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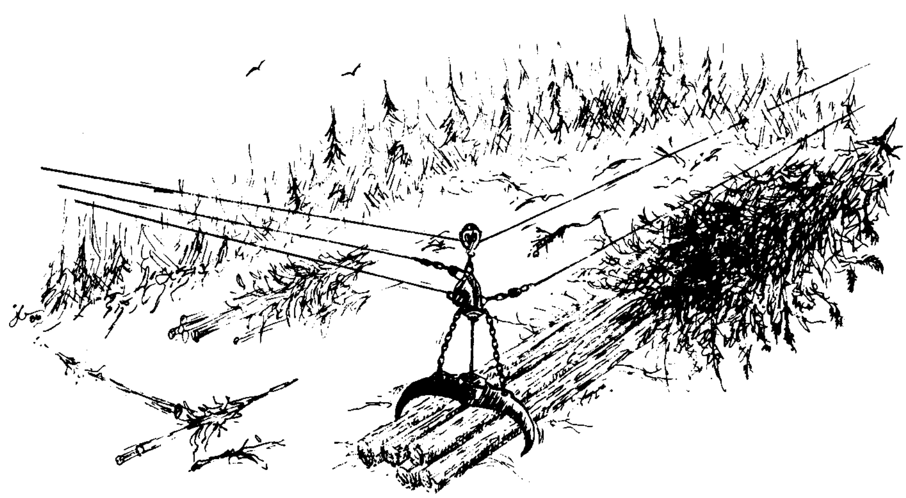
COMPARISON OF THREE HARVESTING SYSTEMS IN A COASTAL BRITISH COLUMBIA SECOND-GROWTH STAND

J.T. Peterson

December 1986



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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.

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SUMMARY

The objective of this study was to monitor and evaluate the productivity and costs of falling, skidding, yarding, processing, and loading as a result of:

- full-tree grapple yarding with roadside processing;
- bunch skidding with landing processing; and
- bunch grapple-yarding with roadside processing.

The study block was located approximately 5 km west of Buckley Bay, B.C. Stand composition was mainly second-growth Douglas-fir, with lesser amounts of hemlock and cedar. To facilitate studying the different systems, the 34-ha study block was divided into three areas.

The logging system found to be most efficient and cost-effective was bunch skidding with landing processing, combined with close supervision. On a cost-per-piece basis, this system was 13% cheaper than the other systems studied.

The other two systems were full-tree grapple yarding and bunch grapple yarding. Yarding of bunches reduced the cost per piece by over $1.50. Production increased more than 65% on a pieces-per-shift basis.

The side-by-side system comparisons resulted in a number of other findings. First, grapple design and size is critical to yarding productivity. For example, there was a 42% improvement in productivity when a different grapple was introduced into the handfelled area.

Second, falling patterns and methods play a decisive role in skidding, yarding, and roadside processing productivities. For instance, yarding the handfelled area resulted in tree tops facing the road when windrowed. This reduced processing productivity.

Third, there was a noticeable reduction in logging residue left on the site in the bunched-wood areas.

Fourth, roadside processing offered the extra advantage of allowing presorting in the woods. This saved dollars on those pieces which bypassed the dryland sortyard processing phases.

One of the major problems still existing in coastal B.C. is the inability to remove full-tree wood efficiently from windrows for roadside processing. This must be solved in order to make roadside processing more cost effective in the future and permit the full gains of mechanization to be achieved.

SOMMAIRE

L'objectif de cette étude fut d'enregistrer et d'évaluer la productivité et les coûts d'abattage, de débusquage, de téléphérage, de transformation et de chargement résultant du:

- téléphérage à grappins d'arbres entiers avec transformation au chemin;
- débusquage par ballot avec transformation à la jetée; et du
- téléphérage à grappins par ballot avec transformation au chemin.

La zone étudiée était située à approximativement 5 km à l'ouest de Buckley Bay, C.B. Le peuplement était composé principalement de sapin de Douglas de second pousse, avec une moindre quantité de pruche et de cèdre. Afin de faciliter l'étude des différents systèmes, les 34 ha de la zone d'étude furent divisés en trois parties.

Le systéme d'exploitation qui s'est avéré le plus efficace avec les coûts les plus avantageux fut le débusquage par ballot avec transformation à la jetée, en combinaison avec une étroite surveillance. Sur une base de coût-par-morceau, ce système était 13% moins cher que les autres systèmes étudiés.

Les deux autres systèmes étaient le téléphérage à grappins d'arbres entiers et le téléphérage à grappins par ballot. Le téléphérage de ballots a réduit le coût par morceau de plus de $1.50. La productivité fut augmentée de plus de 65% sur une base de morceau-par-quart de travail.

De nombreuses constatations résultèrent des comparaisons côte-à-côte des systèmes. Premièrement, la conception et les dimensions du grappin sont d'une importance majeure quant à la productivité par téléphérage. Par exemple, la productivité s'est accrue de 42% lorsqu'un grappin différent fut introduit dans la zone d'abattage manuel.

Deuxièmement, les méthodes et les modes d'abattage ont joué un rôle décisif dans la productivité du débusquage, de téléphérage et de transformation en bordure de chemin. En effet, le téléphérage des zones abattues manuellement, avec le mode en rangées au bordure de route, donnait lieu à des cîmes d'arbres face au chemin. Ceci réduisit la productivité de la transformation.

Troisièmement, il y eu une diminution importante de résidus de coupe sur les sites ou les arbres étaient assemblés par ballots.

Quatrièmement, la transformation en bordure de chemin offrit un avantage supplémentaire en permettant un triage préliminaire en forêt. Ceci occasionna des économies de coûts pour les billes évitant la voie du parc de triage pour les phases de transformation.

Un des problèmes majeurs toujours persistant sur les côtes de la C.B. est l'incapacité de sortir efficacement les arbres entiers abattus en rangées au bordure de route, pour ensuite être transformés en bordure de chemin. Ce problème doit être solutionné afin de rendre la transformation en bordure de chemin plus rentable dans le futur et d'atteindre tous les bénéfices de la mécanisation.

INTRODUCTION

The objective of this study was to compare the cost, productivity, and operational factors of three different harvesting systems in a B.C. coastal second-growth stand.

MacMillan Bloedel Ltd.'s Northwest Bay Division has been logging second-growth stands for several years. To increase profitability, feller-bunchers, skidders, and mechanical processors have been used to log these lower-value stands. However, it was recognized that ground-skidding systems are limited on the coast of B.C. because of site disturbance and mountainous terrain. Since the division also had experienced cable-yarding crews and equipment available, there was interest in determining if conventional cable-logging systems could be modified to harvest second-growth stands economically in some areas. In 1985, a decision was made to harvest a second-growth stand on a test basis to determine the advantages and disadvantages of partially mechanizing a cable-logging system. FERIC was asked to monitor and evaluate the test. This report gives the results of the evaluation.

FERIC also used this project to begin collecting detailed information on how productivity and cost are affected by tree size, terrain, distance, and other factors for the Harvesting Economics Project.

The objective of the Harvesting Economics Project is to provide industry with a method to estimate more accurately the marginal costs of harvesting logs to determine economic utilization standards for various logging areas. The yarding and falling phases were examined intensively during this study. The results of the examination will be reported in more detail in subsequent reports.

STUDY METHOD

The study was conducted at MacMillan Bloedel Ltd.'s Northwest Bay Division on the east coast of Vancouver Island. Falling started in April 1985 and logging was completed in October 1985. The study area was a 34-ha opening in a 110-year-old second-growth stand. The area was divided into three parts and a different system was used in each. The systems were:

System 1 - Mechanically fall and bunch
- Grapple yard to roadside and windrow
- Process at roadside from windrow
- Load

System 2 - Handfall with selective bucking
- Grapple yard to roadside and windrow
- Process at roadside from windrow
- Load

System 3 - Mechanically fall and bunch
- Ground skid to landing
- Process in landing
- Load

In Systems 1 and 2, yarding preceded processing but in System 3, skidding and processing were concurrent.

Prior divisional experience had shown that processing in a landing in conjunction with skidding was productive and cost-effective. However, the division had less experience in processing at roadside from windrowed logs. Consequently, it was decided to try a variety of roadside processing methods with Systems 1 and 2 to determine their cost and productivity. The roadside processing systems tested were:

- Hahn Harvester
- Hahn Harvester II
- Log loader and hand buckers

All production data were obtained by FERIC personnel using timing boards and stopwatches. The company supplied stand and log-volume information and conducted the waste-assessment survey after logging.

The timing results, in which all mechanical and operational delays were recorded, were converted to an 8-hour-shift basis (6.5 hours in the case of the handfallers) to determine productivity. Delay time includes all delays, both major and minor. The utilization levels used were those observed during detailed timing. However, when making comparisons between the same machine used in different systems, a standard utilization level was used.

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 distributors and a standard owning, repairing, and operating formula is used. Unless stated, costs such as supervision, overhead, and crew and equipment transportation are not included. Interest or opportunity costs are excluded from the machinery costs reported in the text, but are listed in Appendix I.

DESCRIPTION OF STUDY AREA

Forest cover maps show the establishment date of the present stand as 1874, following the blow down of the previous stand. Most remaining old-growth timber was logged in the late 1940s. A few old-growth trees and some sound, cedar windfalls were scattered throughout the present stand.

Terrain was rolling and sloped to the east. Slopes varied from 0 to 52%, with an average of 17.5 percent. (More detail on the terrain can be found in Appendices II and III.) The only obstacles were old-growth stumps and windfalls. Understory was mainly sword fern and Oregon grape with some small salal patches in the northwest corner of the block.

Site index of the stand was 24 (BASE 50) and stocking was 89 percent. Stand information was derived from MacMillan Bloedel Ltd.'s forest cover maps and local knowledge. Appendix IV gives area and volume information on the trial site.

RESULTS AND DISCUSSION

1. Falling

Each area was felled to suit the harvesting system. As Figure A shows, the falling patterns were quite different for each system.

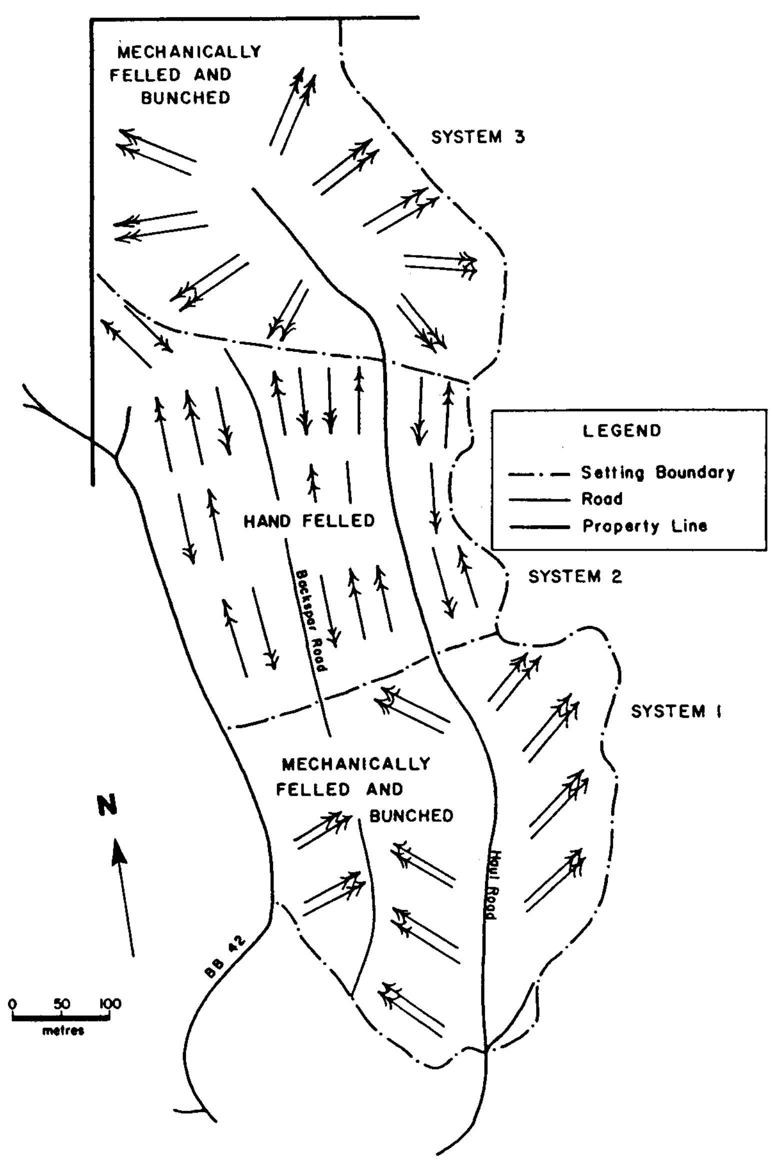

FIGURE A. Falling Pattern.

