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HARVESTING ECONOMICS: CASE STUDIES OF A CYPRESS 7280B SWING YARDER AND MOBILE BACKSPAR

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Abstract

This report presents the results of seven case studies of two Cypress 7280B swing yarders working with a grapple on various timber-harvesting sites on Vancouver Island, British Columbia in 1988. Both yarders used mobile backspars. This is the second in a series of reports that document productivity and costs of a variety of cable-yarding systems operating in Coastal British Columbia. This information has been collected to supply site-specific, rather than average, cost and productivity data to the forest industry. The data were collected as part of a joint project between the Forest Engineering Research Institute of Canada (FERIC) and the Department of Harvesting and Wood Science, Faculty of Forestry, University of British Columbia (UBC). The project was funded by FERIC, UBC, and the Natural Sciences and Engineering Research Council of Canada.

Introduction

This report presents results from a series of grapple-yarding studies that were conducted by the Forest Engineering Research Institute of Canada (FERIC) to provide industry with information about the range of harvesting costs and productivity as related to yarding system and yarding equipment. Productivity figures and costs for specific conditions are presented and the influence of stand conditions, log size, yarding distance, and terrain on productivity and costs is discussed. These grapple-yarding studies were carried out as part of FERIC's ongoing Harvesting Economics Project. The Harvesting Economics Project was initiated by FERIC member companies in 1983. Previous FERIC studies have addressed hand falling, grapple yarding with a swing yarder, and highlead cable yarding (Kooistra et al 1990; MacDonald 1987 and 1988; Peterson 1986, 1987a, 1987b, 1987c, and 1988).

Information about harvesting costs and productivity is important to the forest industry because loggers usually determine harvesting costs for each phase of their operation (falling, skidding or yarding, and loading) by averaging costs over a setting, a region, or a time period. As a result, harvesting costs represent productivity for a broad range of timber and terrain conditions. The disadvantage of using costs determined in this manner is that they are only averages. While a given average cost may seem satisfactory, a breakdown of costs for specific sites may reveal individual cost situations that are not profitable (Adams 1965).

Specific information about the productivity and cost of using alternative harvesting systems is also required to determine the ideal yarding system for individual stands of timber. The influence of variables such as log size, stand density, yarding distance, terrain, equipment, and labour on harvesting productivity and costs must be known and related to the stands to be harvested in the future. All of this information is important to logging planners and woods foremen in allocating equipment or analyzing crew and equipment performance, and in determining whether or not it is economically feasible to harvest a particular stand of timber with the equipment and system used.

Keywords: Cable logging, Skyline, Grapple yarder, Machine evaluation, Time study, Productivity, Costs, Economic analysis, Mobile backspar, Cypress 7280B swing yarder.
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The data collected for this report were obtained in 1988 at the operations of MacMillan Bloedel Limited on Vancouver Island. Five of the studies were carried out at Port McNeill Division and two were carried out at Menzies Bay Division. All sites were yarded with a combination Cypress 7280B swing yarder and excavator/backspar using a running skyline system and a grapple (Figure 1).

Data were collected as part of a cooperative project that was jointly funded by the Natural Sciences and Engineering Research Council of Canada; the Department of Harvesting and Wood Science, Faculty of Forestry, University of British Columbia (UBC); and FERIC.

Study Methods

One of UBC's study objectives was to collect data for developing mathematical models for individual elements of the yarding cycle; therefore, attention was focussed on recording the time for various elements of each cycle and cataloguing sites rather than examining how the yarding operations could be improved. Data were collected by UBC field crews, who used hand-held computerized data recorders to collect timing data for elements of each cycle and for the duration of both mechanical and non-mechanical delays. Because the mathematical models did not require detailed explanations of delay time, delays were accumulated into general categories. Additional data were collected to describe yarding distance, stands, terrain, weather, crew size, and yarding.

Except for Case Study 6, all individual logs were scaled and numbered with paint prior to yarding. These marked logs were matched to their appropriate turns during data analysis. In Case Study 6, the piece size was estimated from company records.

