WOOD HARVESTING

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FERIC

COMMERCIAL THINNING A COASTAL SECOND-GROWTH FOREST WITH A TIMBERJACK CUT-TO-LENGTH SYSTEM

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Abstract

Pacific Forest Products Limited began commercially thinning Douglas-fir dominated second-growth forests on southeastern Vancouver Island with mechanized shortwood systems in 1992. In the summer of 1994, the Forest Engineering Research Institute of Canada (FERIC) monitored a thinning operation near Cowichan Lake to determine productivities, costs, and impacts to sites and residual stands. The thinning treatment was carried out with a Timberjack 1270 harvester and a Timberjack 910 forwarder.

Introduction

Commercial thinning recovers fibre that would be lost to mortality or not utilized at final harvest, increases the value of stems at final harvest by concentrating growth on preferred trees, reduces the cost of final harvest by increasing average piece size, and allows some fibre recovery before final harvest. Although commercial thinning in British Columbia is not common today, it is not new. Commercial thinning took place in Coastal second-growth forests during the 1970s but was discontinued when fibre market values declined. During this period, cable systems—usually small standing skyline configurations—and ground-based systems involving rubber-tired skidders or small crawler-tractors were used. Although the yarding and skidding phases of both systems were effective, overall viability was limited by the difficulties associated with safely hand falling small, densely spaced trees into patterns that were compatible with subsequent yarding or skidding phases. Today, two factors have affected the attractiveness of commercial thinning. Firstly, fibre shortages have increased log values to the level that commercial thinning operations are economically viable, and secondly, the recent introduction of Nordic harvesters may overcome many of the falling limitations of the 1970s.

For the past three years, Shortlog Thinning Inc. of Victoria has been contracted by Pacific Forest Products Limited to commercially thin Douglas-fir dominated second-growth forests on its private land on southeastern Vancouver Island, using a Timberjack 1270 6-wheel-drive harvester with a 762B head and a 910 forwarder. In the summer of 1994, the Forest Engineering Research Institute of Canada (FERIC) monitored this equipment as it operated on two commercial thinning treatment blocks near Cowichan Lake, British Columbia.

The objectives of the study were to determine the productivity and cost of the harvester and forwarder operation, and the impacts of the treatment in terms of site disturbance and damage to the residual stand.

Methods

Pre- and post-treatment stand volumes for the study areas were determined by sample cruising 0.01-ha plots uniformly distributed at 1 plot/ha. The cruise was carried out by FERIC researchers and Mike Wall Consulting, and the data were compiled by Timberline Forest Inventory Consultants. Machine productivities and

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costs were evaluated by collecting shift-level and detailed-timing data. The shift-level study was conducted using a DSR Servis recorder mounted on the forwarder.

The DSR Servis recorder did not function on the harvester, so the operator maintained detailed notes of operating times and delays. Detailed-timing of machine operations was done by FERIC researchers using hand-held data loggers to sample cycle times. The distances travelled by the forwarder were also measured. The stems processed and pieces forwarded were tallied by 10-cm butt-diameter classes to compare productivities of detail-timed areas. Individual logs and stems were scaled at the stump to generate average volumes by butt-diameter class. A regression analysis was carried out to determine the relationship between forwarder productivity and distance travelled. Harvested volumes were derived from the weigh-scale records compiled by the trucker. Cost estimates were developed using FERIC's standard costing procedure (Appendix I).

Following thinning, damage to residual stems and roots was sampled using 0.025-ha plots uniformly distributed at 1.5 plots/ha. For stem and root scars, the length and width of exposed cambium, and the height above ground or distance from the tree were measured. The area of each scar was estimated by multiplying the average length by average width. The specific machine causing the damage was not determined. BCMOF soil disturbance survey procedures (Curran and Thompson 1991) were adapted to estimate dispersed soil disturbance. In addition, all forwarding trails were traversed and mapped, to determine trail distribution, spacing and width, and the area affected by trails. Trail width was measured from outside track to outside track, including the mound between tracks.

Soil bulk densities were measured following harvesting with a Campbell Pacific model MC-1DR moisture/density gauge. In each of the three study areas, 24 pairs of readings were made, evenly distributed over the blocks. Readings were made in the centre of a wheel-track and on adjacent undisturbed ground. Sampling of the machine tracks alternated between the left and right sides of the trails. Bulk densities were sampled at 10- and 20-cm depths, and then subjected to a paired t-test analysis of variance.

Site and System Descriptions

The study was conducted in three stages on two blocks of land privately owned by Pacific Forest Products Limited, 3 km west of Lake Cowichan (Figure 1). Operations were suspended in Block 1 (13.8 ha) in June 1994 because of wet conditions, and then completed in September after Block 2 (9.9 ha) was thinned.

The study sites are located in the very dry maritime variant of the Coastal Western Hemlock (CWHxm) biogeoclimatic zone (Green and Klinka 1994). The stands are approximately 55 years old, and regenerated naturally following the first harvest. Site index ranges from 38-39 m (at 50 y), and mean annual increment ranges from 9.1-11.6 m³/ha/yr.[1] Both blocks contained Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*), western red cedar (*Thuja plicata*), bigleaf maple (*Acer macrophyllum*), and red alder (*Alnus rubra*). Block 1, dominated by Douglas-fir, is typical of many of the surrounding stands (Table 1) and is scheduled for final harvest in 10 years. Block 2, closer to the Cowichan River, and a more fertile site, was dominated by western hemlock and contained a greater diversity of stem dimensions, including an understory of unmerchantable cedar. The thinning in Block 2 can be considered a "prelog" treatment to salvage volume, because the block is scheduled for final-harvest within 2-3 years. Block 2 contained numerous obstacles, i.e. large old-growth stumps and sound logs from residual old-growth stems that had been felled during the 1960s

Figure 1. Study site location.

[1] Clayton Chu, Forester, Saanich Forestry Centre, Pacific Forest Products Limited, Saanichton, B.C.; personal communication, March 1995.