A. System 1

Trees were mechanically felled and bunched by a Case 1187 feller-buncher equipped with a 50-cm Drott shear head. Trees were laid in bunches at approximately a 45° angle to the yarding road to improve yarding efficiency. Trees with a butt diameter greater than 50 cm were handfelled and those under a 60-cm butt diameter were left full-tree. The bottom one or two logs were hand bucked from trees with more than a 60-cm butt diameter and the remainder of the tree was left for roadside processing. Ninety-seven percent of the trees (87% of the total volume) were within the cutting capacity of the Case 1187 feller-buncher.

Terrain in the System 1 area was suited for mechanical falling. Slope ranged from 0 to 38%, with an average of 18% and there were few obstacles to travel. The Case 1187 feller-buncher was able to traverse the entire area.

Table 1 is a summary of the detailed timing study on the Case 1187 feller-buncher. The machine spent 77% of its time on productive functions. The majority of maintenance time was for hydraulic hose repair, general servicing, and track repairs.

TABLE 1. Case 1187 Feller-Buncher--Timing Summary.

Average Tree Volume = 0.54 m^3
Number of Trees Cut = 1877

PHASE	TOTAL TIME (MINUTES)	%
Productive		
Move	400.6	19
Swing Empty	235.3	12
Position & Cut	395.2	19
Swing Loaded	310.5	15
Bunch	39.8	2
Brush	214.5	10
Subtotal	1 595.9	77
Delay		
Move Windfall	39.5	2
Mechanical	249.0	12
Other	179.0	9
Subtotal	467.5	23
Total	2 063.4	100

Table 2 summarizes the production results and presents the costs of felling and bunching with the Case 1187 feller-buncher.

TABLE 2. Case 1187 Feller-Buncher--Productivity and Cost Summary.

No. trees per productive machine hour (PMH)	70.6
No. trees per scheduled machine hour (SMH)	54.6
Volume per shift (8 hours), m³	235.8
No. trees per shift	436.6
Total equipment cost per shift*	$674.08
Cost per m³	$2.85
Cost per tree	$1.54

*Cost includes machine and operator. Interest excluded.

A butt-damage evaluation on mechanically felled trees was carried out by FERIC (see Guimier 1981 and McMorland 1985 for method). Based on all trees measured in the bunch-turn yarding area, the average loss was 1.89 percent. The estimated mill loss, assuming all logs were cut into 2 x 6s, would be 2.54 percent.

From the operational cruise data, the handfaller felled 3% of the stems (13% of the total volume). In addition, he felled snags and a few trees that were inaccessible to the feller-buncher and hand bucked some large windfalls. Table 3 gives the productivity and cost summary for the handfaller.

TABLE 3. Handfalling--Productivity and Cost Summary.

Average tree volume, m³	2.50
No. trees per productive hour	18.6
Volume per shift (6.5 hours), m³	151.3
No. trees per shift	60.5
Falling cost per shift*	$319.65
Cost per m³	$2.11
Cost per tree	$5.28

*Cost includes faller and saw at 50% utilization.

When working directly with the feller-buncher, the handfaller experienced long delays while waiting for the machine to get into the clear. As a result, the faller would wait until the machine had felled a sizeable area and then he would fall the remaining standing trees. In addition to reducing delays, this freed the faller for more productive work in other cutting areas.

Table 4 shows the combined falling costs for System 1.

TABLE 4. Combined Falling Costs.

Cost per tree:	
Feller-buncher - 97% of pieces @ $1.54 per tree	
Faller - 3% of pieces @ $5.28 per tree	
	Weighted average cost per tree = $1.65
Cost per m^3:	
Feller-buncher - 87% of volume @ $2.85 per m^3	
Faller - 13% of volume @ $2.11 per m^3	
	Weighted average cost per m^3 = $2.76

B. System 2

All trees were handfelled perpendicular to the yarding road to improve yarding efficiency (Figure B). Trees under 60-cm butt diameter were left as full trees. Selective bucking was done on those over 60 cm, e.g., the bottom one or two logs were hand bucked and the remainder left for roadside processing. Only 3% of the trees required hand bucking.

FIGURE B. Handfaller.

Table 5 is a summary of the detailed timing results on the handfallers. Move time includes walk-in and walk-out at the beginning and end of each shift and at lunch time. Delay time will normally be greater than shown because such delays as safety meetings and high-wind days are not included.

TABLE 5. Handfalling--Timing Summary.

PHASE	TOTAL TIME (MINUTES)	%	MINUTES/ TREE	TREES/ HOUR
Productive				
Move*	3 708.0	30	0.53	
Brush	872.7	7	0.12	
Cut	4 252.1	34	0.60	
Limb & Buck	480.5	4	0.07	
Buck Windfall	74.5	1	0.01	
Subtotal	9 387.8	76	1.33	45.2
Delay				
Fuel & Oil	668.5	5	0.10	
File Chain	281.0	2	0.04	
Saw Repairs	435.1	4	0.06	
Other	1 645.7	13	0.23	
Subtotal	3 030.3	24	0.43	
Total	12 418.1	100	1.76	34.2
No. Trees				
Merchantable	5 341			
Sapling	1 100			
Snag	633			
Total	7 074			

*Includes walk in and out time.

Table 6 gives a productivity and cost summary for the handfalling required for System 2.

TABLE 6. Handfalling with Selective Bucking--Productivity and Cost Summary.

No. trees per PMH	45.2
No. trees per SMH	34.2
Volume per shift (6.5 hours), m^3	204.5
Trees per shift	222.3
Total cost per shift*	$319.65
Cost per m^3	$1.56
Cost per tree	$1.44

*Cost includes faller at 76% utilization.

C. System 3

Trees under 50 cm were mechanically felled and bunched by a Drott 50 feller-buncher equipped with a 50-cm Drott shear head (Figure C). Throughout the study period the machine operated on a single-shift basis. Trees with a butt diameter greater than 50 cm were handfelled and those under a 60-cm butt diameter were left full-tree. The bottom one or two logs were hand bucked from trees with more than a 60-cm butt diameter and the remainder left for roadside processing.

FIGURE C. Drott 50 Feller-Buncher.

Terrain in the System 3 area was suited for mechanical falling. Slope ranged from 0 to 19%, with an average of 12 percent. The Drott 50 feller-buncher had little difficulty traversing the area.

There were many windfalls and a higher percentage of large stems in this area than in the other areas. This necessitated a handfaller working with the feller-buncher almost full time. Thirteen percent of the trees (45%

of the total volume) required handfalling and bucking. This reduced the efficiency of the feller-buncher as it had to work around these large trees.

Bunches were laid with the butts facing the landing to achieve maximum skidding efficiency.

Detailed timing data for the Drott 50 feller-buncher are shown in Table 7 and are based on approximately 55 hours of detailed timing information. Table 8 is a summary of productivity and cost for the Drott 50 feller-buncher.

TABLE 7. Drott 50 Feller-Buncher--Timing Summary.

Average Tree Volume = 0.70 m^3
Number of Trees Cut = 3050

PHASE	TOTAL TIME (MINUTES)	%
Productive		
Move	795.0	24
Swing Empty	437.0	13
Position & Cut	553.5	17
Swing Loaded	466.1	14
Bunch	101.6	3
Brush	250.1	8
Subtotal	2 603.3	79
Delay		
Move Windfall	91.7	3
Mechanical	177.1	6
Other	404.5	12
Subtotal	673.3	21
Total	3 276.6	100

TABLE 8. Drott 50 Feller-Buncher--Productivity and Cost Summary.

No. trees per PMH	70.3
No. trees per SMH	55.9
Volume per shift (8 hours), m^3	313.0
No. trees per shift	447.1
Total equipment cost per shift*	$674.08
Cost per m^3	$2.15
Cost per tree	$1.51

*Cost includes machine and operator. Interest excluded.

Based on all trees measured, the average wood loss as a result of butt damage was 1.34 percent. Estimated mill loss, assuming all logs were cut into 2 x 6s, would be 1.92 percent.

Handfalling was done on 13% of the stems, which accounted for 45% of the total volume. The faller experienced long delays while waiting for the feller-buncher to get in the clear. He also felled snags and trees that were inaccessible to the feller-buncher, and bucked windfalls. Production data for handfalling are shown in Table 9. Costs per cubic metre and per tree include a faller and saw at 50% utilization.

Table 10 shows the combined mechanical and handfalling costs for System 3.

TABLE 9. Handfalling--Productivity and Cost Summary.

Average tree volume, m^3	3.62
No. trees per productive hour	13.8
Volume per shift (6.5 hours), m^3	162.4
No. trees per shift	44.9
Falling cost per shift*	$319.65
Cost per m^3	$1.97
Cost per tree	$7.12

*Cost includes faller and saw at 50% utilization.

TABLE 10. Combined Falling Costs.

Cost per tree:
- Drott - 87% of trees @ $1.51 per tree
- Faller - 13% of trees @ $7.12 per tree
- Weighted average cost per tree = $2.24

Cost per m^3:
- Drott - 55% of volume @ $2.15 per m^3
- Faller - 45% of volume @ $1.97 per m^3
- Weighted average cost per m^3 = $2.07

D. System Comparison--Falling

The high capital costs of the feller-bunchers make them the higher cost method (Table 11). The number of trees felled per shift for the two machines studied were about the same. The difference in cost per cubic metre between the two machines is mainly because of piece size variance. The average tree volume for the Case 1187 was 0.54 m^3 versus 0.70 m^3 for the Drott 50. On a long-term basis, handfalling costs will be higher than shown because delays such as high-wind days and safety meetings are not included.

TABLE 11. Falling--Production and Costs.

SYSTEM	m^3/SHIFT	TREES/SHIFT	\$/m^3	\$/TREE
1. Case 1187 feller-buncher*	387.1	497.3	$2.76	$1.65
2. Handfall	204.5	222.3	$1.56	$1.44
3. Drott 50 feller-buncher*	475.4	492.1	$2.07	$2.24

*Includes handfalling cost.

2. Skidding/Yarding

Each of the areas was yarded or skidded according to terrain and haul-road layout constraints. Figure D shows the yarding patterns.

