectives of this study were to:

- Monitor a yarding crane using chokers to yard bunches.
- Determine the costs and productivity of such a system.
- Determine the effect of turn volume and hookup times on productivity.
- Compare choker yarding with grapple yarding.
- Determine the marginal log volume required for profitable yarding.

The Cameron Logging Division of MacMillan Bloedel Limited (MB) agreed to conduct the trial in one of its second-growth logging areas near Port Alberni, B.C. The setting was felled in March and April of 1989, and the study area was yarded in June 1989.

This study was funded by Forestry Canada, under the Canada/British Columbia Forest Resource Development Agreement (FRDA).

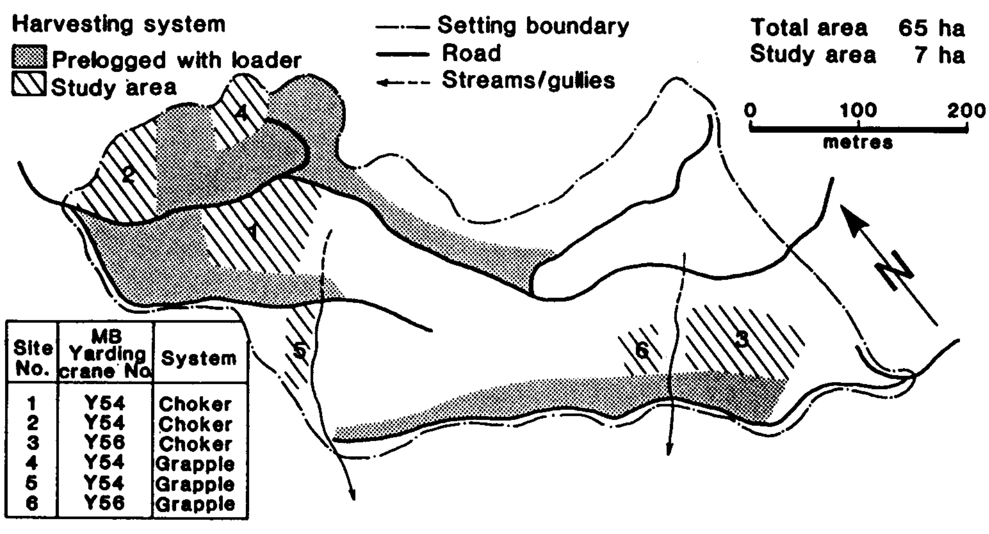
SITE AND SYSTEM DESCRIPTION

The trial was conducted in a setting located approximately 10 km south of Port Alberni, B.C. in an area with predominantly Douglas-fir second-growth timber (Figure 1). MB agreed to conduct the trial as an experiment and a small area within the setting was identified as a study site (Site 1). However, because of a change in operational plans after falling and prior to yarding, a portion of the study site was logged with another system, and Sites 2 and 3 were included in the trial. Grapple-yarding operations were monitored in adjacent Sites 4, 5, and 6.

The sites included in the trial were selected because they were suited to yarding with a choker system. Other areas within the setting were rejected for the trial because the trees were hand-felled, the bunches less compact, the yarding distances too short, or the areas were better suited for ground-based harvesting.

Falling and Prelogging

A Chapman FB122 feller-buncher with a 56-cm Roto-Saw head was used for the primary falling and bunching. Large trees and steep areas were hand-felled. Also, poles and pilings had been harvested from much of the



Site No.	MB Yarding crane No.	System
1	Y54	Choker
2	Y54	Choker
3	Y56	Choker
4	Y54	Grapple
5	Y54	Grapple
6	Y56	Grapple

Figure 1. Location and layout of the trial sites.

setting before feller-buncher operations were undertaken. This affected subsequent activities in several ways:

- Long butts cut from the poles were scattered throughout the area; these long butts hindered the mobility of the feller-buncher. On several occasions during yarding, however, they were propped against stumps to help prevent hangups.
- The diameter of many of the poles exceeded the capacity of the feller-buncher, and would have required hand falling even if they had not been prelogged. Hand-felled trees were yarded individually, and, by prelogging the poles, the number of stems to be individually yarded was reduced. This procedure enhanced the yarder's productivity when using chokers.
- The total setting volume was reduced, which reduced the volume for each yarding road. Thus, the number of turns per road was reduced, and the moving time per turn was increased.

The poles in Sites 2 and 3 had not been prelogged because the terrain was too steep.

For Site 1, the area which had been originally identified as the study site, the feller-buncher operator was instructed to ensure there were choker-holes under all the bunches to facilitate choker setting. This was done by piling the stems on long-butts or windfalls, or over small depressions in the ground. However, Sites 2 and 3 had been planned for grapple yarding, therefore the operator made no special allowance for making choker-holes in those areas.

The operator was also instructed to make the bunches as large as possible for the yarding trial, and observations made during falling showed that this objective was accomplished. Bunch size was limited by the number of trees at each felling site and, for this stand, could have been increased only if a larger feller-buncher had been used, or if the feller-buncher had moved the stems from one bunch to the other.

Portions of Sites 1 and 3 were prelogged with a hydraulic loader. This machine operated on the flatter areas near the road, and moved the bunches closer to the road for subsequent loading. This reduced the amount of timber on each yarding road for the yarding cranes, and increased the moving time per turn. Site 2 was too steep for the loader to operate.

Yarding, Processing, and Loading

Before the project commenced, FERIC and MB realized that the labour cost would be higher for the choker system than for the grapple system. The crew size for a conventional grapple system would have to be increased by two or more workers; one for hooking the chokers and another for unhooking at the landing. Furthermore, the need to unhook the chokers at the landing would increase the cycle times if conventional chokers were used. Therefore, it was proposed that radio-controlled self-releasing chokers be used during the trial. Self-releasing chokers would minimize the increase in crew size, and would be faster and safer to unhook than conventional chokers. However, MB was concerned about the durability of the existing self-releasing chokers when yarding bunches. Fortunately, prototypes of a larger model of self-releasing choker were available for testing, and the manufacturer, Johnson Industries Ltd., agreed to participate in the trial.

The trial involved two Madill 044 yarding cranes (Appendix I), each rigged in a different configuration. In order to conduct the trial with minimum machine modifications, the first machine (MB No. Y54) was outfitted with conventional butt rigging. This machine was used for choker logging on Sites 1 and 2, and for grapple yarding on Sites 4 and 5. A Hitachi UH 171 excavator was used for a backspar.

Initially, one 2.5-cm-diameter choker was used and, as the viability of the yarding system was proven, a second 2.2-cm-diameter choker was added. The chokers were 8.5 m long to facilitate reaching on either side of the yarding road. Large-diameter chokers were used for two reasons:

- The self-releasing choker bells (Appendix II) were designed for 2.5-cm-diameter chokers.
- The load weights were unknown and the smaller-diameter cables may have been inadequate.

When yarding on Sites 1 and 2 was completed, the chokers were moved to another Madill 044 yarding crane (MB No. Y56, Figure 2) which was rigged with a dropline carriage. It was hoped that by using a dropline carriage, shorter and lighter chokers could be used to reduce the incidence of hang-ups and enhance

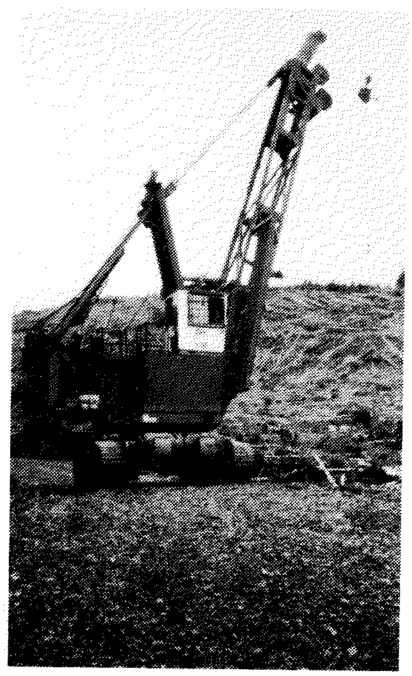


Figure 2. Madill 044 yarding crane (MB No. Y56) rigged with dropline carriage.

the choker handling. Two 5.5-m by 1.9-cm chokers were attached to a hook on a 10-m by 1.9-cm diameter dropline. A Caterpillar D8K was used as a mobile backspar.