Data were collected between November 1987 and April 1988. The length of each study varied from 1.5 to 4 shifts and was determined by the length of time required to harvest site-specific areas and the availability of the data-collection crew.

Productivity was determined by converting the productive time, road-change time, and all delay times (regardless of length) to an 8-h shift basis, and dividing by the total volume or number of logs yarded during the study. The calculated machine-utilization levels are those observed during the study, and may vary if longer delays are prorated over a longer period of time. Costs were estimated by the authors and are not the actual costs incurred by the cooperating Divisions.

Site and System Description

Case Studies 1 and 2 were located on the northeast side of Vancouver Island near Campbell River, British Columbia. Case Studies 3 to 7 were located on the northern end of Vancouver Island near Port McNeill, British Columbia. Table 1 provides a description of each study area.

In Case Studies 1 to 6, the stands were hand felled and processed at the stump according to falling and bucking rules issued by the company. In Case Study 7, the area was mechanically felled by a Caterpillar FB219 feller-director. At each of the sites, a Hitachi UH14 excavator/backspar worked with a Cypress 7280B swing yarder to yard logs to roadside with a grapple. The logging chance (yarding deflection, number of obstacles encountered during yarding, terrain, visibility, and falling pattern) was considered to be moderate in Case Studies 1 and 2, and good for Case Studies 3 to 7. Operating specifications for the yarders and backspars are shown in Table 2.

Detailed-Timing Results

A summary of the data collected and the productivity and costs derived are given in Table 3 and a summary of non-productive time is presented in Appendix I. Within the productive time category, yarding averaged 64% (ranging from 49 to 74%) of total scheduled machine time, and yarding road changes averaged 15% (ranging from 5 to 29%). Table 4 shows that the time to move the yarder ranged from 0.1 to 50.2 min and averaged 5.2 min/occurrence, while the time to move

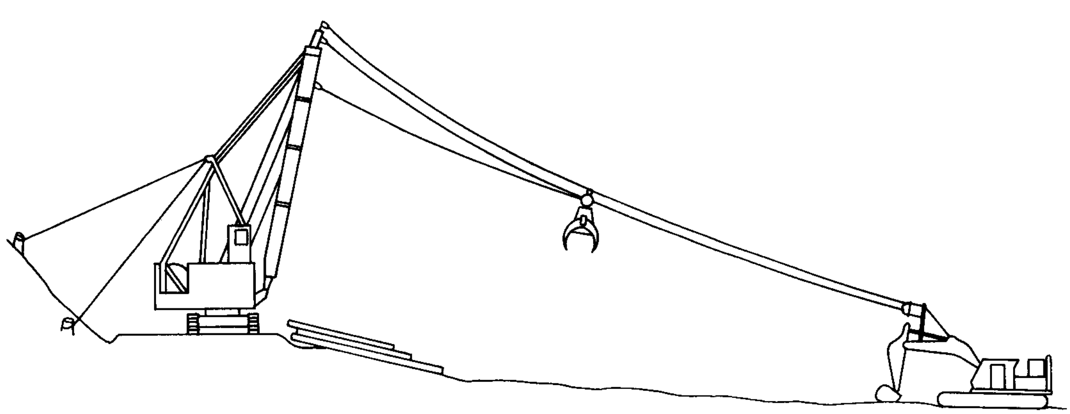

Figure 1. Yarding configuration for swing yarder and excavator/backspar.