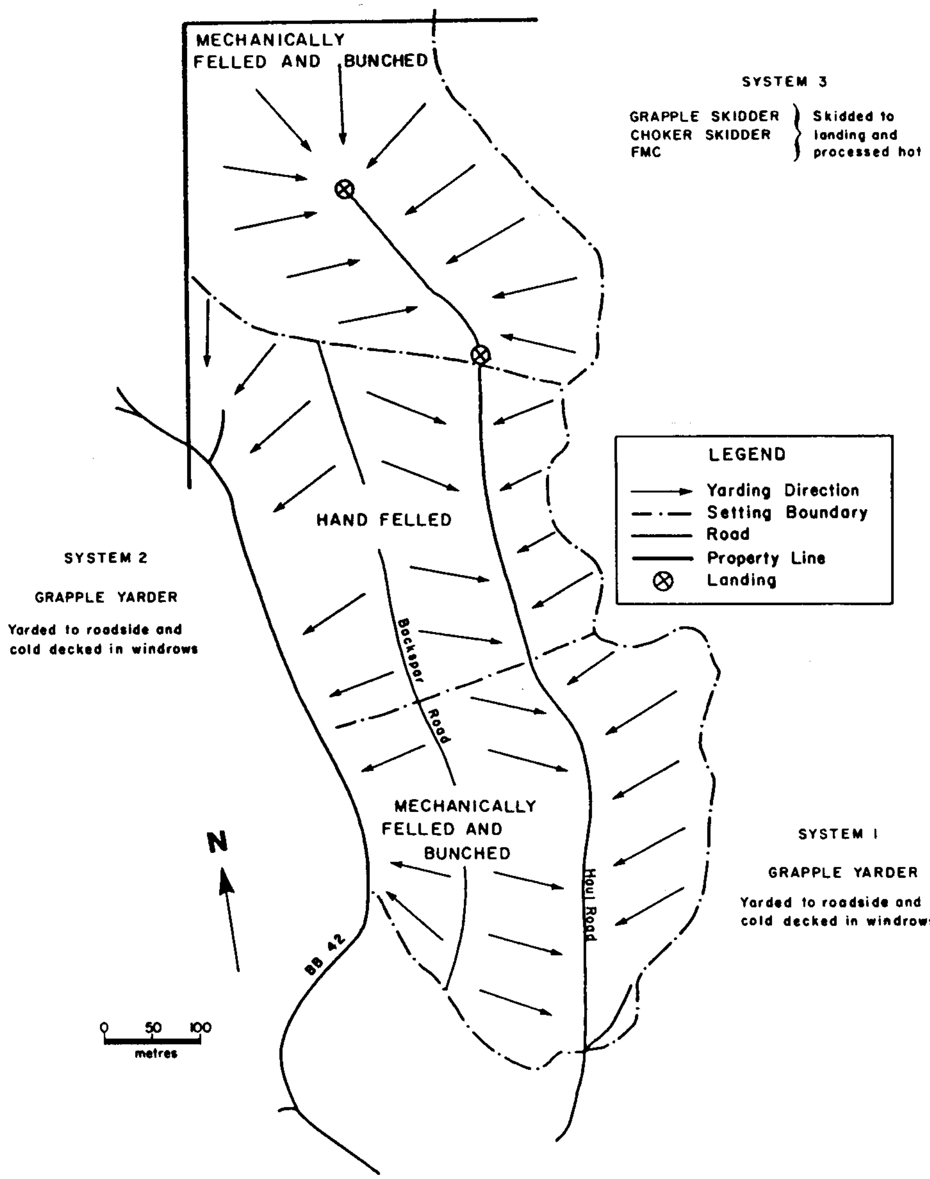

FIGURE D. Skidding/Yarding Patterns.

A. System 1 (Mechanically Felled)

Yarding was done by a 1982 Madill 084 grapple yarder using a 1978 Hitachi UH14 mobile backspar (Figure E). Pieces were yarded to roadside and decked in windrows. Yarding deflection was generally good, with a maximum yarding distance of 145 m. The bunching pattern resulted in good operator visibility and opportunity for the grapple to yard multiple pieces per turn. Bunching also resulted in all tree butts facing the road. This increased the efficiency of roadside processing.

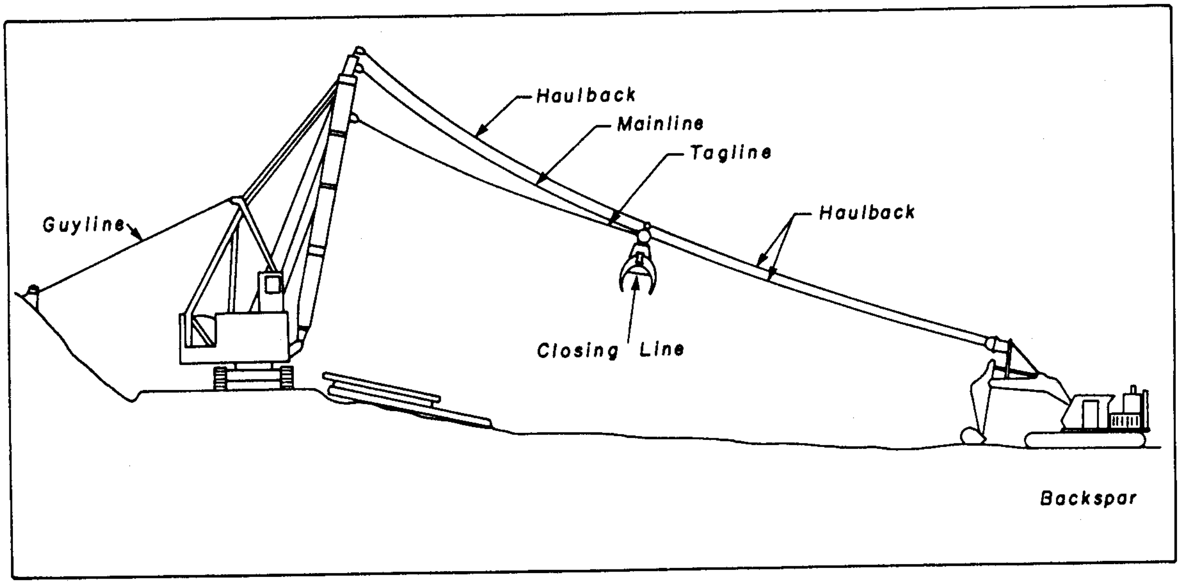

FIGURE E. Grapple Yarder Setup.

The yarding crew averaged 2.75 men per shift. The operator and hooker were there all of the time and a utilityman was there when significant machine move time was involved. Figure F shows the grapple yarder studied.

The results of the detailed timing study of the yarder are given in Table 12. Table 13 shows a summary of cost and productivity for the grapple yarder.

B. System 2 (Handfelled)

Yarding was done by the same crew and backspar as in System 1. Pieces were yarded to roadside and decked in windrows.

Yarding deflection was generally good except for one section in the northwest corner of the block. 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 was aided by the hooker giving directions by radio. Compared to the prior day, hookup time increased by 22% during the 2.5-hour period he yarded this area.

FIGURE F. 1982 Madill 084 Grapple Yarder.

TABLE 12. Grapple Yarding (Bunched)--System 1--Timing Summary.

Average Piece Size = 0.59 m³
Number of Pieces Yarded = 4380
Number of Turns = 2011

PHASE	TOTAL TIME (MINUTES)	%	PIECES/ HOUR	TURNS/ HOUR	m³/ HOUR
Productive					
Move	551.1	17			
Yard	1 765.8	56			
Deck	117.8	4			
Subtotal	2 434.7	77	107.9	49.6	63.7
Delay					
Mechanical	476.2	15			
Other	265.1	8			
Subtotal	741.3	23			
Total	3 176.0	100	82.7	38.0	48.8
Average yarding time/turn, min					
Move		0.27			
Outhaul		0.22			
Hookup		0.29			
Inhaul		0.29			
Unhook		0.07			
Deck		0.06			
Total		1.20			

TABLE 13. Grapple Yarding (Bunched)--Productivity and Cost Summary.

Average yarding distance, m	70.7
Average no. pieces per turn	2.18
Average move time, min	3.16
No. moves per PMH	3.60
Volume per shift (8 hours), m^3	390.6
No. pieces per shift	661.6
Total equipment cost per shift*	$1 650.24
Cost per m^3	$4.22
Cost per piece	$2.49

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

The results of approximately 110 hours of detailed timing are given in Table 14. Table 15 summarizes the productivity and cost information for the grapple yarder in System 2.

TABLE 14. Grapple Yarding (Handfelled)--System 2--Timing Summary.

Average Piece Size = 0.91 m^3
Number of Pieces Yarded = 5071
Number of Turns = 3592

PHASE	TOTAL TIME (MINUTES)	%	PIECES/ HOUR	TURNS/ HOUR	m^3/ HOUR
Productive					
Move	815.6	13			
Yard	3 295.3	51			
Deck	556.4	8			
Subtotal	4 667.3	72	65.2	46.2	59.3
Delay					
Mechanical	1 394.3	22			
Other	409.9	6			
Subtotal	1 804.2	28			
Total	6 471.5	100	47.0	33.3	42.8
Average yarding time/turn, min					
Move			0.23		
Outhaul			0.22		
Hookup			0.34		
Inhaul			0.29		
Unhook			0.07		
Deck			0.15		
Total			1.30		

TABLE 15. Grapple Yarding (Handfelled)--Productivity and Cost Summary.

Average yarding distance, m	76.6
Average no. pieces per turn	1.41
Average move time, min	6.64
No. moves per PMH	1.50
Volume per shift (8 hours), m^3	342.4
Pieces per shift	376.0
Total equipment cost per shift*	$1 650.24
Cost per m^3	$4.82
Cost per piece	$4.39

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

The falling pattern, with trees perpendicular to the yarding road, allowed the operator good opportunity to grab the trees. Some disadvantages were:

- Tops lay both ways. To facilitate roadside processing, it is preferable to have all butts facing the road. This falling pattern does not make for efficient butt-first yarding.

- If more than one piece was grappled, then quite often a piece would not stay in lead. This caused more hangups, more strain on the grapple, and longer decking time.

Right-of-way logs were not picked up and loaded prior to yarding. This reduced yarder productivity as many of these pieces had to be pulled away from the road and aligned for windrowing.

C. Grapple Yarding--Grapple Comparison

Two different yarding grapples (Table 16) were used in the System 1 area. The use of the larger Johnson Y106 grapple resulted in a 20% increase in the number of pieces yarded per Productive Machine Hour (PMH). This increase results from the size and design differences of the two grapples (Appendices V and VI).

TABLE 16. Grapple Yarding--Grapple Comparisons.

	MANTLE 65 (165 cm)		JOHNSON Y96 (244 cm)		JOHNSON Y106 (269 cm)	
	SYSTEM 1	SYSTEM 2	SYSTEM 1	SYSTEM 2	SYSTEM 1	SYSTEM 2
No. pieces per turn		1.26	1.75	1.40	2.36	1.85
No. pieces per PMH		46.1	92.4	65.5	110.9	80.8

Three different yarding grapples were used in the System 2 area. As in System 1, the use of the larger Johnson Y106 grapple resulted in increased productivity. It was 23% more productive than the Y96 grapple and 75% more productive than the Mantle 65 yarding grapple.

D. System 3 (Mechanically Felled)

All pieces were skidded by choker or grapple skidders. They were landed either at the Hahn Harvester for immediate processing or were decked for later forwarding to the Hahn. Bucked, oversize logs were skidded directly to the Barko 250 log loader for sorting and loading.

Figure G shows the skidding area and a Clark 667 grapple skidder with four full-tree pieces.

FIGURE G. Clarke 667 Grapple Skidder.

The bunched wood provided excellent hookup opportunity for the skidders. The falling pattern, with the butts facing the landing, decreased the amount of breakage that would otherwise happen when pulling trees into lead.

Three to four skidders were used daily in this system with an average of 3.5 per day for the study period. Six different skidders were timed during the project--four were grapple and two were choker skidders. Table 17 gives a summary of detailed timing for all the machines. Table 18 shows that on both a pieces-per-hour and a turns-per-hour basis, the grapple skidders outperformed the choker skidders. As derived from the Table, the choker skidder utilization was 89% compared to the grapple skidder utilization of 62%. This difference was mainly due to one grapple skidder being used almost full time to forward wood from cold-decks and to do landing clean-up work. Productivity and cost summary data for skidding are shown in Table 19 and are based on the detailed timing information.

TABLE 17. Skidding--System 3--Timing Summary.

Number of Pieces Skidded = 5963
Number of Turns = 1507

PHASE	TOTAL TIME (MINUTES)	%
Productive		
Skid	10 446.5	71
Delay		
Cleanup	2 648.8	18
Mechanical	618.4	4
Other	1 103.0	7
Subtotal	4 370.2	29
Total	14 816.7	100

TABLE 18. Choker Versus Grapple Skidder Production.