Table 1. Pre- and Post-Harvest Stand Descriptions

	Net Volume								
	Douglas-fir (m^3/ha)	Hemlock & Grand fir (m^3/ha)	Cedar (m^3/ha)	Other (m^3/ha)	Total (m^3/ha)	Merchantable trees (no./ha)	Net volume (m^3/tree)	Average DBH (cm)	Basal area (m^2/ha)
Block 1									
Preharvest	473	178	106	18	775	698	1.1	35.6	69.7
Harvest	122	8	34	17	181	385	n/a	n/a	19.0
Residual stand	351	170	72	1	594	313	1.9	45.4	50.7
Block 2									
Preharvest	304	563	135	18	1020	950	1.1	33.2	82.3
Harvest	21	130	95	18	264	600	n/a	n/a	26.5
Residual stand	283	433	40	0	756	350	2.2	45.1	55.8

to reduce the fire risk from lightning strikes. No other stand-tending activities had been carried out on either block. Elevation ranges from 210-250 m and slopes are gentle, ranging from flat to pitches of 30% on one boundary. Soils are generally coarse textured and well drained. Some wet areas lay adjacent to the operating areas. Steep pitches occurred in Block 1, but the machines did not operate on slopes greater than 20% because soils were moist at the time and there was a risk of excessive soil disturbance.

Diameter was the main criteria affecting the selection of trees. Generally, stems less than 30-cm dbh were removed, along with diseased or damaged stems. This resulted in a thinning "from below", but no effort was made to select for crown development of crop trees. In two portions of the study, the harvester operator selected and cut the forwarding trails as he thinned his way through the stand (Figure 2). The spacing and density of forwarding trails were determined by the reach of the boom, and by operator preference. Often, because large trees were retained, the trail made frequent curves around crop trees. Usually the harvester would cut a trail from the main forwarding trail to the back of the block, dead-end, and then reverse out. Sometimes, where terrain permitted, the machine would continue in a loop, thinning the adjacent trail back to the main trail. On the third portion of the study, a premarked main trail was cut by the harvester and then destumped and graded with an excavator before thinning. The excavator was required to install a culvert, and some trail building was undertaken to improve forwarder productivity.

Trees were felled, delimbed, and bucked with a Timberjack 1270 harvester (Figures 3 and 4) (Table 2). Wherever convenient, stems were processed on the trail in front of the machine to provide a slash mat for the machine to travel on. Logs were piled at the side of the

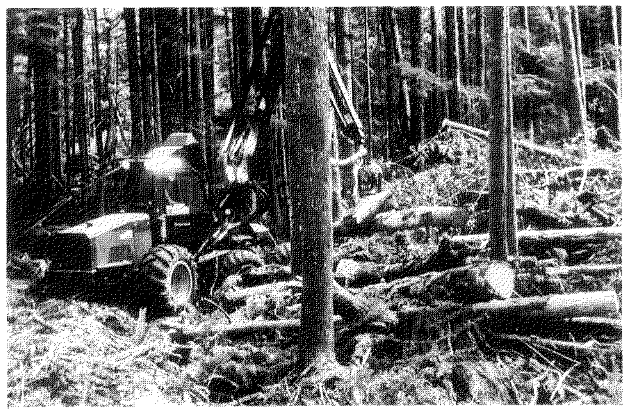

Figure 2. Thinned (foreground) and unthinned (background) portions.

trail. Log lengths were identified by the harvester's onboard computer, based on minimum length (6.25 m), and top diameter criteria (6 and 10 cm for pulp and sawlogs respectively), but the operator had the option to override the computer decision. Some log sorting by species and grade was done by the harvester operator.

The 910 forwarder has a load capacity of 11-t (Figure 5) (Table 2). Because longer logs were produced than the machine was designed to carry, the stakes were reinforced. The operator would usually back to the end of the trail, stakes first, load the machine, and then turn the seat around and drive forward toward the main trail. A minimum of two passes were made at the edges of the block, but numerous forwarder passes could occur close to the main trails, depending on the length of the extraction trail. One pass was made for Douglas-fir, and another pass for a combination of cedar, hemlock, and grand fir. Often pulp logs were sorted on one side of the bunk and sawlogs on the other. This reduced

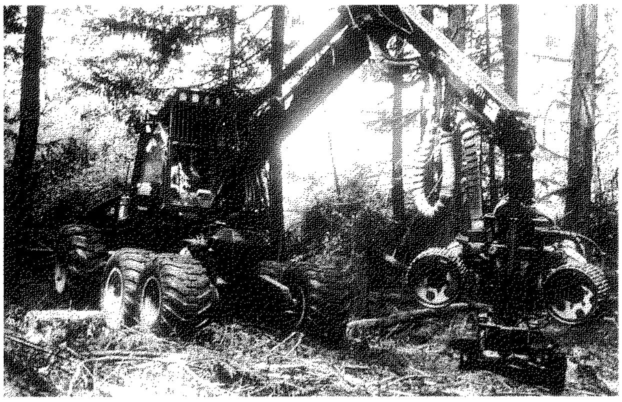

Figure 3. Timberjack 1270 harvester.

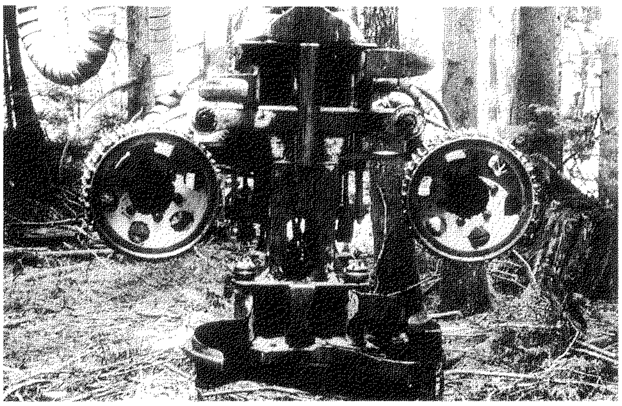

Figure 4. Timberjack 762B felling/processing head.