Table 1. Site Description

Description	Case study 1	Case study 2	Case study 3	Case study 4	Case study 5	Case study 6	Case study 7
Falling method	Hand felled	Hand felled	Hand felled	Hand felled	Hand felled	Hand felled	Feller-director
Stand type	Old growth	Old growth	Mixture[a]	Mixture[a]	Mixture[a]	Mixture[a]	Mixture[a]
Yarding direction	Uphill	Downhill	Downhill	Uphill	Downhill	Downhill	Downhill
Slope							
Range	40-80%	25-70%	0-30%	0-20%	0-15%	0-20%	0-15%
Average	65%	40%	15%	15%	5%	5%	10%
Aspect	Southeast	Southeast	Northwest	Variable	North	South	Variable
Terrain	Broken	Rolling/broken	Rolling	Rolling	Rolling	Rolling	Even
Exposed rock	1-10%	1-10%	None	None	None	None	None
Underbrush	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Obstacles	Blowdown Rock outcrops	Blowdown Rock outcrops	Blowdown (minor)	Blowdown (minor)	Blowdown (minor)	Blowdown (minor)	Blowdown (minor)
Volume/ha (gross)	687 m^3	687 m^3	961 m^3	774 m^3	986 m^3	986 m^3	961 m^3
Number stems/ha	294	294	658	197	528	528	658
Species composition	46% Douglas-fir 21% cedar 21% hemlock 9% balsam 3% spruce	46% Douglas-fir 21% cedar 21% hemlock 9% balsam 3% spruce	83% hemlock 12% balsam 3% spruce 2% cedar	50% balsam 48% hemlock 2% cedar	63% hemlock 37% balsam	63% hemlock 37% balsam	83% hemlock 12% balsam 3% spruce 2% cedar

[a]Mixture of old growth and second growth due to major wind storm in 1918 (approximate date).

Table 2. Operating Specifications: Cypress Swing Yarder and Hitachi Excavator/Backspar

	Case Studies 1 & 2		Case Studies 3 to 7	
Description	Swing yarder	Backspar	Swing yarder	Backspar
Make/model	Cypress 7280B	Hitachi UH14	Cypress 7280B	Hitachi UH14
Year of manufacture	1985	1981	1984	1981
Engine type	GM12V71 389 kW (525 HP)	n/a[1]	KTA Cummins 333 kW (450 HP)	n/a
Undercarriage	Tracked	Tracked	Tracked	Tracked
Tower height	20.4 m (67 ft)	5.5 m (18 ft)	19.8 m (65 ft)	5.5 m(18 ft)
Number of guylines	2	n/a	2	n/a
Machine weight	72 575 kg	n/a	77 112 kg	n/a
Grapple make/size	Homemade 240 cm	n/a	Johnson 182 cm	n/a

[1]n/a = not applicable

the back-spar ranged from 0.2 to 25.7 min and averaged 2.3 min/occurrence. Overall, there were approximately three moves of the mobile backspar for each move of the yarder.

Total productive time averaged 79% (ranging from 60 to 89%) of total scheduled machine time. Case Studies 1 and 2 had the lowest productive times, at 64% and 60% respectively. In Case Study 1, the majority of non-productive time was due to rigging problems. In Case Study 2, time was lost mainly to yarder maintenance and rigging problems. More time could have been spent yarding during the working shift if line replacement and mechanical maintenance had been scheduled for non-working periods.

Non-productive time was found mainly in three categories (Appendix I). Rigging problems accounted for 43% of the total non-productive time, safety for 15%, and maintenance for 15%. Rigging delays at both sites included replacing grapple closing lines, grapple repair and service, and changing yarding cables. Safety delays included safety discussions and waiting for crew members to get clear.

Table 3. Timing Summary

Description	Case Study 1 min	Case Study 1 %	Case Study 2 min	Case Study 2 %	Case Study 3 min	Case Study 3 %	Case Study 4 min	Case Study 4 %	Case Study 5 min	Case Study 5 %	Case Study 6 min	Case Study 6 %	Case Study 7 min	Case Study 7 %	Combined min	Combined %
Productive time																
Yarding	455.6	59	412.2	49	392.0	56	764.0	67	1 277.5	74	544.5	59	924.7	70	4770.5	64
Yarding road change	38.9	5	92.4	11	199.1	29	254.6	22	175.1	10	141.9	15	164.4	13	1 066.4	15
Subtotal	494.5	64	504.6	60	591.1	85	1 018.6	89	1 452.6	84	686.4	74	1 089.1	83	5 836.9	79
Nonproductive time																
Mechanical	15.0	2	120.7	14	20.6	3	12.9	1	28.9	2	14.8	2	110.0	8	322.9	4
Other	269.1	34	217.6	26	83.8	12	108.9	10	248.1	14	217.9	24	115.2	9	1 260.6	17
Subtotal	284.1	36	338.3	40	104.4	15	121.8	11	277.0	16	232.7	26	225.2	17	1 583.5	21
Total scheduled machine time	778.6	100	842.9	100	695.5	100	1 140.4	100	1 729.6	100	919.1	100	1 314.3	100	7 420.4	100