Initially, MB was reluctant to use the dropline carriage on the Madill 044 for two reasons:

- The Madill 044 yarding crane had a non-interlocking winch, and it was perceived that the dropline carriage would be difficult to control during hookup operations without the interlock. The operator suspected that the carriage might drop to the ground as he slacked the lines, thereby possibly injuring a chokerman. However, after a short practice period, the operator was able to control the dropline with minimal carriage movement.

- The fairlead sheaves on older Madill 044 yarding cranes were too narrow to accommodate the two cables required to operate a dropline carriage. Therefore, MB designed and built a special narrow-profile "Double-D" attachment (Figure 3) to fit through the fairlead. The fairlead sheaves on newer Madill 044 yarding cranes are wider and will accommodate standard hardware.

The crew on each yarding crane consisted of an operator, a hooktender, a rigging slinger, and a chokerman. FERIC rated all the workers to be competent; however, they were reluctant to change from a grapple-based yarding system to a choker-based yarding system, and often expressed doubts about the system's viability. Four-man crews were used during the trial, although FERIC had observed another similar yarding operation where the crew consisted of only three men. With three men, the hooktender also performed the rigging slinger's duties.

After yarding, the stems were pulled from the windrow piles with either a Caterpillar 528 grapple skidder or a Chapman 1825 hydraulic loader. The stems were processed into log lengths with a Hahn harvester, and loaded with the Chapman log loader for hauling to either the dryland log sort on the Alberni Canal or to the pulp mill at Port Alberni.

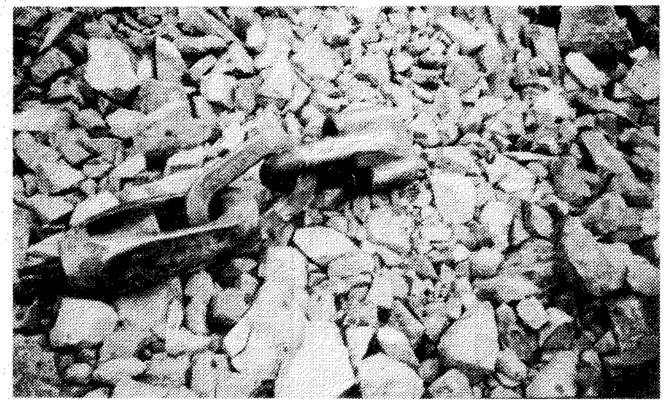


Figure 3. Narrow-profile "Double-D" to fit fairlead of the Madill 044 yarding crane.

Setting Characteristics

It was impossible to calculate the net volume/ha for the study sites since only a portion of the setting was harvested using the choker system, and all logs were combined for loading and scaling. Stand-volume calculations were further complicated because the poles and pilings were harvested and scaled separately. Therefore, the volumes shown in Table 1 were based only on the cruise figures, and not on the net volume harvested.

All three choker-yarding sites were logged downhill, and the slopes ranged from 0 to 50% (Figure 4). Site 5 (grapple yarding) was logged uphill. Access for the backspars was via the haul road for Site 1, and via backspar trails for the other sites. Deflection on all sites

Table 1. Setting Characteristics

Characteristics	Description
Cutting area	
Study area	7 ha
Total setting	65 ha
Slope range	0-50%
Terrain	Gently rolling, except flat near roadsides Deflection good
Exposed rock	None in study areas
Underbrush	Light
Obstacles	Nil
Cruise volume/ha	420 m^3/ha
Stem size from scale results	
Average	1.12 m^3/stem
Range	0.11-5.02 m^3
Species distribution	
Douglas-fir	75%
Hemlock	20%
Cedar	5%

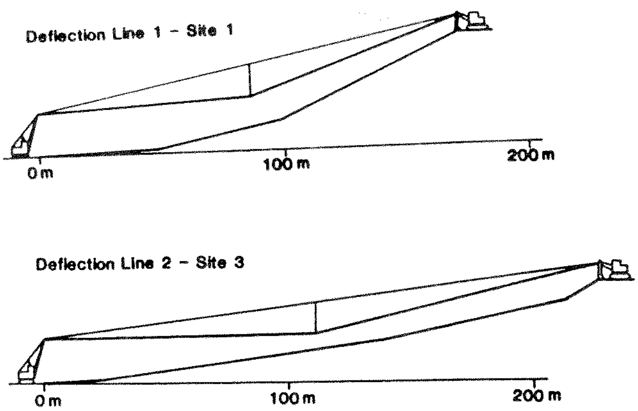


Figure 4. Typical deflection lines in the study sites.

was good, and the operators had good visibility for the full length of the yarding roads. The three choker-yarding sites could have been successfully yarded with a grapple yarder if they had not been included in the trial.

STUDY METHODS

Prior to being yarded, the bunches in the study areas were measured and marked with identification numbers. Bunch height and width, the number of stems in each bunch, and butt-diameter classes were tallied. Each bunch was classified for hookup difficulty; bunches in hookup difficulty Class 1 had obvious choker holes, while those in Class 2 had no clear holes.

Sample stems were scaled by a licensed scaler according to B.C. Ministry of Forests standards. Average stem volumes, in 10-cm butt-diameter classes, were calculated and applied to stem counts to derive the bunch volumes and turn volumes.

During yarding operations, the cycle elements (Appendix III) were timed using the stopwatch function of a handheld computer. Other data besides timing information were collected for each turn, including the yarding distance, bunch number, number of chokers, butt-diameter class of individual stems not from a bunch, whether it was the first or subsequent turn from a particular bunch, and whether stems were broken during yarding.

The yarding cranes were also monitored in adjacent grapple-yarding areas to develop comparative cycle times and productivities.

The feller-buncher was monitored in Site 1 to document the amount of preparation time required to ensure that each bunch had a choker-hole underneath. It was also monitored in Site 4 for comparison purposes.

RESULTS AND DISCUSSION

General

Table 2 shows the timing summaries for the five systems monitored during the study, i.e. the dropline system, the butt-rigging system with one choker, the butt-rigging system with two chokers, the Y54 grapple yarder operating in smallwood in Site 4, and the combined results of the Y54 and Y56 grapple yarders in larger timber.

As expected, cycle times were shorter and average turn volumes were less for the grapple machines than for the choker machines. The grapple yarders averaged about 1.5 min/turn and about 2.1 m^3/turn, while the choker machines averaged about 5.0 min/turn and about 6.0 m^3/turn.

The Y54 grapple yarder operating in the smallwood area had the highest productivity at 108 m^3/productive machine hour (PMH). However, its average yarding distance was the shortest and it also had very short moving times. During the timing period, the yarder remained in one location; this would not be expected over a longer duration. Productivities for the other systems ranged from 61-75 m^3/PMH. The productivity with the dropline carriage was 75 m^3/PMH even though the average yarding distance was longer than for any of the other systems.

The timing data that were collected for this study did not include the longer-term delays that FERIC normally uses to calculate machine utilization; all delays over 10-min duration were excluded from the analysis. Therefore, machine utilization (i.e., the ratio of productive time to scheduled time) was estimated at 83% in order to calculate productivity per scheduled machine hour (SMH). This utilization level was calculated in the previous two studies on second-growth yarding techniques (MacDonald 1987 and 1988).

Appendix IV shows estimated machine costs for the Madill 044 yarding crane configured with grapple and dropline carriages. Also included is the cost of the Hitachi UH 171 backspar, and estimated total system costs. The costs shown were estimated by FERIC in consultation with equipment suppliers, and are not the actual costs experienced by the company. The system costs include ownership and operating costs for the crew, yarding crane, and backspar, but exclude supervision, overhead, transportation, and interest. Based on these criteria, the estimated system costs are \$211.09/h for the grapple system and \$255.19/h for the dropline system. Cost differences between the dropline and butt-rigging systems were negligible.

Based on the system costs presented in from Appendix IV and the estimated productivity per SMH, Table 2 also shows the average yarding cost for each of the five yarding systems. The yarding cost for the Y54 when yarding the smallwood was the lowest because of very short delay and move times. Yarding costs for the dropline system, the butt-rigging system with two chokers, and the grapple system in the largewood area were nearly equal at about \$4/m^3.