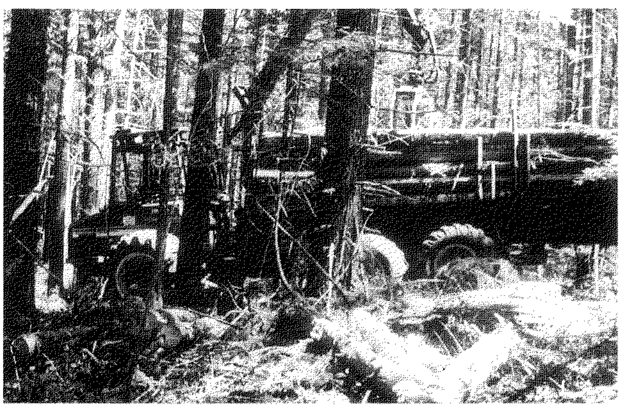

Figure 5. Timberjack 910 forwarder.

the distance travelled and number of moves required to load the forwarder. Pulp log and sawlog decks were on opposite sides of the landing, so the forwarder did not have to advance to unload the same species. Logs were stamped on one end by the operator at the landing before unloading, and at the other end after unloading.[2]

Table 2. Machine Specifications: Timberjack 1270 Harvester and 910 Forwarder

	Harvester	Forwarder
Engine power (kW)	114	82
Power transmission	6-wheel-drive hydrostatic	6-wheel-drive power-shift
Approximate weight (kg)	16 410	13 330
Width (m)	2.68	2.68
Crane reach (m)	8.30	6.80
Ground clearance (m)	0.59	0.71

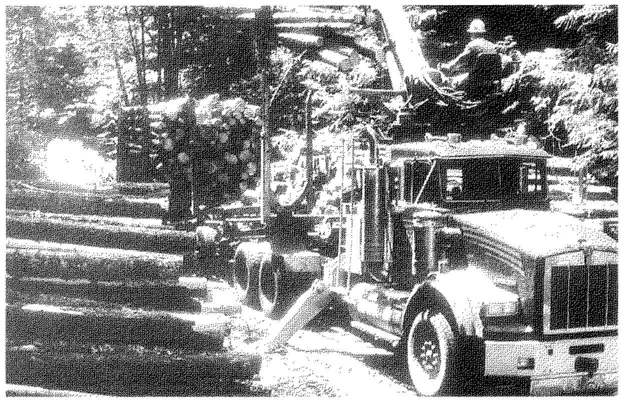

Figure 6. Self-loading shortwood logging truck.

Logs were hauled to the Ladysmith sawmill by an independently contracted trucker with a self-loading shortwood B-train configuration (Figure 6). Supervisors from Shortlog Thinning Inc. and Pacific Forest Products Limited visited the operations briefly once or twice each week. Both the harvester and forwarder operators had approximately three years of experience in operating the equipment.

Results and Discussion

Shift-Level Study

Shift-level time distributions are presented in Figures 7 and 8 for the harvester and forwarder, respectively. Utilization and mechanical availability for the harvester were similar to the forwarder, with the forwarder having slightly higher utilization (79%) and availability (86%). The harvester required more time for organization, reconnaissance, and servicing.

Productive machine hours (PMH) refers to the time the machines are engaged in prime function activities and excludes mechanical and non-mechanical delays

[2] Provincial regulations require a timber mark or marine log brand to be hammer indented on each end of each piece of timber.

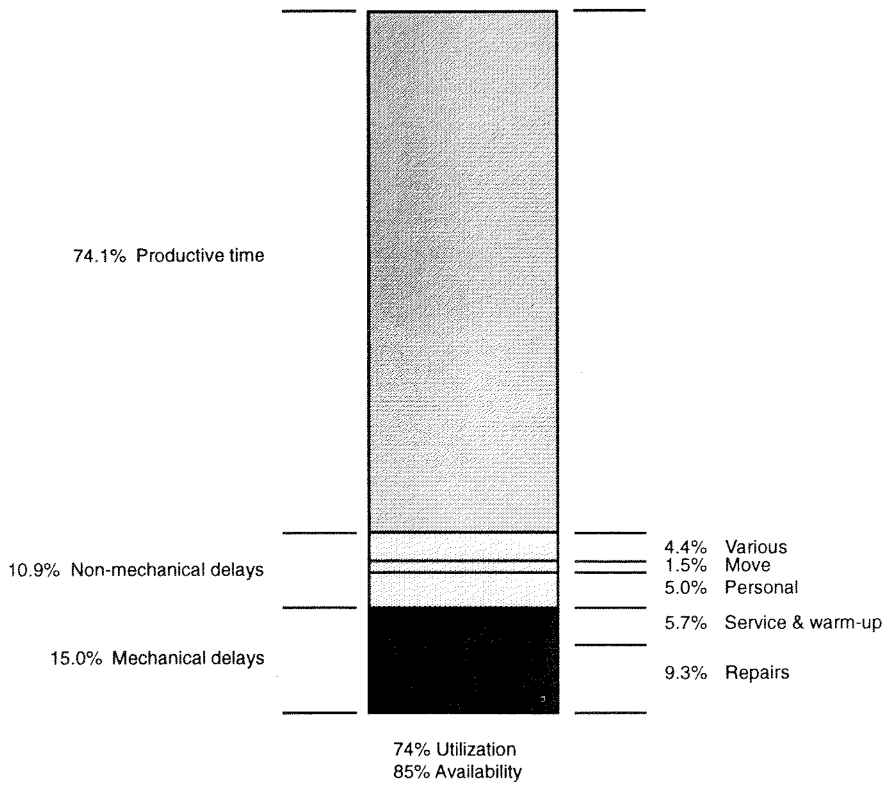

Figure 7. Time distribution, 42 shifts, Timberjack 1270 harvester.