	CHOKER	GRAPPLE
No. pieces per PMH	24.6	40.9
No. pieces per SMH	22.0	25.2
No. turns per PMH	6.0	10.4
No. turns per SMH	5.4	6.4

TABLE 19. Skidding--Productivity and Cost Summary.

Average piece volume, m^3	0.94
Average no. pieces per turn	3.96
No. pieces per PMH	34.2
No. pieces per SMH	24.1
No. turns per PMH	8.66
No. turns per SMH	6.10
Volume per shift (8 hours), m^3	181.2
No. pieces per shift	192.8
Total equipment cost per shift*	$495.12
Cost per m^3	$2.73
Cost per piece	$2.57

*Cost includes machine and operator. Interest excluded.

When the choker skidders fed the Hahn Harvester directly, it caused delay time for the harvester. This was because the Hahn loader had to wait for the skidder operator to unhook chokers before he could resume loading logs. The contractor corrected this problem by having the choker skidders cold-deck, and the harvester was fed by a grapple skidder only.

E. System Comparison--Skidding/Yarding

Table 20 compares the three methods used during the study. For comparative purposes, machine utilization is set at 75% for all three methods.

TABLE 20. Skidding/Yarding--Production and Costs.

SYSTEM	m^3/SHIFT*	PIECES/SHIFT*	$/$m^3$	$/PIECE
1. Grapple yarding - bunches	382.2	647.4	$4.32	$2.55
2. Grapple yarding - handfelled	356.0	391.2	$4.64	$4.22
3. Skidding - bunches	192.9	205.2	$2.57	$2.41

*75% utilization.

Skidding resulted in the most economic cost. This was mainly because of the lower total equipment cost per hour for skidders. Skidders cost about $60 per hour whereas grapple yarders cost about $180 per hour. Also, the skidder area had the gentlest terrain and the highest piece size average.

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

- The cost of yarding bunches was $0.32/$m^3$ cheaper despite a piece size disadvantage averaging 0.32 m^3/piece.

- The cost of yarding bunches was $1.67/piece less than yarding non-bunched wood.

- Pieces yarded per shift increased by 65% for the bunched wood. 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.

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

3. Processing

A. System 1 (Mechanically Felled, Grapple Yarded)

Roadside processing was done both manually and mechanically. Two different models of Hahn Harvesters were tried for mechanical processing.

i. Roadside Processing--Manual Processing

A Poclain HC 300 hydraulic log loader was utilized to pull trees out of the windrow and place them on the road. Trees were then processed by one or two hand buckers using chain saws (Figure H). The second bucker acted as a helper to the loader operator when he was not assisting with processing. Processing included taping for length, long butting, limbing, bucking, and topping. Pieces were then loaded onto trucks or decked for loading. Some sorting was occasionally done.

FIGURE H. Manual Processing.

Tables 21 and 22 give the results of detailed timing of the manual processing.

When two buckers were utilized, there was a 37% increase in the number of trees per productive hour. This is because of the increased taping efficiency and less moving time per person.

TABLE 21. Manual Processing--System 1--Timing Summary.

	1 BUCKER	2 BUCKERS	TOTAL
Number of Trees	386	819	1 205
Number of Logs Produced	635	1 229	1 864
Productive Minutes	278.5	431.4	709.9
% of Total Time Productive			26.8

TABLE 22. Poclain Log Loader (Manual Processing)--System 1--Timing Summary.

PHASE	TOTAL TIME (MINUTES)	%	PIECES
Productive			
Load	389	30	1261
Move	46	3	
Pile Logs	197	15	965
Pull from Windrow	345	27	792
Subtotal	977	75	
Delay			
Cleanup	35	3	
Mechanical	50	4	
Other	231	18	
Subtotal	316	25	
Total	1 293	100	

Manual processing productivity was largely dependent on the log loader. Normally, trees were pulled from the windrow and laid on the road (parallel to the road) to be processed. Because of frequent waiting for trees and logs to be moved, manual processing was productive only 26.8% of the time.

Table 23 gives a cost and productivity summary for manual processing in System 1. The results are based on the detailed timing data.

The cost of manual processing includes the Poclain log loader (64% of its time--operator and helper), hand bucker, and chain saw costs. The remaining 36% of the loader's time is accounted for under loading in System 1.

TABLE 23. Manual Processing--Productivity and Cost Summary.

Average Tree Volume = 0.53 m³			
	1 BUCKER	2 BUCKERS	COMBINED TOTAL
No. of trees per productive hour	83.2	113.9	101.8
No. logs per productive hour	136.8	170.9	157.5
Volume per shift (8 hours), m^3			115.7
Pieces per shift			218.3
Total equipment cost per shift*			$861.49
Cost per m^3			$7.45
Cost per tree			$3.95

*Interest excluded.

ii. Landing Processing--Hahn Harvester

The Hahn Harvester operated only one day in System 1. The machine was set up in a landing. Table 24 gives the detailed timing results.

TABLE 24. Hahn Harvester--System 1--Timing Summary.

No. of Trees = 799 No. of Logs Produced = 1129		
PHASE	TOTAL TIME (MINUTES)	%
Productive		
Process	248.0	48
Wait Hahn Loader	133.2	26
Subtotal	381.2	74
Delay		
Cleanup	28.8	5
Mechanical	72.7	14
Other	35.9	7
Subtotal	137.4	26
Total	518.6	100

Trees were pulled out of the grapple-yarded windrow by choker and grapple skidders and cold-decked on the road. They were then placed alongside the Hahn Harvester infeed deck by a grapple skidder. Trees under 81-cm butt diameter were put through the Hahn Harvester. Each piece was delimbed, measured for length, and bucked or topped. Long butting was done where required. Processed logs were loaded directly or sorted and decked for loading. Logs with greater than an 81-cm butt diameter bypassed the harvester. Table 25 gives a summary of cost and productivity for the Hahn Harvester.

TABLE 25. Hahn Harvester--Productivity and Cost Summary.

Average tree volume, m^3	0.53
No. trees per PMH	125.8
No. trees per SMH	92.4
No. logs per PMH	177.7
No. logs per SMH	130.6
Volume per shift (8 hours), m^3	391.8
Trees per shift	739.2
Total equipment cost per shift*	$2 420.58
Cost per m^3	$6.18
Cost per tree	$3.27

*Interest excluded.

Costs for the Hahn Harvester include the harvester itself (one operator), Barko log loader (one operator and machine 55% of the time), and three skidders. The remaining 45% of the log loader's time is accounted for under loading in System 1.

Delimbing efficiency and quality was good on limbs up to 9 cm in diameter. On those over 9 cm, the Hahn Harvester occasionally had to process them two or more times. Length accuracy was not checked by FERIC.

Skidders were observed to be efficient in breaking down the grapple-yarded windrows. The crew had several years of experience working together. This was evident by the continuous wood flow in the skidding, processing, sorting, and loading phases. There was also constant supervision which increased efficiency.

iii. Roadside Processing--Hahn II Harvester

The Hahn II Harvester was run by two operators--one on the loader and one operating the processor.

Trees were either pulled out of the windrow by the Hahn II loader, swung into lead, and placed in the delimbing carriage to start processing, or trees were lifted from predecked piles and placed in the delimbing carriage. Predecked piles were prepared by the Poclain HC 300 log loader, which would pull trees from windrows and deck them parallel to the road to facilitate processing. Trees under 81-cm butt diameter were processed through the Hahn II Harvester. Oversize logs bypassed the processor. Processed logs were loaded direct or decked for loading by the Poclain log loader. Table 26 gives details of observed processor time.

TABLE 26. Hahn II Harvester--System 1--Timing Summary.

No. of Trees = 2607
No. of Logs Produced = 4436

PHASE	TOTAL TIME (MINUTES)	%
Productive		
Process	1 485.2	43
Wait Hahn Loader	398.0	12
Subtotal	1 883.2	55
Delay		
Cleanup	54.1	2
Mechanical	253.3	7
Wait Poclain Loader	538.1	16
Other	706.7	20
Subtotal	1 552.2	45
Total	3 435.4	100

Normally, the Hahn II Harvester sat parallel to the road (Figure I). This meant the trees had to be lifted from the windrow and swung approximately 45 degrees to feed the machine. Much of the time, the Hahn II loader had trouble breaking trees loose (tops entangled) and lifting them from the windrow (piles up to 5-m high). This necessitated the assistance of the Poclain log loader in preparing predecked piles. This assistance is the main reason for the high delay time experienced in this system. The delay time also includes the time waiting for the Poclain log loader to clear away processed logs.

Delimbing efficiency and quality were good on limbs up to 9 cm in diameter. On those over 9 cm, the Hahn II Harvester would sometimes have to process them two or more times. Length accuracy was not checked by FERIC.

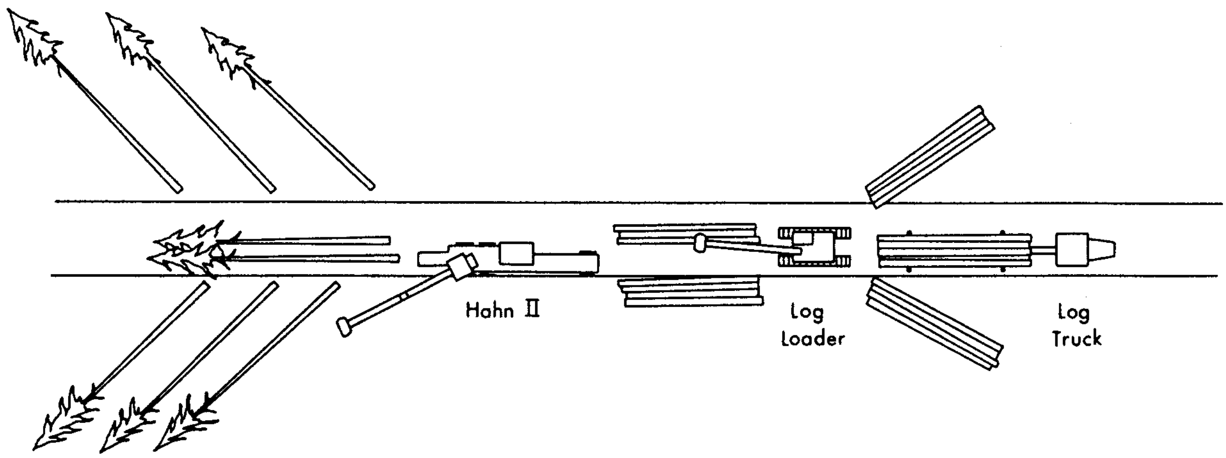

FIGURE I. Typical Hahn II Harvester Setup.

Wood flow in the Hahn II Harvester operation was not as smooth as in the Hahn Harvester operation. The crews had not worked together before and there was little supervision.

A cost and productivity summary for the Hahn II Harvester is shown in Table 27. Figures are based on approximately 57 hours of detailed timing information.

TABLE 27. Hahn II Harvester--Productivity and Cost Summary.

Average tree volume, m^3	0.53
No. trees per PMH	83.1
No. trees per SMH	45.5
No. logs per PMH	141.3
No. logs per SMH	77.5
Volume per shift (8 hours), m^3	192.9
Trees per shift	364.0
Total equipment cost per shift*	$1 525.07
Cost per m^3	$7.91
Cost per tree	$4.19

*Interest excluded.

Costs for the Hahn II Harvester include the harvester itself (two operators) and the Poclain log loader (one operator, a helper, and the machine for 56% of the time). The remaining 44% of the log loader's time is accounted for under loading in System 1.

B. System 2 (Handfelled, Grapple Yarded)

i. Roadside Processing--Manual Processing

The same method was used as in System 1 for manual processing. The results of the detailed timing study are given in Tables 28 and 29.

TABLE 28. Manual Processing--System 2--Timing Summary.