Cycle Elements

Outhaul and Inhaul Times. Outhaul and inhaul times for the grapple yarders were shorter than for the choker machines. Scatter diagrams for outhaul and inhaul times versus yarding distance showed the times to be influenced by yarding distance and turn volume. Therefore, regression analysis, using the least-squares method, was used to generate equations for the times as functions of yarding distance and turn volume. (Other models which did not include turn volume or which kept the outhaul and inhaul times separate were examined and rejected.) The analysis was done for three systems: the Y56 dropline, the Y54 with butt rigging and two chokers, and the combined results for the two grapple yarders. Table 3 shows the regression coefficients and the correlation coefficients for all the models, and Figure 5 shows the regression line and actual times for the

Table 2. Summary of Detailed Timing

Yarding statistics	Y56 yarder,[a] dropline		Y54 yarder[b] Butt rigging, one choker		Y54 yarder[b] Butt rigging, two chokers		Y54 yarder[b] Grapple, smallwood		Y56[a] & Y54[b] yarders; grapple, largewood	
Pieces yarded	1 066		683		1 217		843		456	
Volume yarded (m^3)	1 343		817.3		1 244		686		462	
Productive time (h)	17.83		13.46		17.50		6.34		7.25	
Turns yarded	218		171		192		279		276	
Average turn volume (m^3)	6.2		4.8		6.5		2.5		1.7	
Average no. stems/turn	4.9		4.0		6.3		3.0		1.7	
Average yarding distance (m)	126		106		100		79		99	
Maximum yarding distance (m)	210		210		185		120		195	
Productivity and cost										
Stems/PMH	60		51		70		133		63	
m^3/PMH	75.3		60.7		71.1		108.2		63.7	
m^3/SMH	62.5		50.4		59.0		89.8		52.9	
System cost excluding interest ($/h)	255.19		255.19		255.19		211.09		211.09	
$/$m^3$	4.08		5.06		4.32		2.35		3.99	
Cycle element times	**%**	**min/turn**	**%**	**min/turn**	**%**	**min/turn**	**%**	**min/turn**	**%**	**min/turn**
Net yarding										
Outhaul	9	0.44	8	0.38	6	0.33	19	0.26	21	0.33
Walk	14	0.69	12	0.57	15	0.82	-	-	-	-
Hookup	38	1.87	27	1.27	34	1.86	35	0.48	22	0.35
Inhaul	19	0.93	17	0.80	15	0.82	22	0.30	27	0.43
Unhook	7	0.34	6	0.28	3	0.16	8	0.11	6	0.09
Deck	3	0.15	5	0.24	4	0.22	1	0.01	2	0.03
Total net yarding	90	4.42	75	3.54	77	4.21	85	1.16	78	1.23
Move yarder or backspar	6	0.29	11	0.52	14	0.77	9	0.12	17	0.27
Minor delay	4	0.20	14	0.66	9	0.49	6	0.08	5	0.08
Productive time	100	4.91	100	4.72	100	5.47	100	1.36	100	1.58

[a] Refers to MB yarder No. Y56, a Madill 044 rigged with a dropline carriage.
[b] Refers to MB yarder No. Y54, a Madill 044 outfitted with conventional butt-rigging.

Table 3. Outhaul-Plus-Inhaul Time versus Yarding Distance and Turn Volume [a]

Statistic coefficient	Y56[b] dropline	Y54[b] two chokers	Y54[b] grapple
n	207	183	463
r^2	0.64	0.53	0.55
b_0	0.20	0.38	0.03
b_1	0.00818	0.00639	0.00730
b_2	0.0293	0.0250	0.0117

[a] Outhaul-plus-inhaul = $b_0 + b_1 d + b_2 v$
Where outhaul-plus-inhaul is estimated in minutes
b_0 = constant (min)
b_1 = distance coefficient
d = yarding distance (m)
b_2 = volume coefficient
v = turn volume (m^3)
[b] See footnotes for Table 2.

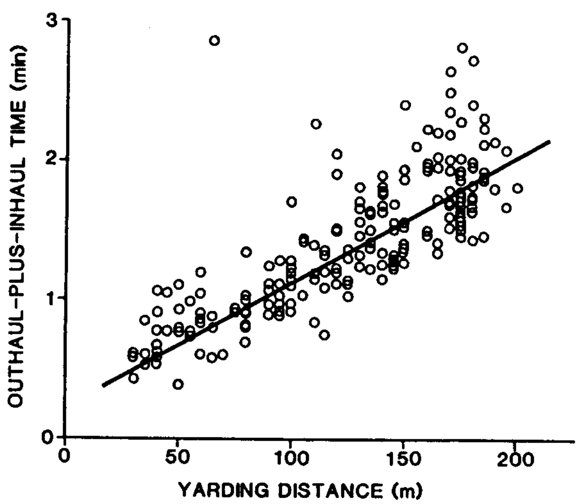


Figure 5. Regression line and actual results for outhaul-plus-inhaul times for the dropline system.

dropline system model. Note that some turns did not have recorded volumes, therefore were not included in Table 3.

Hookup Times. The hookup time for the grapple was approximately 0.4 min/turn, while the average hookup time with chokers ranged from 1.3-2.0 min/turn plus 0.6-0.9 min/turn walking time. Figure 6 shows two typical bunches being hooked in Site 3.

Table 4 shows the effect of hooking difficulty on hookup time. These times include only those turns for which the difficulty class was recorded; single-stem turns and cleanup turns were not included. Hookup times for turns in hookup difficulty Class 1 were significantly less than for turns in Class 2 at the 95% confidence level. Ensuring a clear choker-hole existed under each bunch reduced the hookup time by 0.4 min/turn.

The average hookup time with one choker was about 0.6 min/turn less than with two chokers. When using only one choker, the hookup time for hookup difficulty Class 1 bunches declined slightly as the number of stems/bunch increased (Figure 7), but the hookup time continued to increase with more stems/bunch for hookup difficulty Class 2 bunches. However, hookup time was highly variable, depending on the hookup difficulty of the particular bunch.

The average hookup difficulty class for Site 1 was less than for Sites 2 and 3 because it had been originally designated as the study site and the feller-buncher operator had been instructed to ensure each bunch on the site had a clear choker-hole. The other sites had been scheduled for grapple-yarding, and the feller-buncher operator made no attempt to ensure each bunch had a clear choker-hole. Detailed-timing of the feller-buncher (Appendix V) showed that it spent approximately 5% of its time preparing bunches when choker-holes were required, compared to about 2% when they were not required. Scatter plots were generated to determine if hookup times were correlated to any of the other parameters measured during the study. No correlations were found between hookup times and bunch height, width, or end area.

The average times for each hookup difficulty class were used to determine overall yarder productivity, while the average hookup times for a given number of stems yarded with one choker and for all difficulty classes were used for the marginal log volume analysis.

Unhooking and Decking Times. Unhooking times averaged 0.1 min/turn for the grapple and 0.2-0.3 min/turn for the chokers. Also, decking time was longer when the chokers were used: 0.2 min/turn versus 0.02 min/turn for the grapple. This confirmed observations made during the study; the operator simply dropped the turns in place when decking with the grapple, but when using chokers, more time was required to align the stems in the deck. For comparison, the total time spent unhooking and decking with the grapple was 0.1 min/turn, and with the chokers it was 0.4-0.5 min/turn.

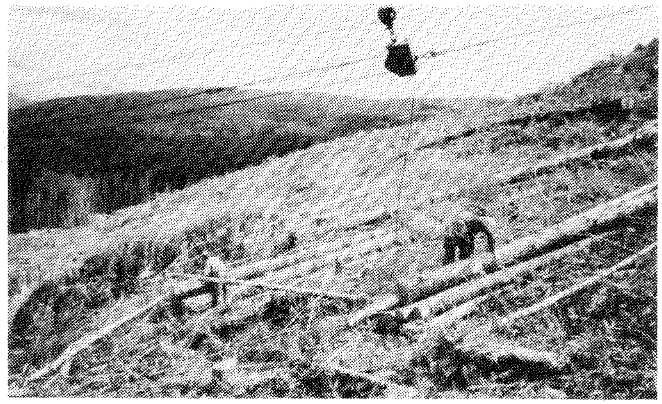


Figure 6. Hooking two bunches on dropline system.

Table 4. Hookup Time versus Hookup Difficulty Class

System	Class 1 (min)	Class 2 (min)	Average hookup difficulty (Class)
Y56 yarder [a]			
Dropline, Site 3	1.80	2.52	1.55
Y54 yarder [a]			
Butt rigging, one choker, Site 1	1.49	1.97	1.43
Butt rigging, two chokers, Site 2	2.05	2.42	1.48

[a] See footnotes for Table 2.