Description	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Case Study 5	Case Study 6	Case Study 7	Combined
Yarding phase summary								
Minutes/turn								
Outhaul	0.49	0.28	0.25	0.31	0.24	0.22	0.22	0.26
Choke	-	-	0.01	0.12	0.01	-	-	0.02
Hookup	0.49	0.28	0.17	0.29	0.22	0.23	0.21	0.24
Inhaul	0.50	0.25	0.25	0.34	0.32	0.25	0.29	0.30
Unhook	0.18	0.20	0.03	0.06	0.11	0.20	0.11	0.12
Total	1.66	1.01	0.71	1.12	0.90	0.90	0.83	0.94
Yarding piece size (gross volume)								
Range (m^3/log)	0.17 to 13.33	0.11 to 13.32	0.08 to 9.39	0.37 to 17.28	0.39 to 18.25	-[a]	0.92 to 10.36	0.08 to 18.25
Average (m^3/log)	2.8	2.6	2.3	4.1	2.6	2.6[a]	2.2	2.7
Total no. logs yarded	313	502	777	867	1 874	843	1 684	6 860
Total number turns	273	411	566	683	1 393	609	1 122	5 057
Average number logs/turn	1.1	1.2	1.4	1.3	1.3	1.4	1.5	1.4
Average volume/turn (m^3)	3.1	3.1	3.2	5.3	3.4	3.6	3.3	3.8
Yarding distance (m)								
Average	123	85	55	88	94	51	86	83
Maximum	211	170	100	170	180	75	135	211
Logs/8-h shift	193	286	536	365	520	440	615	444
Volume/8-h shift (m^3)	540	744	1 233	1 496	1 352	1 144	1 353	1 199
Total equipment cost/8-h shift[b]	$1 857.44	$1 857.44	$1 857.44	$1 857.44	$1 857.44	$1 857.44	$1 857.44	$1 857.44
Cost/piece	$9.62	$6.49	$3.47	$5.09	$3.57	$4.22	$3.02	$4.18
Cost/m^3	$3.44	$2.50	$1.51	$1.24	$1.37	$1.83	$1.37	$1.55

[a] No logs scaled - average piece size based on company records.
[b] Interest costs are excluded.

Table 4. Summary of Yarding Road Changes

Case study no.	Yarder			Backspar			Yarding distance (m)
	No. occ.	Range (min/occ.)	Average (min/occ.)	No. occ.	Range (min/occ.)	Average (min/occ.)	
1	15	0.5 - 6.3	2.4	1	2.9	2.9	123
2	21	1.4 - 20.1	4.2	4	0.8 - 1.6	1.2	85
3	6	1.0 - 34.7	14.0	52	0.4 - 25.7	2.2	55
4	20	0.5 - 50.2	8.6	22	0.7 - 8.1	3.8	88
5	10	0.2 - 33.1	4.8	67	0.2 - 7.0	1.9	94
6	12	0.2 - 6.8	1.7	53	0.2 - 6.4	2.3	51
7	3	0.1 - 1.9	0.8	66	0.4 - 19.8	2.5	86
Combined	87	0.1 - 50.2	5.2	265	0.2 - 25.7	2.4	