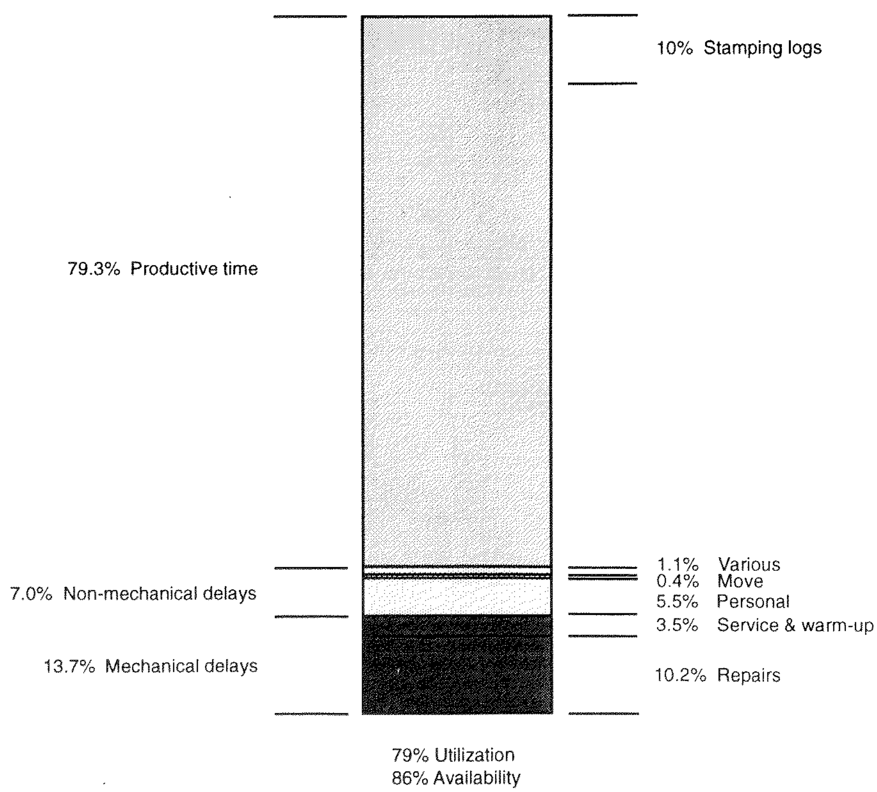

Figure 8. Time distribution, 43 shifts, Timberjack 910 forwarder.

greater than 10 min. Productivities of the harvester and forwarder, based on volumes determined from the hauling weigh-scale summaries and shift-level study, were 13.7 and 12.8 m³/PMH, respectively (Table 3). In terms of scheduled machine hours (SMH), productivities for the two machines were similar (10.2-10.1 m³/SMH).

Detailed-Timing Study

The results of the detailed-timing of the harvester are shown in Table 4. The average cycle time for the harvester to select, cut, and process a tree was 1.37 min. The most time-consuming work elements were cleaning unmerchantable stems and obstacles (28%), moving (19%), and swinging empty (17%). In Block 2, where there was a higher frequency of obstacles and unmerchantable stems, the proportion of cleaning time was 34%. When making access trails in the prelog block, old downed logs that were larger than the capacity of the felling head (60 cm), were severed with several cuts. Cleaning unmerchantable stems was necessary to allow the operator to position the felling head, improve visibility, and prevent damage to the carrier. Unmerchantable stems were cut and slashed onto the trail in front of the machine.

Table 3. Productivity Summary of Shift-Level Study: Harvester and Forwarder

	Harvester	Forwarder
Productive machine hours (PMH)	313.5	336.4
Scheduled machine hours (SMH)	423.0	424.3
Volume produced		
m³	4298	4298
m³/PMH	13.7	12.8
m³/SMH	10.2	10.1

Table 4. Distribution of Productive Timing Elements (1358 cycles): Harvester

Activity	Observed time (%)	Average time/cycle (min)
Swing empty	16.6	0.23
Fall	9.3	0.13
Process 1st log	8.7	0.12
Process other logs	7.0	0.10
Deck	1.6	0.02
Buck	1.8	0.02
Move	19.0	0.26
Clean	27.5	0.38
Delays (<10 min)	6.0	0.08
Abort cycles	2.4	0.03
Total productive time	99.9	1.37

Where there is a high frequency of unmerchantable stems and obstacles, a motor-manual pretreatment to slash small stems and cut access through obstacles may be a cost-effective way to increase the productivity of the harvester (Gunnarsson and Hellström 1991). In a FERIC study of Tapio harvester heads mounted on small carriers, Makkonen (1990) reported harvesting costs of \$18.90/m³ in a natural stand with 3000 unmerchantable trees/ha. In an adjacent precleaned stand, after adding the cost of the power saw operator, the harvesting cost was \$12.40-14.20 /m³. Future machine work studies should determine break-even conditions where it is economical to motor-manually or mechanically treat unmerchantable stems and obstacles.

The effect of stem diameter on harvester productivity is shown in Table 5. The projected harvester productivity was very low (4.3 m³/PMH) with stems less than 15 cm in diameter at the butt. The average sampled productivity for the study was 14.8 m³/PMH or 44 stems/PMH which corresponds to an average diameter of approximately 24 cm. Sampled productivities for the harvester were 13.1 and 21.2 m³/PMH for median butt-diameter classes 20 and 30 cm, respectively. Harvester productivity was 13% lower in the prelog block (Block 2) than in the conventional thinning block (Block 1), mainly because of the higher incidence of obstacles and unmerchantable stems.

The average processed log length was 6.26 m, with a standard deviation of 0.09 m. Based on a sample of 794 logs, 89% of the measured logs were within 10 cm of the 6.25-m target length.

The results of the detailed timing for the forwarder in each of the three portions of the study are shown in Table 6. The overall average turn time was 59 min and average productivity was 13.6 m³/PMH. The forwarder moved an average of 14 times over an average distance of 97 m/turn, requiring 47 grapple cycles to fill a load, and averaged 78 pieces/turn or 13.4 m³/turn. The most time-consuming elements were loading (20-22 min), and unloading (12-13 min) the forwarder.

Stamping logs took approximately 6 min/turn, which consumed about 10% of the productive time (Figure 8). Stamping many small pieces with an aluminium mallet entails ergonomic risks such as tennis elbow and banged knuckles for the operator. Less demanding and more efficient techniques for log marking should be developed.