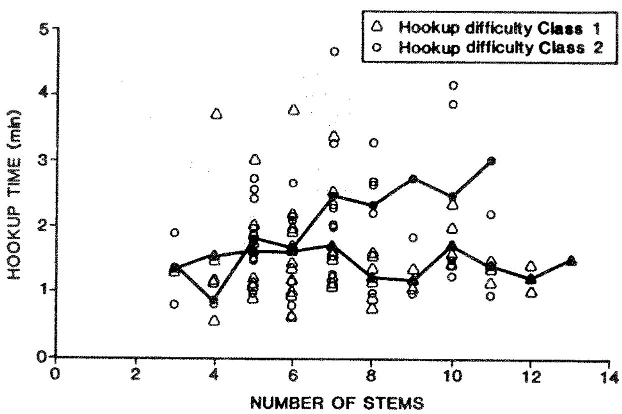


Figure 7. Average hookup time versus number of stems when using one choker.

The most representative sample times for unhooking the radio-controlled chokers were for the butt-rigging system with two chokers. The unhooking times for the dropline system included approximately 0.15 min/turn to raise the dropline hook to the carriage in addition to the actual time to release the chokers. The times for the butt-rigging system with one choker were longer than expected because of project startup difficulties such as weak batteries for the chokers and unreliable releasing caused by poor transmitter antenna location. Once these problems were corrected, the self-releasing chokers worked much better.

Minor Delay Times. Table 5 shows the distribution of minor delay times for the three choker systems. In FERIC's opinion, the minor delays for the dropline system were indicative of expected long-term results; minor delays for the other two systems were skewed by startup difficulties during the project. For example, the choker repair times were long, which reflected the poor condition of the batteries, and the talk-on-radio times were lengthy because the crew often discussed the condition of the chokers. Unknown delays were exceptionally long during the butt-rigging trial with two chokers.

Total-Turn-Time Model. Figure 8 shows the model for total turn time for the dropline-carriage system. Walk, unhooking, decking, minor delay, and move times are from the detailed-timing results, and hookup time is based on hookup difficulty Class 1. Outhaul-plus-inhaul time is derived from the regression equation for the dropline-carriage system, and is based on the average turn volume (6.2 m^3) observed during the trial.

Turn Volumes

An analysis of the distribution of turn volume was undertaken to determine how turn volume affected productivity. Figure 9 shows the distribution of the turn volumes; the dropline system averaged 6.2 m^3/turn and the butt-rigging system averaged 6.5 m^3/turn. The distribution of turn volumes for the butt-rigging system showed a constant downward trend, while the turn volumes for the dropline system had a more even distribution up to approximately 8 m^3/turn, after which it declined. This reflected the differences in conditions and rigging systems on the two sites: the loader left more single logs during the prelogging operation on Site 1 than on Site 3. This increased the proportion of turns with few logs. Also, the butt-rigging system used heavier rigging than the dropline carriage system, therefore, the chokermen could hook two large bunches at one time. With the lighter rigging on the dropline carriage system, the chokermen were reluctant to hook more than one large bunch at a time.

Table 6 shows that most of the bunches were yarded with only one turn; only 4% of the bunches for the butt-rigging system required two turns. The proportion of two-turn bunches for the dropline system was higher because some of the bunches situated along the backspar trail could not be hooked with one choker. However, Table 6 also shows that many turns contained single stems. Single-stem turns occurred for several reasons:

- Some bunches were too large, or too awkwardly situated, to be easily hooked. Therefore, partial bunches were hooked. For example, bunches beside the backspar road were re-aligned during construction of the backspar trail, and could not be hooked with a single choker.

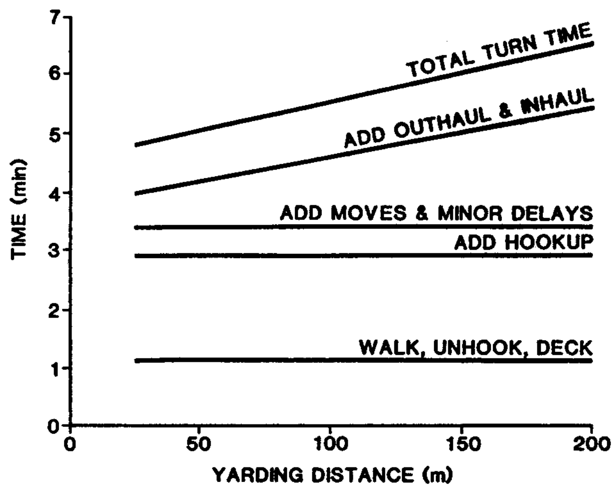


Figure 8. Model of total turn time for the dropline-carriage system.

Table 5. Distribution of Minor Delay Time

	Dropline		Butt rigging: One choker		Butt rigging: Two chokers	
Delay	%	min/turn	%	min/turn	%	min/turn
Talk on radio	22	0.04	23	0.15	19	0.10
Lines/hangups	23	0.04	15	0.10	12	0.06
Rigging	18	0.04	12	0.08	1	0.01
Mechanical						
Choker repair	4	0.01	24	0.16	39	0.20
Yarder or backspar	13	0.03	15	0.10	0	0.00
Personnel	5	0.01	5	0.03	2	0.01
Miscellaneous	15	0.03	6	0.04	27	0.14
Total	100	0.20	100	0.66	100	0.52

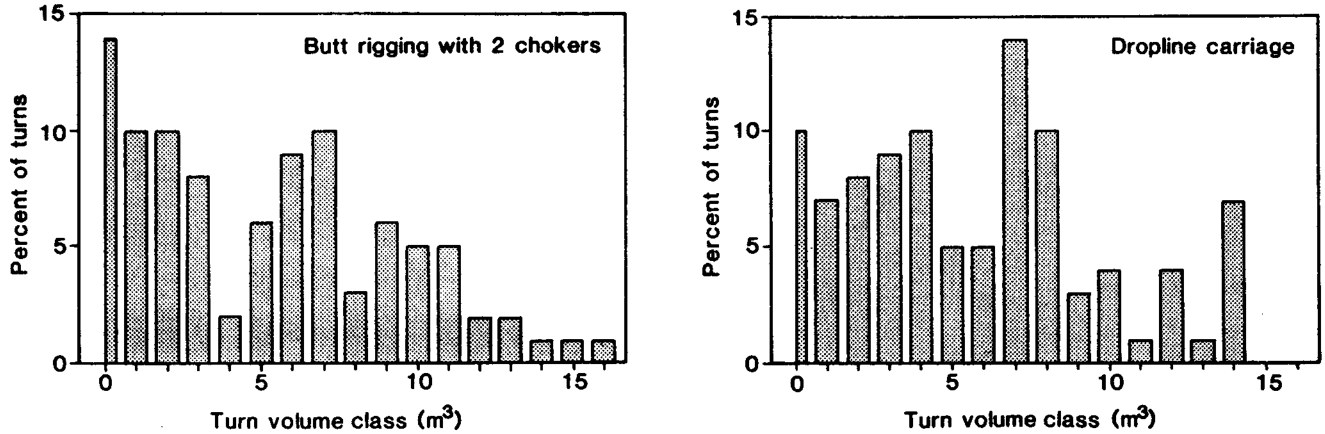


Figure 9. Distribution of volume per turn, by turn volume. (The smallest volume class includes turns less than 0.5 m³. It has been arbitrarily labelled the "0" volume class. All other classes are defined by the half-m³ volume, e.g. 1.5 to 2.5 is labelled as 2.)

Table 6. Potential Average Turn Size

Turn characteristics	System	
	Dropline	Butt rigging
Average turn size (m³)	6.2	6.5
Average bunch size (m³)	6.9	7.6
Number of turns	209	186
Number of bunches yarded	85	93
Number of bunches yarded with one turn	73	89
Number of turns with single logs caused by other activities	46	23
Potential turn size if single logs replaced by average bunch size (m³)	7.3	7.3

- Much of the flat portions of the study site had been prelogged with a loader prior to commencing yarding operations. Many single logs were left behind by the loader, and required yarding with the chokers. This contributed to small turn volumes and inefficient yarding.
- Stems occasionally slipped from the choker during yarding and had to be hooked again.

The activities that caused logs to be left as single logs fell into two classes: those beyond the control of the yarding crews (e.g. logs left by the loader during the prelogging phase, or stems too large for the feller-buncher), and those which are inherent to the logging systems (e.g. single logs left along the backspar trail, or logs which slipped from the chokers). An analysis determined what the average turn volume would have been if the single logs that resulted from conditions beyond the control of the yarding crew had actually been average-sized bunches. Table 6 shows the increase in average turn size that could be expected under such conditions.

When the single logs were replaced with average-sized bunches, the average turn volume for both systems increased to 7.3 m³/turn. This analysis was not extended to include turns with only two or three stems, although a further increase in average turn volume could be expected. A typical two-bunch turn with the butt-rigging system is shown in Figure 10.