	1 BUCKER	2 BUCKERS	COMBINED TOTAL
Number of Trees	445	834	1 279
Number of Logs Produced	723	1 232	1 955
Productive Minutes	469.3	547.2	1 016.5
% of Total Productive Time			34.9

TABLE 29. Poclain Log Loader (Manual Processing)--System 2--Timing Summary.

PHASE	TOTAL TIME (MINUTES)	%	PIECES
Productive			
Load	1 087	33	3 295
Move	119	3	
Pile Logs	536	16	2 085
Pull from Windrow	951	29	2 044
Subtotal	2 693	81	
Delay			
Cleanup	89	3	
Mechanical	84	3	
Other	462	13	
Subtotal	635	19	
Total	3 328	100	

Because of long delays waiting for trees and logs to be moved, manual processing was productive only 34.9% of the time. Manual processing productivity was very dependent on the Poclain log loader. Average piece size before manufacturing was 0.82 m^3.

Table 30 is a summary of the cost and productivity of manual processing in System 2.

TABLE 30. Manual Processing--Productivity and Cost Summary.

Average Tree Volume = 0.82 m³			
	1 BUCKER	2 BUCKERS	COMBINED TOTAL
No. of trees per productive hour	56.9	91.4	75.5
No. logs per productive hour	92.4	135.1	115.4
Volume per shift (8 hours), m³			172.9
Trees per shift			210.8
Total equipment cost per shift*			$861.49
Cost per m³			$4.98
Cost per tree			$4.09

*Interest excluded.

Cost of manual processing includes the Poclain log loader (64% of its time--operator and helper), hand bucker, and chain saw costs. The remaining 36% of the loader's time is accounted for under loading in System 2. Processing by two buckers increased production by 61% (Table 28).

ii. Landing Processing--Hahn Harvester

The Hahn Harvester (one operator) operated for two days in System 2. The same method was used to recover logs from the windrows and forward them to the Hahn Harvester as in System 1.

The skidders had problems maintaining the production rates in System 1 because tree butts were facing both directions in the windrow. Much of the skidder's time was spent getting trees untangled from the windrow. As trees had to be skidded to the Hahn Harvester butt first, top ends were sorted out and left for skidding from the other side of the windrow.

Table 31 gives the results of the detailed timing on the Hahn Harvester in System 2. Table 32 is a cost and productivity summary for the Hahn Harvester, Barko log loader, and skidders used in this method of roadside processing.

Costs for the Hahn Harvester include the harvester itself (one operator), Barko log loader (one operator and machine 55% of the time), and three skidders. The remaining 45% of the log loader's time is accounted for under loading in System 2.

TABLE 31. Hahn Harvester--System 2--Timing Summary.

Number of Trees = 1469
Number of Logs Produced = 2236

PHASE	TOTAL TIME (MINUTES)	%
Productive		
Process	580.9	54
Wait Hahn Loader	277.8	25
Subtotal	858.7	79
Delay		
Cleanup	63.8	6
Mechanical	40.8	4
Other	117.0	11
Subtotal	221.6	21
Total	1 080.3	100

TABLE 32. Hahn Harvester--Productivity and Cost Summary.

Average piece volume, m^3	0.82
No. trees per PMH	102.6
No. trees per SMH	81.6
No. logs per PMH	156.2
No. logs per SMH	124.2
Volume per shift (8 hours), m^3	535.3
Trees per shift	652.8
Total equipment cost per shift*	$2 420.58
Cost per m^3	$4.52
Cost per tree	$3.71

*Interest excluded.

iii. Roadside Processing--Hahn II Harvester

The same method was used to process trees at roadside as in System 1. Table 33 gives the results of the detailed timing.

The high delay time (Table 33) was partly because the Hahn II loader had trouble lifting and separating trees from the windrow (Figure J) and partly because the Poclain log loader was not present to clear away logs processed by the harvester.

TABLE 33. Hahn II Harvester--System 2--Timing Summary.

No. of Trees = 584		
No. of Logs Produced = 1116		
PHASE	TOTAL TIME (MINUTES)	%
Productive		
Process	365.1	26
Wait Hahn Loader	79.2	6
Subtotal	444.3	32
Delay		
Cleanup	4.5	-
Mechanical	76.8	5
Wait Poclain Loader	684.3	48
Other	203.6	15
Subtotal	969.2	68
Total	1 413.5	100

FIGURE J. Hahn II Harvester Pulling Trees Out of Windrow.

The harvester and the log loader crews had little experience working together. As in System 1, it is felt that closer supervision would have reduced delay time. Table 34 presents the cost and productivity results for this method.

TABLE 34. Hahn II Harvester--Productivity and Cost Summary.

Average piece volume, m^3	0.82
No. trees per PMH	78.9
No. trees per SMH	24.8
No. logs per PMH	150.7
No. logs per SMH	47.4
Volume per shift (8 hours), m^3	162.7
Trees per shift	198.4
Total equipment cost per shift*	$1 525.07
Cost per m^3	$9.37
Cost per tree	$7.69

*Interest excluded.

Costs for the Hahn II Harvester include the harvester itself (two operators) and the Poclain log loader (one operator, a helper, and machine for 56% of the time). The remaining 44% of the log loader's time is accounted for under loading in System 2.

C. System 3 (Mechanically Felled, Skidded)

i. Landing Processing--Hahn Harvester

Trees were skidded from feller-bunched piles and cold-decked or landed alongside the Hahn Harvester infeed deck. Figures K and L show a typical landing setup.

The harvester often handled multiple stems which increased productivity. No decrease in delimbing quality was observed. A summary of detailed timing data is given in Table 35. Table 36 is a summary of cost and productivity information for this method.

Costs for the Hahn Harvester include the harvester itself (one operator) and the Barko log loader (one operator and machine 55% of the time). The remaining 45% of the log loader's time is accounted for under loading in System 3.

D. System Comparison

Table 37 compares the various roadside processing methods tried in the three logging systems. For comparative purposes, machine utilization is set at 75% for all methods. Manual processing utilization is set at 35 percent.

FIGURE K. Hahn Harvester.

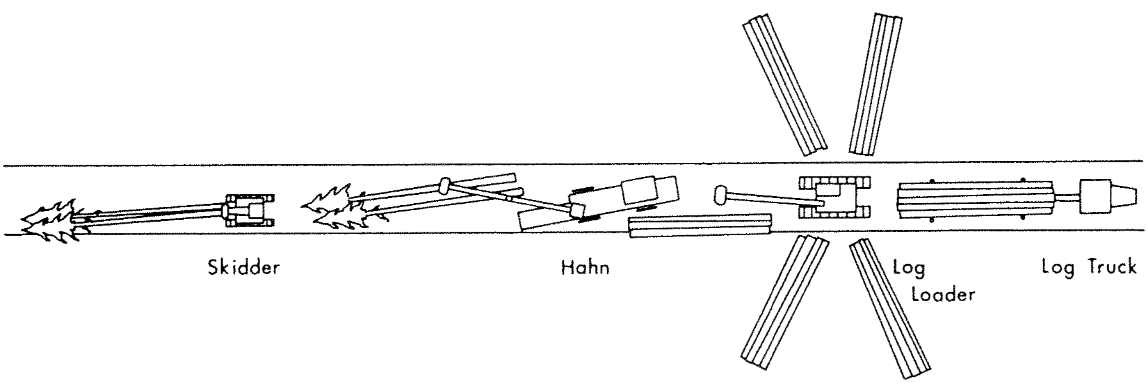

FIGURE L. Typical Hahn Harvester Setup.

TABLE 35. Hahn Harvester--System 3--Timing Summary.

No. of Trees = 5330 No. of Logs = 8034		
PHASE	TOTAL TIME (MINUTES)	%
Productive		
Process and wait		
Hahn Loader	3 341.2	68
Delay		
Cleanup	553.8	11
Mechanical	172.6	4
Other	845.5	17
Subtotal	1 571.9	32
Total	4 913.1	100

TABLE 36. Hahn Harvester--Productivity and Cost Summary.

Average piece volume, m^3	0.63
No. trees per PMH	95.7
No. trees per SMH	65.1
No. logs per PMH	144.3
No. logs per SMH	98.1
Volume per shift (8 hours), m^3	328.1
Trees per shift	520.8
Total equipment cost per shift*	$935.22
Cost per m^3	$2.85
Cost per tree	$1.80

*Interest excluded.

TABLE 37. Roadside Processing Methods--Production and Costs.

SYSTEM	m^3/SHIFT*	TREES/SHIFT*	$/$m^3$	$/PIECE
System 1 - Manual Processing	151.1	285.0	$5.70	$3.02
- Hahn Harvester	400.0	754.8	$6.05	$3.21
- Hahn II Harvester	264.3	498.6	$5.77	$3.06
System 2 - Manual Processing	173.3	211.4	$4.97	$4.08
- Hahn Harvester	504.8	615.6	$4.80	$3.93
- Hahn II Harvester	388.2	473.4	$3.93	$3.22
System 3 - Hahn Harvester	361.7	574.2	$2.59	$1.63

*Machine utilized at 75% and manual processing at 35%.

System 3 resulted in the most economic method of roadside processing. Skidding directly to the Hahn Harvester and then processing was $1.34/$m^3$ or $1.39/tree less than the next lowest costing system.

On a cost-per-cubic-metre basis, System 2 is approximately 25% cheaper than System 1. This is due mainly to the piece size variance, e.g., 0.82 m^3 versus 0.53 m^3.

Within System 1, manual processing results in the lowest costs, but also in the lowest production per manday. The lower cost reflects the high capital cost associated with the mechanical processors.

In Systems 1 and 2, the Hahn Harvester cost includes three skidders to pull material out of the windrows. Further experimentation may show it is feasible to use only one or two skidders and reduce the cost.

In Systems 1 and 2, the Hahn II Harvester had problems with windrowed trees. Some of these problems were:

- Trees were too large for the 9000-kg lift loader.
- Tops were tangled together--especially in the bunched-wood windrows.
- Most trees had to be swung approximately 45 degrees for efficient infeed alignment.
- Trees whose tops faced the road had to be turned around. The windrows in the handfelled area contained a lot of trees with tops facing the road.

Other significant delays occurred with the Hahn II Harvester because processed logs were not cleared away and there was a lack of coordination between the log loader and the processor.

4. <u>Loading</u>

A. <u>System 1 (Mechanically Felled, Grapple Yarded)</u>

i. <u>Loading--Manual Processing</u>

Loading of manually processed logs was done by the Poclain log loader. Productivity and cost information is shown in Table 38 and is based on approximately 22 hours of detailed timing.

Some cedar and pulp logs were sorted at roadside. The cedar was highway-hauled directly to a local sawmill. All other loads were highway-hauled to the dryland sortyard at Northwest Bay. The pulp loads bypassed the dryland sortyard processing area and were dumped directly into the water for booming.

Production costs for loading include the Poclain log loader, operator, and helper for 36% of the time.

ii. <u>Loading--Hahn Harvester</u>

A Barko 250 log loader cleared away logs processed by the Hahn Harvester, sorted them four ways, and loaded them onto trucks. This did not cause significant delays to the Hahn Harvester. In fact, presorting improved loading productivity. When loading from presorted piles, the loader was able to consistently pick up two or more logs. Also, the presorted piles facilitated the efficient loading of trucks. Detailed timing results for the log loader are shown in Table 39.

Production costs for the Barko 250 include the machine and operator for 45% of the time.

All loads were highway hauled to the dryland sortyard at Northwest Bay. Pulp loads bypassed the sortyard processing phase and were put directly in the water.

TABLE 38. Poclain Log Loader (Manual Processing)--Productivity and Cost Summary.

Truck loading	
No. loads	62
No. pieces	2 668
No. minutes	1 053
Average piece volume, m^3	0.57
No. pieces per load	43
No. minutes per load	17
No. loads per hour	1.34
Volume per shift (8 hours), m^3	262.7
Pieces per shift	461.0
Total equipment cost per shift*	$371.43
Cost per m^3	$1.41
Cost per piece	$0.81

*Interest excluded.