Average outhaul, inhaul, and hookup time generally increased as yarding distance increased. The highest time per turn for outhaul (0.49 min), hookup (0.49 min), and inhaul (0.50 min) occurred with the longest average yarding distance. While the increased outhaul and inhaul time for longer distances was related to the greater length of line that had to be pulled in and out each turn, the increased hookup time was related to the reduced visibility of the grapple operator. At longer yarding distances on broken terrain, the dull, grey-coloured yarding grapples and the logs tended to blend into the foliar and ground colour, making it difficult for the operator to place the grapple on the log. When the grapple operator could not see the log or the grapple he relied on a spotter equipped with a radio to direct placement of the grapple. Hookup, or grappling, of bunched logs (Case Study 7) was made easier because the bunches provided a larger target and concentrated logs to fewer locations along the yarding road.

Average unhook times ranged from 0.03-0.20 min/turn. Unhook time included decking time, or the straightening of pieces in the windrow and the reyarding of logs that slid out of the pile.

The effect of piece size on productivity is illustrated in Table 5. Case Studies 2 and 4 had nearly the same number of logs yarded per yarding-hour. However, productivity per yarding-hour for Case Study 4 was 47% greater than Case Study 2 because of the larger log size. The effect of log size on productivity was also illustrated in Case Studies 3 and 7. Though these studies had the highest number of logs yarded per yarding-hour, their hourly production was less than Case Study 4 because of the smaller log size.

The number of logs yarded per turn ranged from 1.1 to 1.5 (Table 3). The smallest turn size occurred at Case Studies 1 and 2 because the logs were in scattered positions, the yarding chance was less than ideal, and the steep sidehill slope reduced the opportunity to grapple more than one log at a time. The opportunity to grapple more than one log at a time appeared to increase with stand density, a favorable yarding chance, and with decreased sidehill slope. Felling individual trees and placing them closer to other stems with a feller-director also increased the number of stems yarded per turn. However, the increase was not as large as

Table 5. Productivity Data

Case study	Total yarding time (min)	No. logs yarded	Logs/ yarding-h	Log size (m^3)	m^3/ yarding-h
1	455.6	313	41.2	2.8	115.4
2	412.2	502	73.1	2.6	190.1
3	392.0	777	118.9	2.3	273.1
4	764.0	867	68.1	4.1	279.2
5	1 277.5	1 874	88.0	2.6	228.8
6	544.5	843	92.9	2.6	241.5
7	924.7	1 684	109.3	2.2	240.5

reported in a previous study (Peterson 1986) where feller-bunchers had been used. This was probably the result of the feller-director not being able to build large bunches. The larger grapple used in Case Studies 1 and 2 did not increase the number of logs/turn because the steep ground conditions caused logs to slip out of the grapple during hookup.

Each crew consisted of three men: yarding operator, hooktender, and utilityman. Current International Woodworkers of America—Canada (IWA) labor rates, plus 38% personal benefits, were used in the cost analysis (Appendix II). Machinery costs, based on information from equipment and supply distributors, are estimated by the authors using a standard FERIC costing spreadsheet. Costs such as supervision, overhead, crew transportation, and equipment transportation are not included. Also, interest or opportunity costs are excluded from the machinery costs reported in the text, but are indicated in Appendix II.

Discussion

The overall study results illustrate that important differences in costs can occur depending on the logging site and system set-up (Table 3), although the average cost for all studies appear reasonable:

- The differences in yarding chance, yarding distance, average log size yarded, and the number of logs in each turn resulted in harvesting costs per log varying by 219% (from $3.02 to $9.62), and the costs per cubic metre varying by 177% (from $1.24 to $3.44).