Productivity Models

The time and volume information developed in the preceding sections was combined in system-productivity models. Figure 11 shows the productivities for the grapple, butt-rigging, and dropline systems using 83% machine utilization and the actual results for element times and turn volumes. Two models each are shown for the dropline and butt-rigging systems to illustrate the differences caused by increased hooking difficulty.

The highest productivity was for the grapple-yarder system at short distances (88 m³/SMH at 25 m), but grapple-yarder productivity decreased markedly as distance increased (45 m³/SMH at 175 m). Productivity for the dropline system was lower than for the grapple-yarder system at short distances (77 m³/SMH at 25 m), but it declined less quickly with increased distance (59 m³/SMH at 175 m). Productivity for the two systems was equal at approximately 60 m. Results with the butt-rigging system were similar, although the breakeven distance was approximately 90 m.

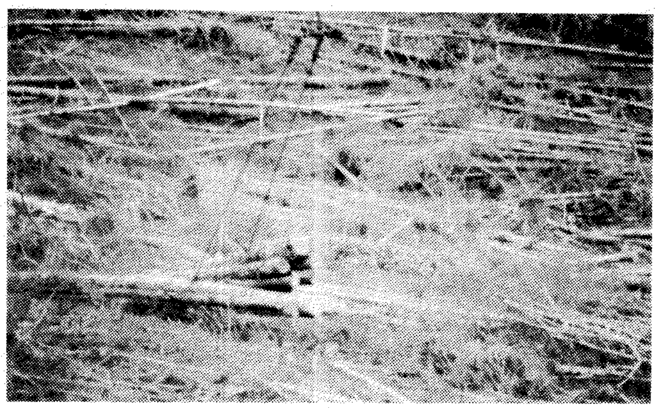


Figure 10. Yarding two bunches at a time in Site 1.

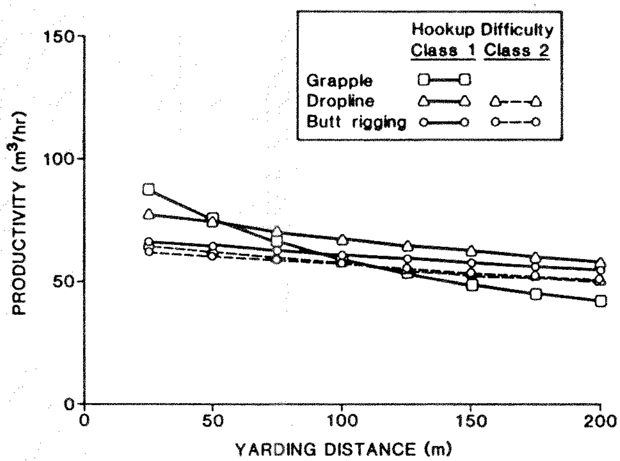


Figure 11. Productivity per SMH for three yarding systems.

The choker and grapple systems responded differently to increased yarding distance because of their different fixed times per turn and different turn volumes. A grapple system has shorter fixed times and smaller turn volumes than a choker system, so it is better suited to short yarding distances. A choker system has longer fixed times; therefore, it is not as effective when yarding short distances. However, a choker system has larger turn volumes which mitigate the effect of longer yarding distances.

The productivity for the butt-rigging (Y54) and dropline (Y56) systems converged as yarding distance increased; the difference in productivity at 25-m yarding distance was 10 m^3/SMH, but was only 2 m^3/SMH at 175 m. This was most likely because of the greater engine power and faster line speeds for the Y54.

Figure 11 also shows the effect of yarding bunches with hookup difficulty Class 2. While productivity for the grapple yarder was unaffected by hookup difficulty, the productivity for the two choker systems was reduced, and the breakeven distance between the grapple and both choker systems increased to approximately 110 m. This illustrates the importance of providing choker-holes under the bunches.

Figure 12 shows the models using some "best-conditions" values for the element times and turn volumes. Moving and minor delays determined from the dropline system were used for the butt-rigging system because they were more representative of expected long-term performance. The turn volume for the grapple was set at 3.1 m^3/turn (MacDonald 1988), and the turn volumes for the choker machines were determined as explained earlier.

The increase in average turn volume for the grapple from the observed 2.1 m^3/turn to the potential 3.1 m^3/turn represented a 47% increase and made a correspondingly large increase in productivity. The increase in turn volume for the choker systems was only 11-17%, so the increase in productivity was less. With both choker systems using the same minor delay times, the baseline productivity for the two systems was nearly equal. Under these "best-conditions" models, the breakeven point of the grapple and the choker systems increased to about 150-160 m.

Cost Models

Using the productivities from the models that were based on actual study results (Figure 11) and the system costs shown in Appendix IV, the yarding cost by distance was calculated (Figure 13). The breakeven distance for the yarding cost of the grapple system and the dropline system was approximately 125 m. At shorter distances, the grapple system was more economical and, at longer distances, the yarding cost for the dropline system was lower. The breakeven distance relative to yarding cost was longer than the breakeven distance relative to productivity because of the higher labour cost associated with the dropline system.

Costs for the butt-rigging system were higher than for the dropline system, and the breakeven distance was longer, because of the lower productivity.

The costs in Figure 13 represent the yarding costs for a given yarding distance, and do not show the accumulated yarding costs for all volumes up to that distance. Therefore, it would be incorrect to say that the total accumulated yarding cost for the dropline system beyond 125 m is less than for the grapple system. Rather, the breakeven point for total cost will occur at some greater distance, depending on the distribution of the volume with respect to yarding distance. To calculate the overall yarding cost, volume versus distance distributions for two cases during the study were plotted in Figure 14. These bar charts show the percentage of total volume in 25-m yarding-distance classes based on the assumptions that the volume nearest the haul road has been prelogged, and that the maximum yarding-distance class is 175 m. Case 1 shows most of the volume concentrated near the haul road, and Case 2 shows volume concentrated at longer yarding distances.

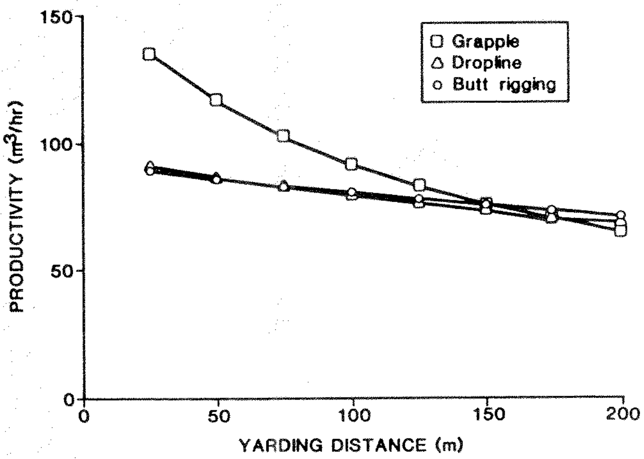


Figure 12. Productivity per SMH using assumed values for cycle elements and turn volumes.

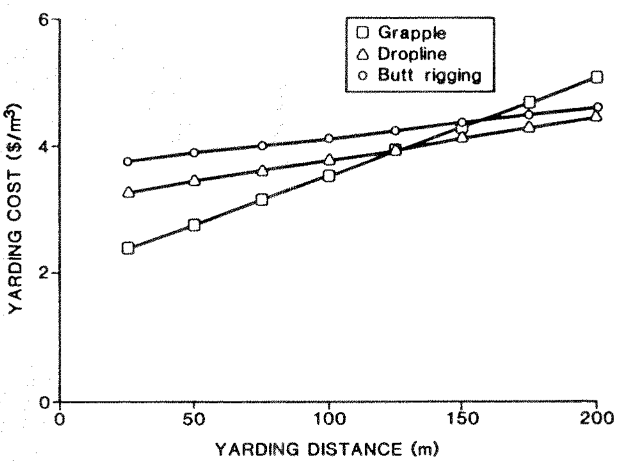


Figure 13. Estimated yarding cost by yarding distance for three yarding systems.