Travel-empty distances ranged from 270-1250 m; however, only a weak relationship between travel-empty distance and forwarder productivity was demonstrated (r^2=0.32). This is due to variation in the proportions of different types of roads travelled. The western

Table 5. Harvester Production, by Butt-Diameter Class

Butt-diameter range (cm)	Average volume/stem (m^3)	Stems processed (no.)	Volume processed (m^3)	Average processing time (min/stem)	Projected productivity (stems/PMH)	Projected productivity (m^3/PMH)
0-14.9	0.07	294	21	0.98	61.2	4.3
15.0-24.9	0.26	693	180	1.19	50.4	13.1
25.0-34.9	0.57	334	190	1.61	37.3	21.2
>35	0.91	37	34	2.01	29.9	27.2
Average						14.8

Table 6. Distribution of Productive Timing Elements: Forwarder (39 turns).

Activity	Block 1 West	Block 1 East	Block 2	Overall
Travel empty (min/turn)	16.63	5.76	8.10	11.12
Load (min/turn)	20.76	21.71	19.69	20.55
Move (min/turn)	5.09	2.86	4.04	4.23
Travel loaded (min/turn)	13.06	5.13	5.29	8.44
Unload (min/turn)	13.36	11.83	12.27	12.63
Deck (min/turn)	0.34		0.61	0.37
Delays <10 min (min/turn)	1.39	2.93	1.46	1.73
Total productive time (min/turn)	70.63	50.22	51.46	59.07
Turns (no.)	16	8	15	39
Average pieces/turn (no.)	79	91	71	78.2
Average volume/turn (m^3)	13.5	15.6	12.1	13.4
Average productivity (m^3/PMH)	11.5	18.6	14.1	13.6
Distance travelled empty (m)	950	473	392	638
Distance travelled loaded (m)	857	408	361	549

boundary of Block 2 is a gravel road. The main forwarding trail in the eastern part of Block 1, built by an excavator, leads onto a smooth old trail and a main gravel road. In the western part of Block 1, the main forwarding trail is very long and poorly constructed, with relatively high stumps, frequent small curves, and a dry creek crossing. The forwarder made more than 100 turns on this road, causing it to compact; thus the interference of the high stumps accelerated machine wear and tear.

Costs

Costs for the two phases of thinning over the three study portions are summarized in Table 7. The unit costs were calculated using the hourly machine rates developed in Appendix I and the shift-level productivities based on scheduled machine hours. The calculated cost of commercial thinning with the Timberjack 1270 and 910 was \$23.25/m^3 at roadside. This is more expensive than the costs determined in other FERIC partial-cutting studies. Cost for individual tree selection on Quadra Island with a small crawler-tractor was \$15.40/m^3 (Bennett 1993). Mitchell (1994) found costs ranging from \$11-18/m^3 when commercial thinning to prevent beetle attack in southeastern British Columbia. Hedin (1994) calculated a cost of \$18.12/m^3 for cable yarding in a shelterwood cut at Roberts Creek in Coastal British Columbia. However, these studies involved lower capital costs or larger log sizes relative to this study.

Table 7. Cost Summary.

	Block 1			
	West ($/m³)	East ($/m³)	Block 2 ($/m³)	Overall ($/m³)
Harvester	14.39	13.45	14.84	14.11
Forwarder	11.40	7.33	9.42	9.14
Total	25.79	20.78	24.26	23.25

The cost for the excavator to build 650 m of trail and install a culvert in the eastern side of Block 1 was approximately $1800, including transport.[3] While the data collected from the study were not adequate to quantify the benefits of excavator-built trails, the contractor estimates that the cost to build main trails would be recovered by faster forwarder cycle times and lower machine wear in areas with long hauls on uneven ground, such as the eastern side of Block 1.[4] Damage to residuals would likely be reduced and the constructed trail could be utilized during final harvest.

The stand and site conditions of this study strongly affected the productivities and costs described. Factors such as average piece size, pre- and post-harvest volumes, amount of unmerchantable volume, slope, and trafficability would affect productivity and cost of operations with the Timberjack 1270 and 910.

Residual Stand Condition

The results of the residual tree damage survey are summarized in Tables 8 and 9. The commercial thinning study was conducted in the early summer when sap was running, and this contributed to the relatively high incidence of scarring. Scars were caused by the forwarder both pulling logs to the trail and picking up logs, and by loaded logs and forwarder stakes contacting trees adjacent to the trail (Figure 9), and carrier wheels contacting stems and roots. The harvester also caused damage while positioning the felling head, falling trees, and processing stems. Although the survey was not designed to identify the causes of scars, it was observed that the majority of scars occurred near trails and were made by the forwarder. In the conventionally thinned block, approximately 18% of residual trees had scars, with 4% of total trees having more than one scar. In the prelog block, damage was high (29% of sampled trees); less care was taken to preserve residuals because final harvest would occur within three years, and because obstacles (windthrow and stumps)

[3] Jim Lambrick, Shortlog Thinning Inc., Victoria, B.C.; personal communication, February 1995.

[4] Mike Steeves, Shortlog Thinning Inc., Victoria, B.C.; personal communication, February 1995.

Table 8. Residual Damage Summary

	Block 1	Block 2
Trees surveyed (no.)	569	123
Total scars (no.)	127	38
Trees with scars (%)	17.9	28.5
Trees with >1 scar (%)	4.4	2.4
Trees with root scars (%)	33.9	39.5
Avg. height on stem (cm)	55	53
Avg. distance on root (cm)	17	34
Avg. stem scar area (cm²)	323	287
Avg. root scar area (cm²)	558	402
Major damage		
Trees with > 900 cm² stem scar (no.)	6	1
Trees with > 225 cm² root scar (no.)	24	9
Trees with major damage (%)	5.3	8.1

Table 9. Distribution of Scars (all scarred trees)