TABLE 39. Barko 250 Log Loader (Hahn Harvester)--Productivity and Cost Summary.

Truck loading	
No. loads	21
No. pieces	1 656
No. minutes	367
Average piece volume, m^3	0.46
No. pieces per load	79
No. minutes per load	17
No. loads per hour	1.96
Volume per shift (8 hours), m^3	569.8
Pieces per shift	1 238.7
Total equipment cost per shift*	$257.26
Cost per m^3	$0.45
Cost per piece	$0.21

*Interest excluded.

iii. Loading--Hahn II Harvester

Loading was done with the Poclain HC 300 log loader. Productivity and cost information for the log loader is shown in Table 40.

TABLE 40. Poclain Log Loader (Hahn II Harvester)--
Productivity and Cost Summary.

Truck loading	
No. loads	54
No. pieces	3 133
No. minutes	956
Average piece volume, m^3	0.52
No. pieces per load	58
No. minutes per load	18
No. loads per hour	1.24
Volume per shift (8 hours), m^3	299.2
Pieces per shift	575.4
Total equipment cost per shift*	$453.97
Cost per m^3	$1.52
Cost per piece	$0.79

*Interest excluded.

Production costs for loading include the Poclain log loader, operator, and helper for 44% of the time.

With the exception of a few cedar loads, all loads were highway-hauled to the dryland sortyard at Northwest Bay. The cedar was hauled directly to a local sawmill.

B. System 2 (Handfelled, Grapple Yarded)

i. Loading--Manual Processing

The same loading method and equipment were used as in System 1. Table 41 gives productivity and cost information.

Costs for loading include the Poclain log loader, operator, and helper for 36% of the time.

ii. Loading--Hahn Harvester

The same loading method and equipment were used as in System 1. Table 42 lists the productivity and cost information.

Costs for loading include the Barko 250 log loader (one operator) for 45% of the time.

TABLE 41. Poclain Log Loader (Manual Processing)--
Productivity and Cost Summary.

Truck loading	
No. loads	80
No. pieces	3 655
No. minutes	1 205
Average piece volume, m^3	0.63
No. pieces per load	46
No. minutes per load	15
No. loads per hour	1.34
Volume per shift (8 hours), m^3	310.7
Pieces per shift	493.1
Total equipment cost per shift*	$371.43
Cost per m^3	$1.20
Cost per piece	$0.75

*Interest excluded.

TABLE 42. Barko 250 Log Loader (Hahn Harvester)--
Productivity and Cost Summary.

Truck loading	
No. loads	38
No. pieces	2 282
No. minutes	574
Average piece volume, m^3	0.57
No. pieces per load	60
No. minutes per load	15
No. loads per hour	1.95
Volume per shift (8 hours), m^3	533.5
Pieces per shift	936.0
Total equipment cost per shift*	$257.26
Cost per m^3	$0.48
Cost per piece	$0.27

*Interest excluded.

iii. Loading--Hahn II Harvester

Logs were loaded by the Poclain log loader. Production and cost data are shown in Table 43.

Costs for loading include the Poclain log loader, operator, and helper for 44% of the time.

TABLE 43. Poclain Log Loader (Hahn II Harvester)--Productivity and Cost Summary.

Truck loading	
No. loads	19
No. pieces	844
No. minutes	255
Average piece volume, m^3	0.70
No. pieces per load	44
No. minutes per load	13
No. loads per hour	1.33
Volume per shift (8 hours), m^3	327.7
Pieces per shift	468.2
Total equipment cost per shift*	$453.97
Cost per m^3	$1.39
Cost per piece	$0.97

*Interest excluded.

C. System 3 (Mechanically Felled, Skidded)

i. Loading--Hahn Harvester

A Barko 250 log loader cleared away logs processed by the Hahn Harvester, sorted them four ways, and loaded them onto trucks. Table 44 lists productivity and cost information.

Costs for loading include the Barko log loader (one operator) for 45% of the time.

TABLE 44. Barko Log Loader (Hahn Harvester)--Productivity and Cost Summary.

Truck loading	
No. loads	153
No. pieces	7 937
No. minutes	2 546
Average piece volume, m^3	0.57
No. pieces per load	52
No. minutes per load	17
No. loads per hour	1.85
Volume per shift (8 hours), m^3	437.6
Pieces per shift	767.8
Total equipment cost per shift*	$257.26
Cost per m^3	$0.59
Cost per piece	$0.34

*Interest excluded

D. System Comparison

Table 45 compares the loading productivity and cost for the various roadside processing methods.

TABLE 45. Loading--Production and Costs.

SYSTEM	m^3/SHIFT	PIECES /SHIFT	\$/m^3	\$/PIECE
System 1				
- Manual Processing (Poclain HC 300)	262.7	461.0	$1.41	$0.81
- Hahn Harvester (Barko 250)	569.8	1 238.7	$0.45	$0.21
- Hahn II Harvester (Poclain HC 300)	299.2	575.4	$1.48	$0.77
System 2				
- Manual Processing (Poclain HC 300)	310.7	493.1	$1.20	$0.75
- Hahn Harvester (Barko 250)	533.5	936.0	$0.48	$0.27
- Hahn II Harvester (Poclain HC 300)	327.7	468.2	$1.39	$0.97
System 3				
- Hahn Harvester (Barko 250)	437.6	767.8	$0.59	$0.34

The smaller Barko log loader was less costly than the Poclain log loader in all three systems. The main reasons are:

- lower capital cost of machine ($125 000 versus $475 000);
- one man on the Barko (operator) versus two on the Poclain (operator and helper); and
- higher loading productivity (cubic metres and number of pieces).

It should be noted that the Barko log loader sorted logs four ways as part of its normal function. This portion of its costs are included in the Hahn Harvester cost. The sorting function did not appear to affect processing or truck-loading productivity in any significant way. Similarly, the Poclain log-loader costs associated with manual and mechanical processing are included with those costs.

5. Logging Residue from the Systems

Residue sampling to close utilization logging standards was done by MacMillan Bloedel Ltd., Woodland Services, in November and December, 1985. As shown in Table 46, System 2 (handfelled) resulted in the largest amount of residue left in the study areas. The System 2 residue volume was not necessarily the result of a machinery or system problem. Most of the volume was in the form of small logs which were left behind because they were hidden by debris and overlooked, or deliberately left because of their low value.

TABLE 46. Close Utilization Residue Sampling.

	SYSTEM 1	SYSTEM 2	SYSTEM 3
Residue volume, m^3/ha (Gross less decay)			
Avoidable[1]	23.21	71.71	14.30
Unavoidable	21.41	8.63	19.09
Total	44.62	80.34	33.39

[1]Avoidable residue includes high stumps, bucking waste, chunks, and logs over 3 m in length and 15 cm in diameter. Everything must be more than 50% sound.

Breakage occurred in all logging phases--i.e., falling, skidding, yarding, processing, and loading. Falling breakage occurred as trees hit the ground and when hit by other falling trees. In the skidding and yarding phases, breakage occurred at the start of the inhaul and when hangups happened. Breakage also occurred when the backspar trail was being built and widened. In the processing and loading phases, breakage occurred as pieces were being pulled out of windrows. FERIC did not monitor breakage by phase during this study.

Systems 1 and 3 resulted in less residue because:

- Feller-buncher operators are able to direct and control the speed of falling trees and thus reduce breakage.

- Yarding and skidding of bunches results in fewer hangups and the bunches retain their integrity as they are being yarded. Bunches also result in fewer logs being hidden by debris and overlooked in the yarding phase.

System 3 had the best results because of the falling pattern and skidding methods used. In this system, the skidders pulled straight on the bunches at the beginning of the skidding phases. In System 1, the grapple yarder pulled sideways on the bunches at the start of the inhaul phase, and more tops were broken.

6. Overall Comparison of the Three Systems

Tables 47 and 48 compare all three logging systems, by processing method, on a cost-per-cubic-metre and on a cost-per-piece basis.

System 3 resulted in the lowest cost per cubic metre and cost per piece of the logging systems studied. The lower cost of skidding combined with immediate processing and close supervision, made this a very productive and cost-effective operation. On a per-cubic-metre basis, it was $3.66 cheaper than the next lowest costing system. On a per-piece basis, it was 13% or $1.00 cheaper.

System 1 resulted in the highest cost per cubic metre, primarily because of the smaller piece size. When compared on a per-piece basis, it became less expensive than System 2.

TABLE 47. System Comparison--All Methods (Cost per Cubic Metre).

SYSTEM - METHOD	MANUAL PROCESSING ($/m³)	HAHN HARVESTER ($/m³)	HAHN II HARVESTER ($/m³)
1 - Feller-buncher[1]	2.76	2.76	2.76
- Grapple yard	4.32	4.32	4.32
- Roadside process	5.70	6.05	5.77
- Load	1.41	0.45	1.48
Total	14.19	13.58	14.33
2 - Handfall	1.56	1.56	1.56
- Grapple yard	4.64	4.64	4.64
- Roadside process	4.97	4.80	3.93
- Load	1.20	0.48	1.39
Total	12.37	11.48	11.52
3 - Feller-buncher[1]		2.07	
- Skidding		2.57	
- Landing process		2.59	
- Load		0.59	
Total		7.82	

[1]Combined falling cost includes handfalling oversize trees.

TABLE 48. System Comparison--All Methods (Cost per Piece).

SYSTEM - METHOD	MANUAL PROCESSING ($/PIECE)	HAHN HARVESTER ($/PIECE)	HAHN II HARVESTER ($/PIECE)
1 - Feller-buncher[1]	1.65	1.65	1.65
- Grapple yard	2.55	2.55	2.55
- Roadside process	3.02	3.21	3.06
- Load	0.81	0.21	0.77
Total	8.03	7.62	8.03
2 - Handfall	1.44	1.44	1.44
- Grapple yard	4.22	4.22	4.22
- Roadside process	4.08	3.93	3.22
- Load	0.75	0.27	0.97
Total	10.49	9.86	9.85
3 - Feller-buncher[1]		2.24	
- Skidding		2.41	
- Landing process		1.63	
- Load		0.34	
Total		6.62	

[1]Combined falling cost includes handfalling oversize trees.

When comparing Systems 1 and 2, we find:

- The $0.21/piece higher cost of mechanical falling is more than offset by the $1.67 favourable effect of grapple yarding bunched wood.
- Roadside processing of handfelled wood (System 2) averaged about $0.65/piece more than the bunched wood (System 1). This is mainly because of the extra handling required when tops face the road in windrows.

In all three systems, roadside processing makes it possible to presort logs in the woods. As shown in System 3, this can be done very efficiently and cost effectively. Presorting can result in additional savings in the other logging phases, e.g., booming, dryland sorting, and hauling (Peterson 1986).

CONCLUSIONS

The falling pattern and method used is critical to the yarding and processing phases which follow. This is shown in the yarding phase where bunching results in more productive yarding, and in the processing phase where having all tree butts facing the road results in more productive processing. Future FERIC research might study the effect of falling pattern, bunching placement, and optimum bunch size.

Study results show that grapple yarding is an acceptable alternative when skidding is not possible or if the company has yarders available. Grapple yarding bunched wood proved to be more productive and cost efficient than grapple yarding handfelled full-tree material. There was a 65% increase in pieces yarded per shift and a 40% reduction in cost per piece.

The yarding grapple has a large effect on productivity. This report shows a 20% difference in pieces/PMH between the two grapples used in the bunched-wood area. Between the three grapples used in the handfelled area, there was a 75% variance.

Of the various processing methods studied, the Hahn Harvester operation was the most efficient and economical. Skidding to the Hahn Harvester and processing directly was $1.34/m^3 and $1.39/piece less than the next lowest costing system. As shown in the Hahn II Harvester results, removing trees from grapple-yarded windrows is difficult. This problem is unresolved and is an area for further FERIC research. Experimentation with grapple skidders pulling trees out of windrows may also be advantageous.