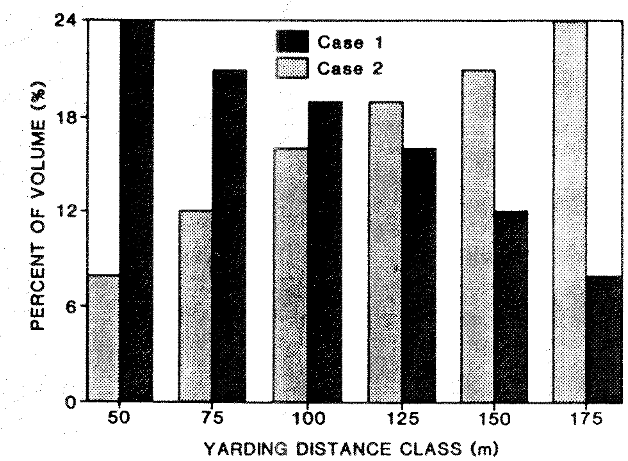


Figure 14. Estimated distributions of total volume per yarding road versus yarding distance.

Table 7 shows the total accumulated yarding cost for the grapple and dropline systems for the two volume distributions. When the volume is concentrated at shorter yarding distances, the cost for the dropline system is \$3.79, compared to \$3.53/m³ for the grapple. However, when the volume is concentrated at longer distances, the costs for the two systems are nearly equal (\$3.97 vs. \$3.95/m³). This illustrates that the grapple system has a definite cost advantage at short yarding distances, but that cost may not be the deciding factor when the volume is concentrated at longer yarding distances. Other factors, such as deflection and ease of hookup, must also be considered.

A third model ("combination"), where the most economical yarding system is used at each distance, is also shown in Table 7. In this model, the grapple is replaced with a dropline carriage for distances beyond the breakeven point (125 m). The cost for this system is \$0.06-0.13/m³ less than for the grapple system; however, the extra time required to reconfigure the carriage for each system is not included in the model. Such delays would negate the cost advantage of switching systems; therefore, it is best to choose one system and use it for the entire yarding road.

Note that these comparisons have assumed no volume is located less than 25 m nor greater than 175 m from the roadside. More short-distance volume will favour the grapple system, while more long-distance volume will favour the dropline system.

Marginal Log Analysis

The marginal log volume is defined as the volume of a log whose variable yarding cost is equal to its net value at roadside. The marginal log is the log which is yarded at neither a profit nor a loss; net income is maximized when yarding standards are determined according to marginal log analysis. This applies regardless of the total volume extracted from the setting because any log above the margin adds to profit, while logs below the margin reduce the profit. The first study in this series (MacDonald 1987) showed that when yarding hand-felled timber, the marginal log volume was determined by species, grade, yarding distance, and turn volume, with turn volume having the greatest

Table 7. Total Accumulated Yarding Cost Weighted by Yarding Distance

Yarding system	Volume distribution: Case 1, concentrated at short yarding distance (\$/m³)	Case 2, concentrated at long yarding distance (\$/m³)
Dropline	3.79	3.97
Grapple	3.53	3.95
Combination	3.47	3.82

effect. The second study (MacDonald 1988) showed that bunching reduced the marginal log volume, but not in the same proportion as the increase in number of logs/bunch.

Expenditures such as road construction, falling, and ownership costs are considered sunk, or irreversible. Therefore, they are excluded from the marginal log volume calculations because they are irrelevant in deciding among current alternatives (Peterson 1987).

The net value at roadside is the sales value of the log less any costs which must be incurred after yarding. Some of these costs are more correctly applied on a per-piece basis (processing and loading), while others are applied on a per-cubic-metre basis (hauling and booming). Therefore, two turns with the same volumes, but each containing a different number of stems, will have different net values at roadside, and their marginal log volumes will be different. Similarly, two turns at different yarding distances will have different yarding times, yarding costs, and marginal volumes.

The marginal log volumes for Douglas-fir J-grade stems were calculated using the following assumptions:

- Element times such as unhooking and decking are based on the dropline system (Table 2).
- Hookup time depends on the number of stems to be hooked, as shown in Figure 7.
- Outhaul and inhaul times depend on turn volume and yarding distance, and are determined according to the linear model developed in Table 3.
- Turn times are adjusted to include machine utilization.
- Processing and loading costs are constant regardless of stem size.
- Each stem produces one log for loading.
- Each stem is individually processed and loaded.

Since the net value at roadside depends on stem size, and the marginal log volume depends on the net value at roadside, an iterative solution is required. A spreadsheet was developed, using the same methodology as in a previous FERIC report (MacDonald 1988) to calculate the yarding costs and net values for various combinations of numbers of stems and yarding distances. The marginal turn volume was determined by trial and error and results are shown in Table 8. Sample calculations are shown in Appendix VI.

The marginal log volume increases only slightly as yarding distance increases. For example, the marginal log volume when yarding one stem from 80 m is 0.69 m^3, while the marginal log volume at 160 m is 0.77 m^3. As the number of stems in the bunch increases, the difference in marginal log volume relative to yarding distance becomes negligible and can be ignored.

However, the marginal turn volume is more noticeably affected by the number of stems in the bunch. When a single stem is yarded from 120 m, it must be 0.73 m^3 for profitable yarding; however, eight 0.31-m^3 stems are profitable to yard as a bunch. The marginal log volume for all yarding distances approaches 0.27 m^3 as the number of stems increases beyond 12 stems/bunch.

These results support those from FERIC's previous study of yarding bunched stems (MacDonald 1988), i.e. the marginal log volume is reduced via bunching, but not in the same ratio as the increase in the number of stems. The results also show that the marginal log volume eventually reaches a point after which adding more stems to the bunch does not significantly decrease the marginal log volume. This is because costs incurred at the processing and loading phases are piece-based, rather than volume-based. If yarding profitability is to be maximized, then the other phases must be designed to handle stems on a volume basis.

Comparison of Studies, and Other Comments

The first study in this series (MacDonald 1987) monitored a Madill 122 yarding crane as it grapple yarded hand-felled second-growth timber. The second study (MacDonald 1988) monitored a Washington 118A yarding crane working in similar conditions, except it yarded bunches. The terrain in the previous two studies was flatter and more uniform than the terrain in this

Table 8. Examples of Marginal Log Volume: Douglas-Fir J-Grade Logs Yarded with Dropline System

	Yarding distance					
	80 m		120 m		160 m	
Number of stems in bunch	Log volume (m^3)	Turn volume (m^3)	Log volume (m^3)	Turn volume (m^3)	Log volume (m^3)	Turn volume (m^3)
1	0.69	0.69	0.73	0.73	0.77	0.77
2	0.47	0.94	0.49	0.98	0.51	1.02
3	0.40	1.20	0.41	1.23	0.43	1.29
4	0.36	1.44	0.37	1.48	0.39	1.56
8	0.30	2.40	0.31	2.48	0.31	2.48
12	0.28	3.36	0.28	3.36	0.29	3.48
16	0.27	4.32	0.27	4.32	0.27	4.32

trial, and the average yarding distances were significantly less (Table 9). The stand conditions were comparable. Productivity for the Washington 118A was the highest of the three studies, while the productivity of the Madill 044 was only slightly less than that of the Washington 118A.

However, the average yarding distance for the Madill 044 was much longer than for the other two studies, primarily because much of the timber near the road was prelogged. Comparisons of systems within this study showed that for longer yarding distances the productivity of the choker system nearly matched that of the grapple. For yarding distances over 175 m, the dropline system should be more productive than the grapple.

Both previous FERIC studies monitored production systems; this study was a trial of a new yarding system and the crews often remarked that they preferred working with a grapple. Specifically, the operators felt that they were no longer in control of production, and had become "slaves to the chokers." During the butt-rigging system trial, especially, this resulted in some lengthy delays which might not have occurred in a production system. Some startup problems also contributed to frequent minor delay times during the butt-rigging system trial. However, in FERIC's opinion, the other elemental times are representative of the system's capability.

The workers commented several times during the trial that breakage was significantly reduced with the choker system. The smaller trees were not exposed to breakage stresses when yarded in intact bunches, in contrast to the grapple system where smaller trees were often yarded individually and could be more easily broken.

At the end of the yarding trial, the crew members were given the option of removing the dropline carriage immediately or continuing to use it through some gullied terrain. They chose to continue using the dropline because it was easy to hookup in the gully. This clearly illustrated that the harvesting system must be chosen to match the ground conditions. For short yarding distances and good deflection, the grapple system has higher productivity and lower cost; however, the grapple system's productivity decreases with longer yarding distance or poor deflection, and the choker system should be considered.

CONCLUSIONS

The trial monitored two Madill 044 yarding cranes which used self-releasing chokers and grapples while yarding bunches of second-growth timber. Of five combinations of yarding cranes and systems, the highest productivity (108 m^3/PMH) occurred when the grapple yarder operated over a short average yarding distance in a smallwood area. Productivities for the other systems ranged from 61 to 75 m^3/PMH; productivity with a dropline carriage system was 75 m^3/PMH.