	% Distribution of scars			
	<225	225-900	>900 (cm²)	Total
Douglas-fir				
Stem	10.5	5.6	0.6	16.7
Root	2.5	7.4	4.3	14.2
Hemlock/ Grand fir				
Stem	6.2	4.3	2.5	13.0
Root	6.2	8.6	4.3	19.1
Cedar				
Stem	18.5	12.3	1.2	32.0
Root	2.5	2.5	0.0	5.0
Total	46.4	40.7	12.9	100.0

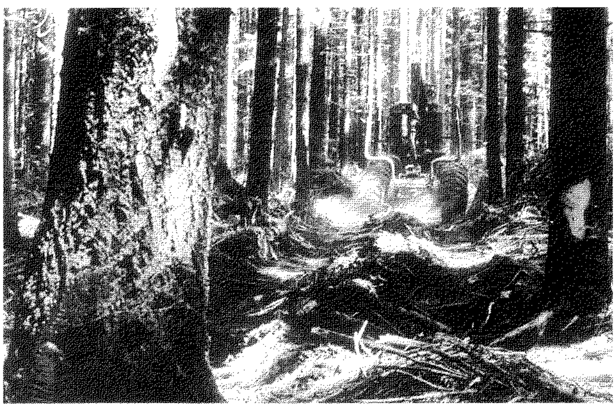

Figure 9. Residual scars.

were numerous. In a nearby study, Kohata (1995) found that damage levels increased directly with the frequency of obstacles.

Stem scars occurred at an average height of 55 cm, and affected an average area of 323 cm^2 (Block 1). Root scars were larger, averaging 558 cm^2 (Table 8). Two-thirds of the scars occurred on the stem. The largest proportion of scars were inflicted on cedar stems (Table 9), which reflects the susceptibility of that thin-barked species to damage when sap is flowing. Scar areas may have been overestimated in this study because scar shapes were uneven, making average length and width difficult to measure. The risk that a scar will reduce tree vigour through invasion of pathogens is influenced by tree species, bark thickness, scar size and depth, the time remaining before harvest, and other factors. Scars close to the ground have a higher susceptibility to incurring root decay than those further up the tree (Bettinger and Kellogg 1993; Hunt and Krueger 1962). Hunt and Krueger found the average surface area of western hemlock scars with decay to be 901 cm^2, and the average surface area of scars without decay to be 177 cm^2. The British Columbia Ministry of Forests may assess penalties for individual scarred trees. A current draft of guidelines for damage assessment for provincial commercial thinning contracts identifies unacceptable scars as: greater than 900 cm^2 area on the stem, or greater than 1 m in length, or girdle more than one third of the stem circumference, or greater than 225 cm^2 area on the root.[5]

Roughly half (46%) of all the surveyed stem and root scars had areas of less than 225 cm^2 (Table 9). In the conventionally thinned block, 11.6% of all trees had stem and root scars greater than 225 cm^2. If 900 cm^2 of stem scar area and 225 cm^2 of root scar area are criteria used to assess major damage, only 5.3% of residual trees in the conventionally thinned block sustained major damage (Table 8).

These unmanaged naturally regenerated stands were densely stocked and relatively varied in structure. This required handling many stems at the stump, which contributed to a high frequency of scarring. It is likely that thinning in a more homogeneous, managed stand with lower stocking would inflict less damage to residuals.

Soil Disturbance

The effects of the mechanized commercial thinning operation on soil disturbance were measured in two ways. The survey results of dispersed disturbance throughout the blocks are shown in Table 10. The results from traversing the trails are shown in Table 11 and Figure 10. Total dispersed disturbance was 23 and 20% in Blocks 1 and 2 respectively, mostly occurring in shallow rutted (5-cm-deep) forwarder trails (18-20%). The traverse results indicate less area occupied by trails in Block 2 (18%) than in Block 1 (24%) because trail spacing in Block 1 was tighter and trail widths were wider in Block 1. In addition, the main gravel forwarding trail on the western boundary was not included in the Block 2 survey (Figure 10). If the trail width in Block 1 were reduced from 3.4 m to 3.1 m, as in Block 2, the area occupied by roads would be reduced by 2%, to 22%. Removing curves and straightening trails by sacrificing more crop trees would have reduced the area occupied by trails, as well as the damage to residual stems. Layout of trails by the operator, or by personnel trained by the operator, on uneven terrain may contribute to wider trail spacing, straighter trails, and reduced stand and site impacts. Average trail spacing (16.8-17.7 m) compared favourably with an Oregon study using similar equipment thinning Douglas-fir and western hemlock where trail spacing averaged 15.2 m (Bettinger and Kellogg 1993). McNeel

Table 10. Soil Disturbance Survey Results

Surface type	Block 1 (%)	Block 2 (%)
Disturbed		
Forwarder trail, 5-cm depth	19.8	17.8
Forwarder trail, 10-cm depth	1.8	2.0
Forwarder trail, 15-cm depth	0.5	0.3
Harvester trail, 5-cm depth	0.7	0.3
Subtotal	22.8	20.4
Undisturbed		
Organic	72.6	68.3
Woody debris	2.4	0.8
Stump	1.3	0.5
Swamp	0.9	
Subtotal	77.2	79.6
Total	100.0	100.0

Table 11. Trial Traverse Results

	Block 1	Block 2
Block area (ha)	13.8	9.9
Avg. trial spacing (m)	16.8	17.7
Avg. forwarding trial width (m)	3.4	3.1
Avg. main trial width (m)	4.0	
Area occupied (%)	23.9	17.9

[5] Stefan Zeglen, Forest Pathologist, Vancouver Forest Region, BCMOF; personal communication, March 1995.