The smaller Barko log loader was less costly than the Poclain log loader in all three systems. The Barko cleared away logs processed by the Hahn Harvester, sorted them four ways, and loaded them onto trucks. The sorting function did not affect processing or truck loading productivity in any significant way.

Significantly less logging residue was left in the areas that were feller-bunched than in the handfelled area. It is felt that this is owing to the falling method, falling pattern, and the skidding/yarding methods used. This may result in cheaper site-preparation costs after logging.

System 3 resulted in the lowest cost per cubic metre and cost per piece of the logging systems studied. The lower cost skidding of bunches, combined with immediate processing and close supervision, made this a very productive and cost-effective operation. On a per-cubic-metre basis, it was $3.66 cheaper than the next closest costing system and on a per-piece basis, it was 13% or $1.00 cheaper.

The large piece-size variance between Systems 1 and 2 makes the cost difference per cubic metre appear insignificant. The piece-size differences were caused by stand differences and the amount of residue volume left. For these areas, the comparisons per piece handled give a clearer picture of what is happening.

When comparing System 1 (mechanical falling and bunching, grapple yarding) and System 2 (hand falling, grapple yarding), we find that the higher cost of mechanical falling ($0.21/piece) is more than offset by the favourable effect of grapple yarding bunched wood ($1.67/piece). Roadside processing of handfelled wood averaged about $0.65/piece more than the bunched wood.

Historically, loggers have had a good grasp of their average logging phase costs, e.g., falling, skidding, yarding, etc. This information is useful and necessary, but more useful would be knowledge of the range of logging costs and comparison values related to log volume, tree diameter, yarding distance, terrain features, and other variables (Adams 1965). To fill this need, FERIC has a Harvesting Economics Project underway. Initial work has concentrated on falling and grapple yarding, and the first report will be published in early 1987.

REFERENCES

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APPENDIX I

LOGGING COSTS

Costs used in this report are prepared by FERIC and are representative of the industry.

Operating labour costs consist of the IWA hourly rate for a particular job plus 35% for fringe benefits. Machine operators' rates include 0.7 of an hour at overtime rates for machine servicing. For example, the IWA rate for a grapple yarder operator is $17.73/hour. 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:

$$\frac{0.7 \times \$23.94 \times 1.5}{8} = \$3.14$$

$$\$3.14 + \$23.94 = \$27.08/\text{hour}$$

Chain saw costs are estimated at $25.00 per day.

Operating Labour Rates

PHASE	JOB POSITION	RATE PER HOUR
Falling (6.5-hour day)	Faller	$45.33
Feller-bunching	Operator	$27.08
Grapple yarding	Operator	$27.08
	Hooker	$27.08
	Utilityman	$20.59
Loading	Operator	$27.08
	Second Loader (Helper)	$20.90
Processing	Operator	$27.08
	Landing Bucker	$23.94
Skidding	Operator	$23.64

	BARKO 250 LOG LOADER (TRUCK MOUNT)	CASE 1187 FELLER-BUNCHER	DROTT 50 FELLER-BUNCHER	HAHN HARVESTER	HAHN II HARVESTER	HITACHI UH14 BACKSPAR	POCLAIN HC 300 LOG LOADER (TRACKED)	MADILL 084 GRAPPLE YARDER	TIMBERJACK 380 GRAPPLE SKIDDER
OWNERSHIP COSTS									
Purchase Price (P)	$125 000	$298 000	$298 000	$285 000	$385 000	$135 000	$475 000	$700 000	$145 000
Salvage Value (30% of P)	$37 500	$89 400	$89 400	$85 500	$115 500	$40 500	$142 500	$210 000	$43 500
Expected Life (yr)	11	6	6	7	7	7	14	10	6
Expected Life (h)	16 000	9 000	9 000	10 000	10 000	10 000	20 160	14 400	9 000
Interest Rate (I) %	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Insurance Rate (Ins) %	1	1	1	1	1	1	1	1	1
Average Investment (AVI) = (P+S)/2	$81 250	$193 700	$193 700	$185 250	$250 250	$87 750	$308 750	$455 000	$94 250
Loss in Resale Value ($/h) = (P-S)/h	$5.47/h	$23.18/h	$23.18/h	$19.95/h	$26.95/h	$9.45/h	$16.49/h	$34.03/h	$11.28/h
Interest ($/h) = (I*AVI)/(h/yr)	$6.98/h	$16.14/h	$16.14/h	$16.21/h	$21.90/h	$7.68/h	$26.80/h	$39.50/h	$7.85/h
Insurance ($/h) = (Ins*AVI)/(h/yr)	$0.56/h	$1.29/h	$1.29/h	$1.30/h	$1.75/h	$0.61/h	$2.14/h	$3.16/h	$0.63/h
OPERATING AND REPAIR COSTS									
Fuel Consumption (L/h)	23	32	32	27	40	20	32	45	21
Fuel Cost ($/L)	$0.36	$0.36	$0.36	$0.36	$0.36	$0.36	$0.36	$0.36	$0.36
Operating Supply Cost Per Year (O)	$5 000	$1 500	$1 500	$3 000	$4 000	$1 500	$1 500	$25 000	$1 500
Annual Tire Consumption (T) (yrs)	5	0	0	2	2	0	0	0	4
Tire Replacement Cost ($/T)	$500	$0	$0	$250	$250	$0	$0	$0	$1 375
Annual Repair & Maintenance Cost (R)	$35 000	$28 500	$28 500	$23 000	$26 000	$10 000	$70 000	$55 000	$20 000
Wages ($/h)	$20.06	$20.06	$20.86	$20.06	$40.12	$0.00	$35.54	$51.56	$17.51
Wage Benefit Loading (%)	35	35	35	35	35	0	35	35	35
Fuel Cost = (L/h)*($/L)	$8.30/h	$11.55/h	$11.55/h	$9.75/h	$14.44/h	$7.22/h	$11.55/h	$16.25/h	$7.58/h
Lube & Oil Cost = 10% * Fuel Cost	$0.83/h	$1.16/h	$1.16/h	$0.97/h	$1.44/h	$0.72/h	$1.16/h	$1.62/h	$0.76/h
Operating Supply Cost = O/(h/yr)	$3.44/h	$1.00/h	$1.00/h	$2.10/h	$2.80/h	$1.05/h	$1.04/h	$17.36/h	$1.00/h
Tire Cost = T*($/T)/(h/yr)	$1.72/h	$0.00/h	$0.00/h	$0.35/h	$0.35/h	$0.00/h	$0.00/h	$0.00/h	$3.67/h
Repair & Maintenance Cost = R/(h/yr)	$24.06/h	$19.00/h	$19.00/h	$16.10/h	$18.20/h	$7.00/h	$48.61/h	$38.19/h	$13.33/h
Labour Cost = ($/h)*{1+(%/100)}	$27.08/h[1]	$27.08/h[1]	$27.00/h[1]	$27.08/h[1]	$54.16/h[2]	$0.00/h[3]	$47.98/h[4]	$69.61/h[5]	$23.64/h[6]
Operating and Repair Costs ($/h)	$65.43/h	$59.79/h	$59.79/h	$56.35/h	$91.40/h	$15.99/h	$110.34/h	$143.03/h	$49.98/h
TOTAL COSTS									
Operating and Repair Costs ($/h)	$65.43/h	$59.79/h	$59.79/h	$56.35/h	$91.40/h	$15.99/h	$110.34/h	$143.03/h	$49.98/h
Loss in Resale Value ($/h)	$5.47/h	$23.18/h	$23.18/h	$19.95/h	$26.95/h	$9.45/h	$16.49/h	$34.03/h	$11.28/h
Insurance ($/h)	$0.56/h	$1.29/h	$1.29/h	$1.30/h	$1.75/h	$0.61/h	$2.14/h	$3.16/h	$0.63/h
TOTAL COST ($/h)	$71.46/h	$84.26/h	$84.26/h	$77.60/h	$120.10/h	$26.06/h	$128.98/h	$180.22/h	$61.88/h
Interest ($/h)	$6.98/h	$16.14/h	$16.14/h	$16.21/h	$21.90/h	$7.68/h	$26.80/h	$39.50/h	$7.85/h
GRAND TOTAL ($/h)	$78.44/h	$100.40/h	$100.40/h	$93.81/h	$141.99/h	$33.73/h	$155.78/h	$219.72/h	$69.74/h

[1] 1 operator
[2] 2 operators
[3] Operator included with Grapple Yarder
[4] Operator and helper
[5] Operator, hooker and 3/4 utilityman
[6] 1 operator

APPENDIX II

TERRAIN INFORMATION

Terrain factors were collected as part of the operational cruise activity. This terrain classification system is outlined in the B.C. Ministry of Forests Appraisal Manual.

Area information by system:

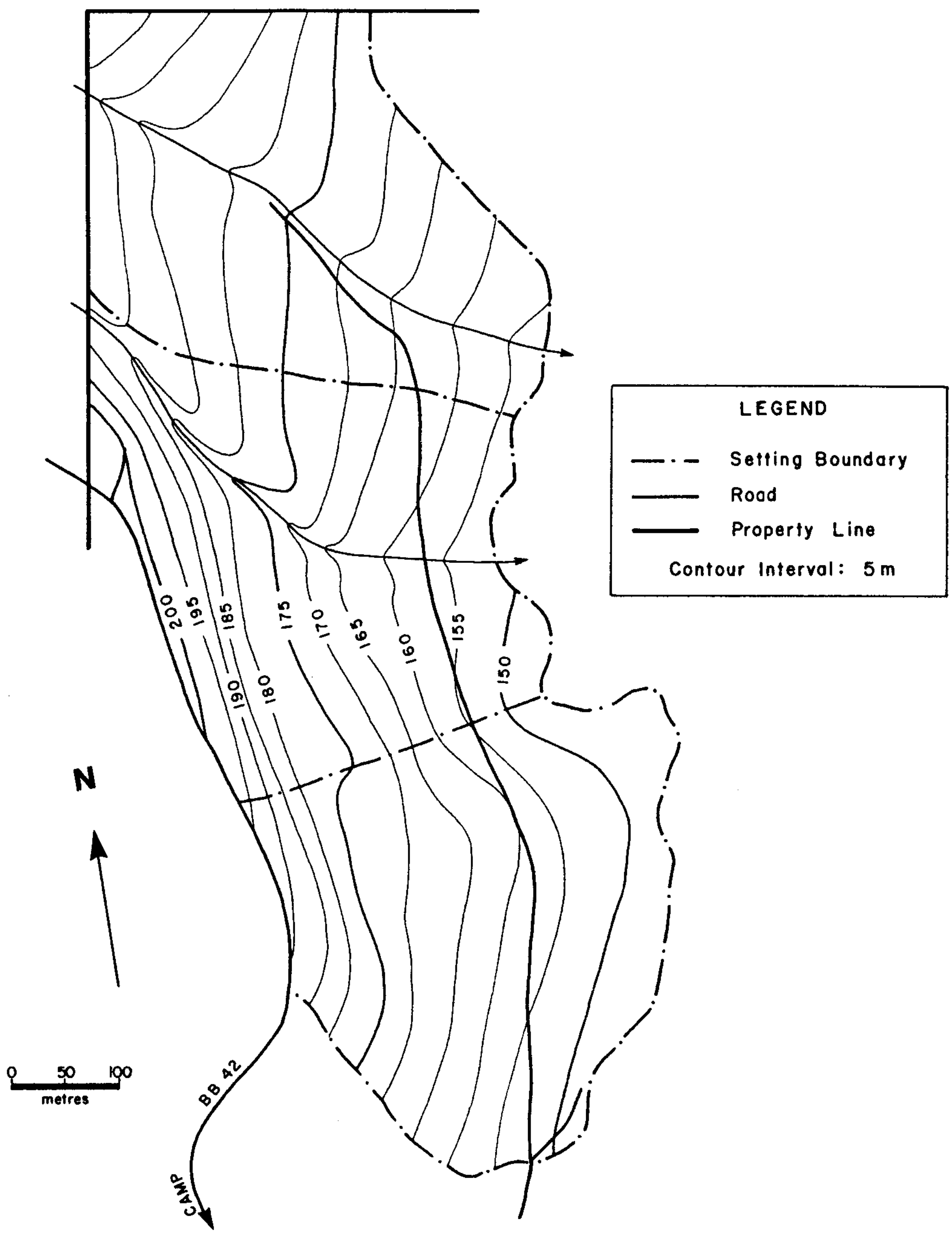
System 1
- slope range = 0 to 38%
- average slope = east 18%
- rolling terrain
- 5 obstacles/ha in height range 0.25 to 0.49 m
- soil depth = 2.0 m
- soil material is mainly loam, with some gravel
- soil moisture = moist
- no exposed rock
- undergrowth is medium to heavy