The difference in the productivity of the grapple and choker systems related primarily to turn size and fixed times per turn. The choker systems required more time for hooking, unhooking, and decking, but the average turn size was larger. The hookup time, including walking time, when using two chokers was 2.6-2.9 min/turn; the unhooking and decking time was 0.4-0.5 min/turn, and the turns averaged 6.2-6.5 m^3. In comparison, the grapple yarders averaged 0.4 min/turn for hooking, 0.1 min/turn for unhooking and decking, and averaged 1.7-2.5 m^3/turn. Turn times for the choker and grapple systems averaged about 5.0 and 1.5 min/turn respectively.

Hookup time varied substantially depending on the difficulty of hooking each particular bunch, but some trends were clear. When the bunches were built with

Table 9. Comparison of Three Yarding Systems

		Mechanically felled	
Site and system	Hand felled	Grapple yarded	Choker yarded
Yarding crane	Madill 122	Washington 118A	Madill 044
Rigging	Grapple with two chokers	Grapple	Dropline carriage
Terrain	Flat	Flat	30-50% sideslope
Bucking specifications	Log length	Tree length	Tree length
Detailed-timing results			
Yarding distance (m)	77	77	126
Pieces/turn	1.2	2.9	4.9
Volume/turn (m^3)	0.9	3.1	6.2
Net yarding time/turn (min)	0.95	1.37	4.42
Average turn time (min)	1.25	2.16	4.91
m^3/PMH	43	86	75

choker-holes underneath, the hookup times were reduced by an average of 0.4-0.7 min/turn, and with clear choker-holes, the hookup time declined slightly with more stems in the bunch. However, for bunches with no clear choker-holes, the hookup time increased as the number of stems in the bunch increased, from about 1.5 min/turn for bunches with 4 stems to about 2.6 min/turn with 12 stems. Results of detailed timing for the feller-buncher showed that approximately 5% of its time was spent preparing bunches when choker-holes were required, and about 1% when they were not required.

The self-releasing chokers were tried in several configurations, i.e. with butt rigging and using one or two chokers, and with a dropline carriage and two chokers. A model for productivity of the various yarding configurations showed the grapple system to be the most productive system up to 80-120 m yarding distance but that the dropline system was more productive for longer distances.

The productivity models were adjusted to reflect the best conditions that might be expected, i.e. maximum turn volume and minimum delay times. The average turn size for the choker system could have been increased from 6.2 to 7.3 m^3/turn by eliminating cleanup turns for pieces left by prelogging activities. However, the grapple systems had even greater potential for improvement; the average turn size during this study was much less than in the previous studies. Under these conditions, the grapple system was more productive than the choker system for yarding distances up to about 150-160 m.

The grapple system had the lower cost/m^3 up to 130-150 m yarding distance for yarding individual turns; beyond 150 m, the dropline system had the lower cost/m^3 for individual turns. However, the weighted average cost for short-distance and long-distance bunches showed the grapple system had lower costs than the choker system for maximum yarding distances up to 175 m. The cost difference between systems depended on the distribution of volume with respect to yarding distance; more volume at short distances increased the cost difference and vice versa. Total cost was lowest when the systems were combined; i.e. grapple yarding at short distances and choker yarding at longer distances. However, costs were only \$0.04-0.12/m^3 less than for grapple yarding alone, which may not be enough to justify the time required to switch systems.

The marginal log analysis showed that the marginal log volume decreased as the number of stems in the bunch increased, but that it eventually reached a minimum limit. For the conditions encountered during the study, the smallest log that was profitable to yard was approximately 0.27 m^3. For logs smaller than this limit, the high cost per cubic metre for loading and processing reduced the net value at roadside. No further profits were gained by bunching smaller logs.

The machine operator was concerned that the dropline carriage would be difficult to control with the non-interlocked winch of the Madill 044 yarding crane, but his concerns proved groundless after he had an opportunity to practice using the carriage. The dropline carriage allowed the use of shorter and lighter chokers than used with the butt-rigging system, which reduced the workload for the chokermen. It also proved easier to operate than the grapple in areas where deflection was poor or visibility was impaired. Both machine operators resisted using chokers because of a perceived loss in autonomy compared to operating a grapple yarder; however, they also felt that using the chokers resulted in less log-breakage. The chokers proved to be reliable after some initial problems with batteries and transmitter antenna location were eliminated.

The trial showed that the choker system was viable for yarding bunches, but that under the conditions encountered, its cost and productivity would, at best, only equal that of a grapple system. However, it should be considered for situations where deflection is poor or visibility is limited, or when the average yarding distance is greater than that encountered during this study.

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APPENDIX I

Machine Specifications: Madill 044 Yarding Crane

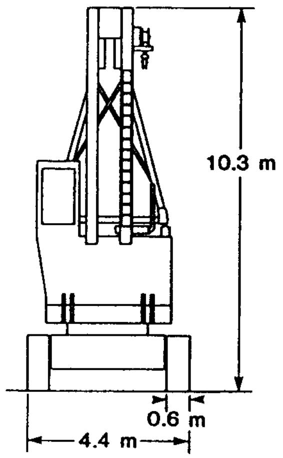

Table I-1. Line Speeds and Pulls

Drum	Mains	Haulback	Strawline	Guyline
Maximum line speed[a] (m/min)				
High gear	644	644	511	511
Low gear	328	328	260	260
Maximum line pull[a] (kg)				
High gear	12 997	14 084	16 352	17 736
Low gear	25 538	27 692	22 998	22 988
Line capacity				
Size (mm)	29	19	10	32
Length (m)	423	950	975	88

[a] Mid-drum.

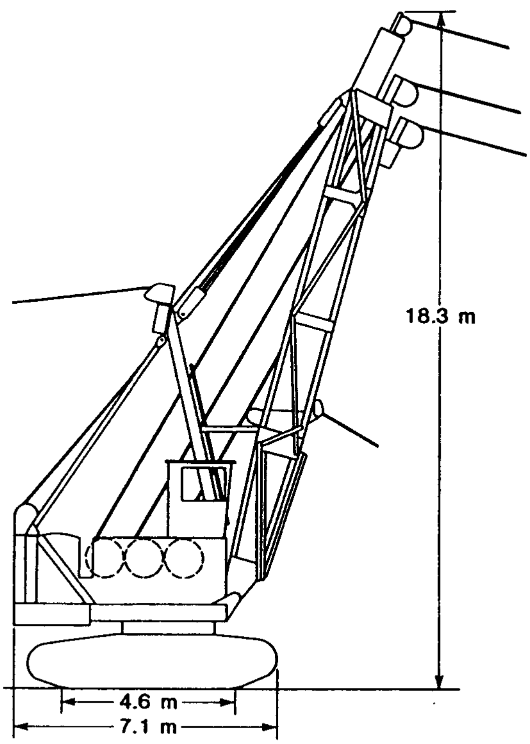

Table I-2. Specifications

Engine	
GM V12 N71	333 kW
Weight	
Undercarriage	42 200 kg
Machinery deck	41 300 kg
Boom, gantry, wire rope	12 700 kg
Total weight	96 200 kg

APPENDIX II

Johnson Industries Ltd. Radio-Controlled Self-Releasing Chokers

The radio-controlled self-releasing chokers used during this trial were prototypes of a new choker model developed from an existing, smaller model. The prototype choker bells accomodate 2.5-cm diameter cables, whereas the older models could accomodate only 1.9-cm diameter cables.

The chokers consist of a choker bell for sliding along the cable, with a hinged assembly that contains the releasing mechanism. Figure II-1 shows three choker bells; two in the closed position, and one in the open position. A spring-loaded plunger in the releasing mechanism engages a hole in the body of the choker to hold the two halves of the choker together to encase the knob. To set the choker, the plunger is pushed out until it protrudes from the body of the releasing mechanism and is held by spring pressure. The choker knob is held in the cavity between the halves of the body, then the two halves are brought together until the plunger snaps into the hole. The choker knob is held firmly until the choker receives a releasing signal via radio.

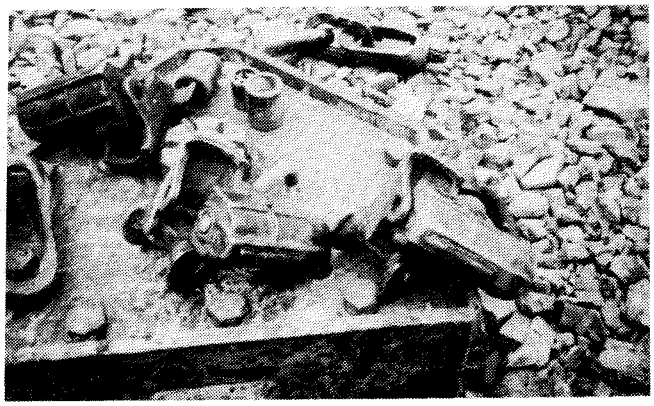

Figure II-1. Johnson Industries Ltd. radio-controlled self-releasing chokers.