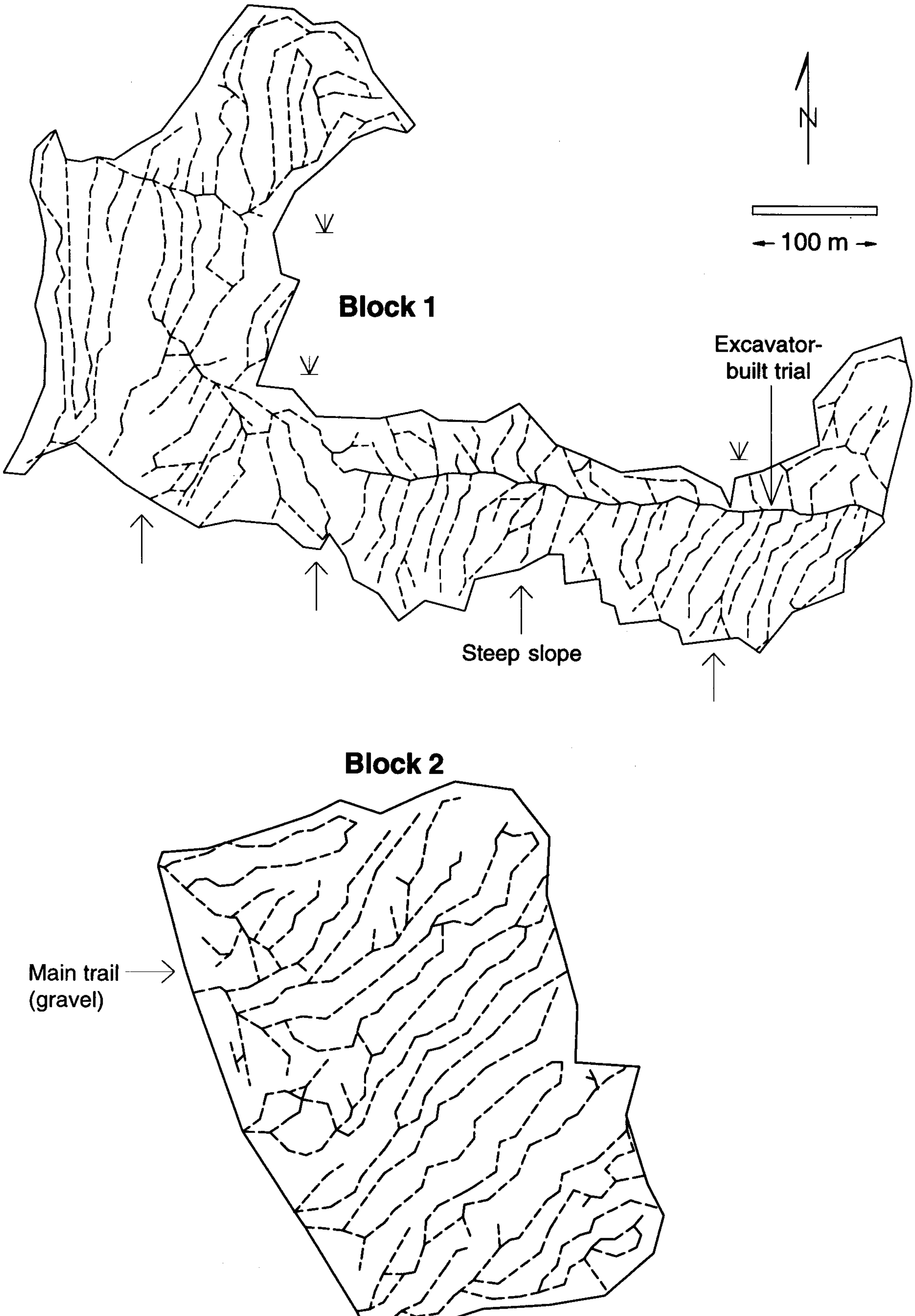

Figure 10. Distribution of forwarding trails.

and Ballard (1992) found roughly 20% of the area affected with 26-m spacing between trails in a similar type of study.

Some Swedish studies indicate that there are no significant differences in growth of young stands with strip road spacing of 15 and 25 m, provided that thinning intensity and damage levels are maintained at recommended levels (Frohm and Thor 1993; Elfving 1985; Eriksson 1982).

Significant increases in soil bulk density were found between paired samples of compacted trails and undisturbed ground at depths of 10 and 20 cm in each of the study areas (alpha = 0.05). Relative increases in bulk density ranged from 6-12% (Table 12). It is difficult to interpret the effect of this increase in bulk density on stand productivity. The degree to which this compaction changes pore size distribution, or other factors affecting tree growth and natural decompaction, is not well understood and requires further research.

The presence of slash on the trails did not appear to have limited soil compaction. Slash depths were relatively shallow and branches disintegrated after approximately 6-8 passes of the forwarder. However, a New Zealand study found that thicker slash accumulations (20-40 cm deep) reduced soil compaction (McMahon and Evanson 1994).

Fibre Utilization

The harvester utilized many small understory stems, processed some pulp pieces down to 5-cm tops, and salvaged old downed material that would not have been recovered by a grapple yarder at final harvest. Thus, a prelog partial cut was deemed worthwhile by Pacific Forest Products Limited in Block 2. It is estimated that a gain of 10% of the final volume was achieved by salvage, and closer utilization with the mechanized thinning operation.[6]

Table 12. Relative Increases in Soil Bulk Densities Between Extraction Trails and Undisturbed Ground

Depth (cm)	Block 1 West (%)	Block 1 East (%)	Block 2 (%)
10	5.6	12.0	7.1
20	5.7	9.7	6.1

[6] Keith Rush, Woodlands Manager, Cowichan Division, Pacific Forest Products Limited, Cowichan Lake, B.C.; personal communication, February 1995.

Omule (1988a) found that potentially usable cumulative volume (including thinnings) was 8% greater in thinned treatments compared to unthinned controls 32 years after commercially thinning 56-year-old western hemlock. Likewise, thinned treatments yielded 12% more cumulative total volume 35 years after commercially thinning 50-year-old Douglas-fir (Omule 1988b). Two to ten years of growth are left for these stands, so the gain in cumulative volume is likely to be less than that quoted in Omule. It is recommended that additional studies should investigate the effect of commercial thinning on incremental volume derived from closer utilization and salvage of material that would be lost to mortality.