System 2
- slope range = 0 to 52%
- average slope = east 23%
- rolling terrain
- 5 obstacles/ha in height range 0.25 to 0.49 m
- 3 obstacles/ha in height range 0.50 to 0.99 m
- 3 obstacles/ha in height range 1.00 to 1.49 m
- soil depth = 2.0 m
- soil material is mainly loam, with some gravel
- soil moisture = moist
- no exposed rock
- undergrowth is medium to heavy

System 3
- slope range = 0 to 19%
- average slope = east 12%
- rolling terrain
- 10 obstacles/ha in height range 0.25 to 0.49 m
- 5 obstacles/ha in height range 0.50 to 0.99 m
- soil depth = 2.0 m
- soil material is mainly loam, with some gravel
- soil moisture = moist
- no exposed rock
- undergrowth is medium to heavy

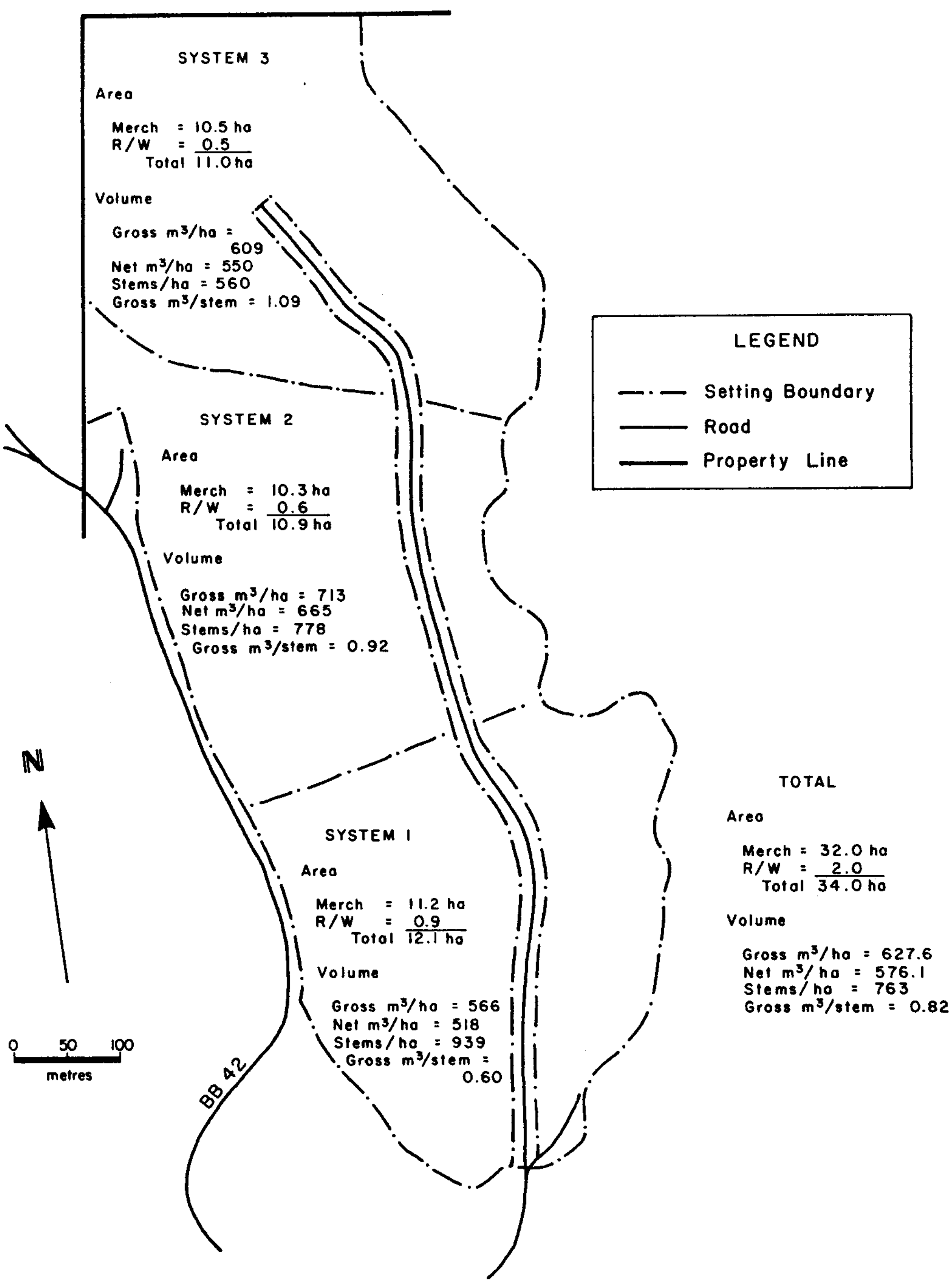
APPENDIX III

CONTOUR MAP



APPENDIX IV

AREA AND VOLUME INFORMATION[1]

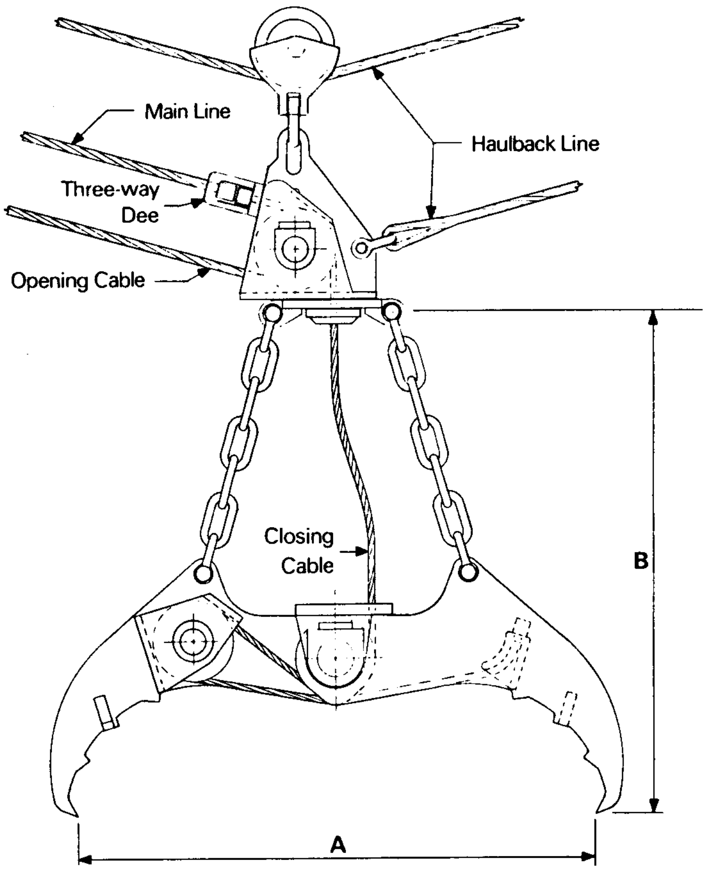


[1] BASED ON OPERATIONAL CRUISE DATA

APPENDIX V

Y96 CHOKER GRAPPLE

DIMENSIONS AND REEVING



GENERAL SPECIFICATIONS

MODEL	JAW THICK.	MAXIMUM CABLE SIZE	LENGTH OF CLOS'G. CABLE	BASIC DIMENSIONS A	BASIC DIMENSIONS B		TOTAL WEIGHT CARRIAGE & GRAPPLE
Y-96	51 mm	25 mm	5.6 m	2.4 m	2.0 m		919 kg

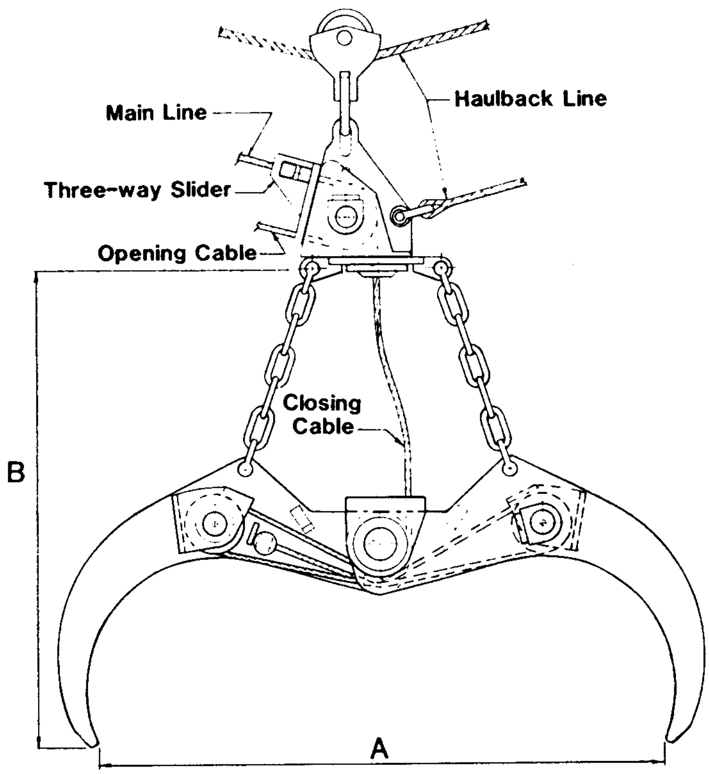
Drawing Courtesy of:

Johnson Industries Ltd.
Richmond, B.C.

APPENDIX VI

Y106 CHOKER GRAPPLE FOR BUNCHES

DIMENSIONS AND REEVING



GENERAL SPECIFICATIONS

MODEL	MAXIMUM CABLE SIZE	LENGTH OF CLOS'G. CABLE	BASIC DIMENSIONS			TOTAL WEIGHT CARRIAGE & GRAPPLE
			A	B		
Y-106	25 mm	6.9 m	2.7 m	2.1 m		1025 kg

Drawing Courtesy of:

Johnson Industries Ltd.
Richmond, B.C.

APPENDIX VII

TREE AND PIECE SIZE STATISTICS[1]

SYSTEM	PHASE	VOLUME PER TREE (GROSS m³)	VOLUME PER PIECE (GROSS m³)
1	Falling - Handfalling	2.50	
	- Case 1187 Feller-buncher	0.54	
	Yarding - Madill 084 Grapple Yarder		0.59
	Roadside Processing - Manual Processing		0.53
	- Hahn Harvester		0.53
	- Hahn II Harvester		0.53
	Loading - Manual Processing		0.57
	- Hahn Harvester		0.46
	- Hahn II Harvester		0.52
2	Falling - Handfalling	0.92	
	Yarding - Madill 084 Grapple Yarder		0.91
	Roadside Processing - Manual Processing		0.82
	- Hahn Harvester		0.82
	- Hahn II Harvester		0.82
	Loading - Manual Processing		0.63
	- Hahn Harvester		0.57
	- Hahn II Harvester		0.70
3	Falling - Handfalling	3.62	
	- Drott 50 Feller-buncher	0.70	
	Yarding - Choker and Grapple Skidder		0.94
	Roadside Processing - Hahn Harvester		0.63
	Loading - Hahn Harvester		0.57

[1]Derived from operation cruise done by MacMillan Bloedel Ltd., Woodland Services, in April 1985, and compiled by Reed, Collins Associates Limited and actual scale results.