Each choker bell contains a digitally coded radio receiver and each bell responds only to its own code. A radio transmitter and programming unit sends the releasing signal to the choker bells. The transmitter can be mounted anywhere on the yarding crane, and a remote keypad mounted in the operator's cab is easily accessible. The keypad has nine buttons for individually releasing up to nine chokers, plus one key that releases all the chokers at one time. During the trial, the transmitter was programmed so that the "All" key was programmed to send several signals to the two chokers to ensure reliable releasing.

The choker bells are powered by batteries that must be discarded when they are exhausted. The batteries in the chokers used during the trial had already been used for about six weeks prior to the trial, and were at the end of their life. Batteries are replaced by pulling the releasing mechanism out of the body of the choker; this work should be done in a shop environment, and takes approximately 20 min per choker.

APPENDIX III

Definitions of Cycle Elements

Time element	Begins	Ends
Outhaul	When rigging starts to travel away from yarder.	When rigging stops at a target log.
Walk	a) End of outhaul, or b) End of hookup.	a) When workers reach rigging and begin to straighten chokers, or b) When chokermen are in the clear and signal for inhaul.
Hookup	End of walk.	When workers begin walking away from bunch.
Inhaul	End of walk.	When incoming turn is first dropped on log deck.
Unhook	End of inhaul.	When rigging is tightened and ready for outhaul.
Deck	When yarder moves a bunch already in the log deck, to straighten or repile the deck.	When rigging is slackened.
Move	When machine stops and crew prepares to move yarder, guylines, or backspar.	When machinery is in position to commence productive function.
Delay	When a productive function is interrupted.	When productive function recommences.

APPENDIX IV

Cost Analysis

Costs	Madill 044, choker system	Madill 044, grapple system	Hitachi UH 171, backspar
Ownership costs			
Purchase price $	900 000	900 000	100 000
Purchase price: Lines, rigging, radios $	25 000	25 000	-
Purchase price: Choker or grapple $	27 000	12 000	-
Expected life (y) yr	10	10	10
Hours per year (h) h	1 500	1 500	1 500
Interest rate (I) %	12	12	12
Insurance rate (Ins) %	1	1	1
Total purchase price (P) $	952 000	937 000	100 000
Salvage value (S) = (0.2 x P) $	190 400	187 400	20 000
Average investment (AVI) = (P + S)/2 $	571 200	562 200	60 000
Expected life (H) = (y x h) h	15 000	15 000	15 000
Loss in resale value ($/h) = (P - S)/H $/h	50.77	49.97	5.33
Interest = (I x AVI)/h $/h	45.70	44.98	4.80
Insurance = (Ins x AVI)/h $/h	3.81	3.75	0.40
Total ownership costs $/h	100.28	98.70	10.53
Operating and repair costs			
Fuel consumption (F) L/h	25	30	8
Fuel cost (f) $/L	0.40	0.40	0.40
Operating supply cost per year (O) $	24 000	24 000	1 500
Annual repair and maintenance cost (R) = (P x h/1000 x 6%) $	81 000	81 000	9 000
Operator and hooktender wage $/h	20.02	20.02	-
Chokerman wage $/h	16.83	-	-
Number chokermen	2	-	-
Wage benefit loading (WBL) %	35	35	-
Fuel cost = (F x f) $/h	10.00	12.00	3.20
Lube and oil cost = (0.2 x fuel cost) $/h	-	-	0.64
Lube and oil cost = (0.1 x fuel cost) $/h	1.00	1.20	-
Operating supply cost = (O/h) $/h	16.00	16.00	1.00
Repair and maintenance cost = (R/h) $/h	54.00	54.00	6.00
Gross labour cost[a] $/h	103.04	57.60	-
Total operating and repair costs $/h	184.04	140.80	10.84
Ownership and operating costs $/h	284.32	239.50	21.37
System cost excluding interest $/h	255.19	211.09	-
System variable costs excluding ownership $/h	194.88	151.64	-

[a] Gross labour costs			
Operator (includes WBL) $/h	27.03	27.03	-
Hooktender (includes WBL) $/h	27.03	27.03	-
Two chokermen (includes WBL) $/h	45.44	0.00	-
Operator and hooktender bonus (0.7 h/8 h @ 1.5 wage rate) $/h	3.54	3.54	-
Total wages $/h	103.04	57.60	

APPENDIX V

Detailed-Timing Summary for Feller-Buncher

The Chapman FB122 feller-buncher was timed in Sites 1 and 4 to determine how its productivity was affected by the requirement that it build bunches with choker-holes underneath. Site 1 was scheduled for yarding with the choker system, while Site 4 was scheduled for grapple-yarding. Site 1 was brushier, and had more broken terrain than Site 4.

Preparation time consisted of the time required to position a pedestal to build the bunch upon or the time required to realign stems once they had been dropped into the bunch. Preparation time in Site 1 occupied 0.04 min/cycle (Table V-1), but a survey of the bunches showed that approximately one-third of the bunches did not have choker holes. This occurred despite the fact that the operator was specifically directed to ensure each bunch was properly positioned. It can be assumed that one-third more preparation time would be required to ensure all the bunches were properly prepared. Total preparation time then would be about 0.05 min/cycle.

When no special provisions were made for choker-holes (Site 4), preparation time occupied only about 0.01 min/cycle. Therefore, the time difference between preparing bunches without specific choker-holes and ensuring all bunches were prepared with choker-holes was approximately 0.04 min/cycle.

Table V-1. Summary of Detailed Timing for Feller-Buncher

	Site 1		Site 4	
Cycle element	%	min/cycle	%	min/cycle
Swing empty	15	0.14	16	0.12
Cut	23	0.22	40	0.29
Swing loaded	23	0.21	24	0.18
Move between bunches	16	0.15	17	0.12
Prepare bunch	5	0.04	2	0.01
Brush	7	0.06	0	0.00
Minor delay	11	0.11	1	0.01
Cycle time	100	0.92	100	0.73
Falling summary				
Number cycles	464		250	
Number trees	521		326	
Trees/cycle	1.12		1.30	

APPENDIX VI

Example of Marginal Log Volume Calculations for Douglas-Fir J-Grade Logs

	\$/shift [a]	\$/piece [b]	One-stem turn, 0.77 m^3/stem [c] (\$/m^3)	Four-stem turn, 0.39 m^3/stem [c] (\$/m^3)	Sixteen-stem turn, 0.27 m^3/stem [c] (\$/m^3)
Calculation of net value at roadside					
Cost					
Processing	1 500	4.20	5.46	10.77	15.56
Loading	1 250	2.33	3.03	5.98	8.64
Hauling	1 760	-	2.93	2.93	2.93
Sorting and booming [a]			6.00	6.00	6.00
Towing [a]			1.00	1.00	1.00
Stumpage and sales expense [d,e]			11.00	11.00	11.00
Total cost			29.42	37.68	45.13
Market value [d]			50.00	50.00	50.00
Net value at roadside			20.58	12.32	4.87
Calculation of marginal-log volume					
Variable yarding cost (\$/h)			194.88	194.88	194.88
Time/turn (min) [f]			4.92	5.75	6.75
Cost/turn (\$)			15.98	18.68	21.94
Marginal-turn volume (m^3) [c,g]			0.78	1.52	4.51
Logs per turn			1	4	16
Marginal log volume (m^3)			0.77	0.38	0.28

[a] FERIC estimate.
[b] Estimated production - Processing 400 m^3/shift (357 stems/shift)
- Loading and hauling 600 m^3/shift (536 stems/shift)
[c] Initial estimates of stem volume used to calculate net value at roadside.
[d] Market value \$50/m^3 - Vancouver log market average for Douglas-fir J-grade logs for three-month period ending August 15, 1989. Source: British Columbia Ministry of Forests, Valuation Branch; 1989; personal communication.
[e] Stumpage and sales expense estimated total is 22% of market value.
[f] Yarding distance is 160 m, average hookup time with one choker.
[g] Marginal turn volume (m^3) = $\frac{\text{Turn cost (\$)}}{\text{Net value at roadside (\$/m}^3\text{)}}$