- Case Study 1, with the highest cost per log and the highest cost per m^3, had more difficult terrain; the longest average yarding distance (123 m); the longest yarding phase time (1.66 min/turn); the fewest pieces yarded per shift (193); and the lowest number of logs per turn (1.1).
- In general, the yarding costs recorded in Case Studies 1 and 2 (whether $/piece or $/m^3$) were the highest of all studies because of the high proportion of non-productive time, and more difficult yarding conditions. Case Study 2 demonstrates the effect that non-productive time has on productivity and cost. During this study, line replacement and in-shift servicing represented 81% of non-productive time. However, if some of this work had been delayed until after the scheduled shift, and the time spent yarding had been increased to represent 85% of the total scheduled time (which was similar to other studies), overall productivity per 8-h shift would have increased by 42% and costs would have decreased by 30%.
- Case Studies 3 and 5 had less than average costs because any differences in yarding turn times (0.71 min vs 0.90 min/turn) were offset by differences in the amount of productive time spent changing roads (51 min vs 14 min of road changes/100 min yarding).
- Case Study 4 had the lowest cost per cubic metre ($1.24), which reflected the highest average log size (4.1 m^3), and the highest proportion of productive time (89%).
- Though yarding distance was shorter (51 m vs 83 m), Case Study 6 had slightly higher costs than average because less productive time was spent yarding (74% vs 79%) and more time was required to change roads (26 min vs 22 min of road changes/100 min yarding).
- Case Study 7 (area mechanically felled with feller-director) had the lowest cost per log; largest average number of logs per turn (1.5); the most logs yarded per shift (615); one of the fastest yarding phase times (0.83 min/turn); and an average yarding distance of 86 m.

The results presented in this report complement a previous study of a Cypress 7280B and excavator/backspar yarding a Coastal second-growth stand (Peterson 1988). That study determined a productivity averaging 293 logs/8-h shift compared to this study's combined average of 444 logs/8-h shift. The differences in the productivity rates of the two studies can be attributed to the 1988 study having a longer yarding distance (134 m) that increased cycle time, and a lower proportion of productive operating time (71%) that reduced the time available for yarding.

Conclusions

This report provides woods foremen and timber-harvesting planners with information about the range in productivity and costs that occur when sites with different ground and stand features are yarded by a Cypress 7280B swing yarder with a grapple and a mobile backspar. While the short duration of each study limits the conclusions that can be drawn, the data indicate that production can be increased and costs reduced by several means:

- Minimize the amount of non-mechanical and mechanical delays by undertaking maintenance or line changes after the working shift.
- Ensure the yarder and mobile backspar are aligned along yarding roads that provide the best yarding chance.
- Use a feller-director to place felled stems close to each other, or a feller-buncher to create bunches of logs, to increase the potential of grappling more than one log at a time. In addition, yarding time can be reduced because the yarder operator has a larger target to see and the logs are concentrated at fewer locations along the yarding road.

The results of these seven case studies of a Cypress 7280B grapple yarder working with a mobile backspar indicate that productivity can vary from 540 to 1496 m^3/8-h shift, while costs can range from $1.24 to $3.44/$m^3$ or $3.02 to $9.62/log. Generally, costs increased and productivity decreased as yarding distance increased, yarding chance deteriorated, and the log size decreased.

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Disclaimer

This report is published solely to disseminate information to FERIC members. It is not intended as an endorsement or approval by FERIC of any product or service to the exclusion of others that may be suitable.

Appendix I

Non-productive Time Summary

	Case Study 1		Case Study 2		Case Study 3		Case Study 4		Case Study 5		Case Study 6		Case Study 7		Combined		
Description	No. occ.	min	No. occ.	min	No. occ.	min	No. occ.	min	No. occ.	min	No. occ.	min	No. occ.	min	No. occ.	min	%
Non-productive time																	
Mechanical																	
Maintenance	1	15.0	3	120.7	2	6.0	1	0.2	1	8.8	-	-	4	80.9	12	231.6	15
Warm-up	-	-	-	-	2	14.6	1	12.7	4	20.1	1	14.8	3	29.1	10	91.3	6
Subtotal	1	15.0	3	120.7	4	20.6	2	12.9	5	28.9	1	14.8	7	110.0	22	322.9	21
Other																	
Backspar	6	21.4	-	-	-	-	-	-	2	8.6	5	58.2	2	28.1	15	116.3	7
Miscellaneous[a]	-	-	3	20.8	9	10.3	3	21.7	7	7.8	7	22.5	3	2.1	32	85.2	5
Operator	17	49.2	-	-	1	4.4	4	1.4	2	55.3	2	24.5	2	1.0	28	135.8	9
Rigging[b]	8	198.5	9	155.2	8	44.7	34	47.2	12	120.8	9	85.4	1	28.1	81	679.9	43
Safety[c]	-	-	21	41.6	38	24.4	41	38.6	54	55.6	23	27.3	51	55.9	228	243.4	15
Subtotal	31	269.1	33	217.6	56	83.8	82	108.9	77	248.1	46	217.9	59	115.2	384	1260.6	79
Total non-productive time	32	284.1	36	338.3	60	104.4	84	121.8	82	227.0	47	232.7	66	225.2	406	1583.5	100