Summary and Recommendations

Pacific Forest Products Limited has been commercially thinning with a mechanized shortwood system in Douglas-fir dominated second-growth forests on private land in southeastern Vancouver Island for three years. The goals of the commercial thinning operations are to obtain fibre prior to final harvest, and to increase the volume yield and value of the stand with minimal damage to the site and stand, at a reasonable cost. In the summer of 1994, FERIC evaluated the Timberjack 1270 harvester with a 762B head, and a Timberjack 910 forwarder thinning two blocks to determine productivities, costs, and impacts to sites and residual stands.

The productivities for the two machines were similar (12.8-13.7 m^3/PMH). Sampled productivities for the harvester were 13.1 and 21.2 m^3/PMH for median butt-diameter classes of 20 and 30 cm respectively. The average cycle time for the harvester to select, cut, and process a tree was 1.37 min. The most time-consuming work elements were cleaning unmerchantable stems and obstacles (28%), moving (19%), and swinging empty (17%). In Block 2, where there was a high frequency of obstacles and unmerchantable stems, the proportion of cleaning time was 34%. It is recommended that further machine work studies determine break-even conditions whereby it is economical to motor-manually or mechanically treat unmerchantable stems and obstacles.

The average cycle time for the forwarder to travel, load, and unload was 59 min. The travel-empty distances ranged from 270-1250 m, with varying proportions of rough extraction trails, rough main trails, and smooth or gravel main trails. Only a weak relationship (r^2=0.32) between forwarder productivity and distance travelled was established, due to the variation in road quality. The most time-consuming elements in the forwarder cycle were loading (20-22 min), and unloading (12-13 min). The number of pieces and volume per turn averaged 78 and 13.4 m^3 respectively.

The cost for thinning with the harvester and forwarder at roadside was calculated to be $23.25/$m^3$, which is more expensive than other FERIC partial-cutting studies undertaken in Western Canada to date. It is recommended that future work studies should investigate the effect of commercial thinning on incremental volume derived from closer utilization and salvage of material that would be lost to mortality.

Most of the study was conducted when sap was running, which contributed to a relatively high frequency of scars on the residual stands (18%). Damage was higher in the prelog block (29%) because residual trees were scheduled to be harvested in 1 to 3 years, so less care was taken. Two thirds of scars occurred on the stem, at an average height of 55 cm, and had an average area of 323 cm^2. The thin bark of western red cedar was more susceptible to scarring than were other species. It was observed that the majority of scars were caused by the forwarder pulling logs to the trail and loading them, or while it travelled loaded. If 900 cm^2 of stem scar area and 225 cm^2 of root scar area are the criteria used to assess major damage, only 5.3% of residual trees in the conventionally thinned block sustained major damage. Because the relationship between scarring severity and residual tree performance is not very well understood, future research in this area would be valuable.

In this study, trails were selected primarily by the harvester operator during thinning, with a preference to leaving large crop trees. As a result, trails had a high frequency of small curves, which contributed to a higher rate of damage to residuals. Sacrificing some crop trees for straighter trails could reduce damage to residuals and may reduce trail width and the area occupied by trails. Layout of trails by the operator, or by personnel trained by the operator, on uneven terrain may contribute to wider trail spacing, straighter trails, and reduced stand and site impacts.

The area occupied by trails in this study (18-24%) is comparable to other ground-based commercial thinning operations. Most of the disturbance occurred in shallow rutted (5 cm deep) forwarder trails (18-20%). While statistically significant increases in compaction were found on the forwarding trails (6-12% relative increase in soil bulk density), the effects on stand productivity are not well understood and long-term mensurational studies are required to better quantify this relationship.

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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

Machine Costing

	Harvester, Timberjack 1270 (1994)	Forwarder, Timberjack 1010 (1994)[a]
OWNERSHIP COSTS		
Total purchase price (P) $	610 954	345 000
Expected life (Y) y	5	5
Expected life (H) h	10 000	10 000
Scheduled hours/year (h)=(H/Y) h	2 000	2 000
Salvage value as % of P (s) %	30	30
Interest rate (Int) %	10.7	10.7
Insurance rate (Ins) %	2.0	2.0
Salvage value (S)=((P•s/100) $	183 286	103 500
Average investment (AVI)=((P+S)/2) $	397 120	224 250
Loss in resale value ((P-S)/H) $/h	42.77	24.15
Interest ((Int•AVI)/h) $/h	21.25	12.00
Insurance ((Ins•AVI)/h) $/h	3.97	2.24
Total ownership costs (OW) $/h	67.99	38.39
OPERATING COSTS		
Fuel consumption (F) L/h	16.0	12.0
Fuel (fc) $/L	0.39	0.39
Lube & oil as % of fuel (fp) %	24	15
Annual tire consumption (t) no.	1.0	1.5
Tire replacement (tc) $	3 150	3 150
Track & undercarriage replacement (Tc) $	9 500	9 500
Track & undercarriage life (Th) h	6 000	6 000
Annual operating supplies (Oc) $	13 170	3 985
Annual repair & maintenance (Rp) $	52 200	20 497
Shift length (sl) h	10.0	10.0
Total wages (W) $/h	21.78	21.78
Wage benefit loading (WBL) %	35	35
Fuel (F•fc) $/h	6.24	4.68
Lube & oil ((fp/100)•(F•fc)) $/h	1.50	0.70
Tires ((t•tc)/h) $/h	1.58	2.36
Track & undercarriage (Tc/Th) $/h	1.58	1.58
Operating supplies (Oc/h) $/h	6.59	1.99
Repair & maintenance (Rp/h) $/h	26.10	10.25
Wages & benefits (W•(1+WBL/100)) $/h	29.40	29.40
Prorated overtime (((1.5•W-W)•(sl-8)•(1+WBL/100))/sl) $/h	2.94	2.94
Total operating costs (OP) $/h	75.93	53.90
TOTAL OWNERSHIP AND OPERATING COSTS (OW+OP)[b] $/h	143.92	92.29

[a] The capital cost for a Timberjack 1010 forwarder was used for the machine cost calculations because the 910 model used in the study is no longer available. Differences in these two models are minor.

[b] These costs are based on FERIC's standard costing methodology for determining machine ownership and operating costs. These costs do not include supervision, profit, or overhead, and are not the actual costs incurred by the contractor or company involved in the study.