[a] Occurrences such as replace radios, send out water, send out saw, etc.
[b] Occurrences such as add, replace, and remove chokers; remove bull hook and shackles; etc.
[c] Wait for someone other than chokerman to walk out of danger area.

Appendix II

Machine Cost Analysis: Cypress 7280B Swing Yarder and Hitachi Excavator/Backspar

	Cypress 7280B swing yarder	Hitachi UH14 backspar
OWNERSHIP COSTS		
Purchase price (P)	$720 000	$135 000
Salvage value (S), (30% of P)	$216 000	$40 500
Expected life (yr)	10	7
Hours per year (h)	1 440	1 440
Interest rate (I), %	15	15
Insurance rate (Ins), %	2	2
Average investment (AVI) = (P + S)/2	$468 000	$87 750
Loss in resale value ($/h) = (P - S)/(yr • h)	$35.00	$9.38
Interest ($/h) = (I • AVI)/(h/yr)	$48.75	$9.14
Insurance ($/h) = (Ins • AVI)/(h/yr)	$6.50	$1.22
Subtotal ownership costs ($/h)	$90.25	$19.74
OPERATING AND REPAIR COSTS		
Wire rope cost (W)		
Mainline, (440 m of 22 mm) @ $270/30 m	$3 960	
Opening, (440 m of 22 mm) @ $270/30 m	$3 960	
Haulback, (1200 m of 22 mm) @ $270/30 m	$10 800	
Strawline, (900 m of 11 mm) @ $107/30 m	$3 210	
Line life (LL), h	880	
Rigging cost (Rc)	$12 500	
Rigging life (Rl), h	5 760	
Fuel consumption (L/h)	36	10
Fuel cost ($/L)	$0.37	$0.37
Annual repair and maintenance cost (R)	$60 000	$10 000
Wages ($/h)		
Operator	$20.02	
Hooktender	$19.46	
Utilityman	$17.41	
Wage benefit loading (%)	38	
Line cost = (Total W)/LL	$24.92	
Rigging cost = Rc/Rl	$2.17	
Fuel cost = (L/h) • ($/L)	$13.32	$3.70
Lube and oil cost = 10% • Fuel Cost	$1.33	$0.37
Repair and maintenance cost = R/(h/yr)	$41.67	$6.94
Labour cost[a]	$85.66	-[b]
Subtotal operating and repair costs ($/h)	$169.07	$11.01
TOTAL COST		
Ownership costs	$90.25	$19.74
Operating and repair costs	$169.07	$11.01
Total cost ($/h)	$259.32	$30.75
Total cost/h, excluding interest	$210.57	$21.61

[a] Operating labor costs consist of the 1989 IWA hourly rate for a particular job plus 38% for fringe benefits. The machine operator and hooktender rates include 0.7 of an hour at overtime rates for machine servicing. For example, the IWA rate for a grapple-yarder operator is $20.02 • 1.38 = $27.63. To account for machine servicing, the $27.63 should be adjusted by:

$$\frac{0.7 \cdot \$27.63 \cdot 1.5}{8} = \$3.63$$

$$\$3.63 + \$27.63 = \$31.26/h$$

[b] Backspar is operated by hooktender.